Dissertation zur Erlangung des Doktorgrades
der Fakultät für Chemie und Pharmazie
der Ludwig-Maximilians-Universität München

Assessing Cognitive Achievement and Affective Outcomes on Chemistry-Related Activities in a Bilingual Science Lab for School Students

Sezen Hollweck (geb. Kabakulak)
aus
Aalen in der Ostalb, Deutschland

2023

Erklärung

Diese Dissertation wurde im Sinne von § 7 der Promotionsordnung vom 28. November 2011 von Herrn Prof. Dr. Stefan Schwarzer betreut.

Eidesstattliche Versicherung

Diese Dissertation wurde eigenständig und ohne unerlaubte Hilfe erarbeitet.

München, den 16.04.2023

Sezen Hollweck

Dissertation eingereicht am 04.05.2023
1. Gutachter: Prof. Dr. Stefan Schwarzer
2. Gutachter: Prof. Dr. Birgit Neuhaus
Mündliche Prüfung am 25.10.2023

Für Jakob.

Acknowledgments

Ich bedanke mich bei Prof. Dr. Stefan Schwarzer für die Bereitstellung dieses spannenden Themas, sowie für die Förderung meines Gastforschungsaufenthaltes.

Prof. Dr. Birgit Neuhaus danke ich für die Hilfe und Erstellung des Zweitgutachtens der vorliegende Arbeit. Für Ihr Mitwirken in der Promotionskommission danke ich Prof. Dr. Thomas Klapötke, Prof. Dr. Hans-Christian Böttcher und Prof. Dr. Ivana Ivanović-Burmazović. Allen Dank gilt dem Vorsitzenden der Kommission, Prof. Dr. Peter Klüfers, der mir insbesondere in den letzten beiden Jahren beratend zur Seite stand.

Der Abteilung der Chemiedidaktik spreche ich herzlichen Dank aus, Dr. Kristina Hock für ihre hilfsbereite Art, Gudrun Baltjan für ihre zahlreichen Ratschläge in Sachen Gefahrenschutz und Dr. Dumenik Diekemper, der mich neben Kaffeepausen und Süßigkeiten auch mit der Korrektur dieser Doktorarbeit unterstützt hat. Ich bedanke mich außerdem bei meiner studentischen Hilfskraft Maximilian Hahn für die organisatorische Unterstützung im Schülerlabor. Großer Dank geht auch an meinen Bürokollegen Florian Johannes, für die immer gute Atmosphäre und sein stets offenes Ohr in sämtlichen Belangen.

Dr. Areenan In-Iam, Dr. Bianca Aas, Dr. Daniel Beck, Torsten Ampßler, Dr. Bahar Rockel und Sanja Frommann danke ich vielmals für das aufmerksame Korrekturlesen dieser Arbeit. Dr. Jan Heinemann danke ich vor allem für das Ausmerzen aller Witwen und Schusterjungen. Besonderer Dank geht an Jens Popp und Christine Neumann, die mich zeitweise intensiv im Labor unterstützten. Dem gesamten Arbeitskreis Klüfers möchte ich für die schöne Zeit danken, sowie die vielen Feste, an die ich mich noch lange erinnern werde.

Großer Dank geht an den Arbeitskreis von Prof. Dr. Ron Blonder am Weizmann Institute of Science für die herzliche Aufnahme, sowie für die Bereitstellung des Arbeitsplatzes und die tatkräftige Unterstützung in meinem Forschungsvorhaben.

Nicht zuletzt aber möchte ich mich bei meiner Familie und ganz besonders bei Thomas Hollweck für die jahrelange Unterstützung bedanken. Ohne euch wäre all das nicht möglich gewesen.

Summary

Due to global developments created by wide-ranging transformation trends in new technologies, many Western nations are facing a growing demand for scientifically and technically trained employees. Consequently, reports of a shortage of young STEM professionals in countries such as Germany, Israel and the US may not come surprising but even accumulated over the past few decades. One of the identified reasons that lead to this development is that science education has been perceived as irrelevant in young adults' daily life. In most science lessons, latest research is still rarely included nor does it provide students with practical examples of real-world relevance that would help to understand the importance of the field.

In order to make these subjects more attractive, out-of-school learning environments were successfully entrenched in Germany and other European countries. These science labs for school students describe a distinct form of extracurricular settings that complement school science by providing learners with an authentic insight into current and applied research. Even though in the past, most studies in this field produced only temporary positive effects, the broad variety of science labs for school students has nevertheless expanded leading to new establishments differing in their conditions. Recent studies thereby addressed the conception of bilingual learning arrangements. These bear an enormous potential to promote learners' interdisciplinary competencies. Besides subject-specific and practical skills these competences have become even more important for scientific literacy. English as today's dominant language of science represents an important tool for the discourse of socially relevant topics in the natural sciences and new technologies. The rare studies from the field of biology confirmed the success reflected by the integration of the interdisciplinary teaching approach *Content and Language Integrated Learning* in the learning site on target variables researched in science labs for school students. To date, however, the effects of implementing this laboratory variable in chemistry are neither understood nor known to be reproducible in the long-term. Therefore, the present work addressed this research gap and investigated the impact on cognitive and affective constructs of a bilingual module on experiments with a nanotechnological background. In addition, the influence of a school-based preparation and follow-up of the contents dealt with in the science lab for school students was considered in order to examine possible long-term effects.

Against this background, the investigation of the science lab for school students LMU *chemlab* on the bilingual module *Modern Materials* focused on three main research areas: subject knowledge (1), activity-related intrinsic motivation (2) and the chemistry self-concept (3). Besides experiments that were designed specifically for this purpose, already tested experiments from the science labs for school students' program *klick!* of the *Kieler Forschungswerkstatt* provided by the Christian-Albrechts University, Kiel were also offered in the learning site. Moreover, in a side study at the *Weizmann Institute of Science*, a similar setting was created to examine Arab- and Jewish-Israeli students on two (1,2) of the three aforementioned objectives.

The study followed a quasi-experimental design with a quantitative approach to evaluate the set objectives. 393 secondary level II students took part in the main study. The module was offered both bilingually-English as well as monolingually-German. The evaluation was conducted using a paper-and-pencil test, which was administered before (pre-pretest, pretest) and after the intervention (posttest, follow-up).
In the side study conducted at the *Weizmann Institute of Science*, an abbreviated version of the setting was applied to examine 199 participants in a pre-post study design. Here, the intervention took place in both monolingual-Arabic, monolingual-Hebrew, and bilingual-English (Arabic or Hebrew).

Results from the main study on the research focus subject knowledge (1) suggest comparable cognitive gains. According to these findings, the use of English as a foreign language had no negative influence on the acquisition of scientific knowledge. However, the preparation and follow-up offered for this purpose led to negligible retention effects.
In this regard, three learner types (language-oriented (1), all-rounder (2), science-oriented (3)) were identified through a hierarchical cluster analysis. The bilingual intervention proved to be particularly beneficial for learners with both linguistic and scientific dispositions (all-rounder students).
Contrary, the measurement of affective constructs revealed clear differences between the monolingually and bilingually instructed students. Measurable variances were found for the research focus on motivation (2) based on the foreign language use. As a result, the bilingual setting turned out to be less intrinsically motivating and did not seem to produce any long-term effects except for the sub-scale on *perceived competence*. In addition, students' previous grades in chemistry, as well as the sub-scales *interest/pleasure* and *perceived competence*, were found to be predictors of students' activity-based intrinsic motivation. Regarding the research focus on learners' chemistry self-concept (3), no significant differences have been measured in the bilingual intervention regardless of the type of learner. Only in the monolingual group weak positive effects were found among science-oriented students. Here, at least a short-term increase in learners' chemistry self-concept could be demonstrated. Furthermore, the preparation and post-processing had no effects on students' chemistry self-concept in

the bilingual intervention. Similar to the variable motivation, a relation was found between students' chemistry grade, gender and their chemistry self-concept.
Likewise, the side study conducted at the *Weizmann Institute of Science* demonstrated similar increases in subject knowledge among Arab-Israeli and Jewish-Israeli students, regardless of the language of instruction. The study further showed that the Arabic-bilingual instructed students exhibited a significantly higher sense of pressure after the intervention, resulting in a negative impact on the learners' intrinsic motivation.

In the light of the results this study has brought about, it can be concluded that implementing CLIL in a bilingual science lab for school students has the potential to promote students' interdisciplinary competencies in chemistry. Moreover, it was demonstrated that the authentic use of English in such a setting fosters a stronger connection to real world problems. This facilitates meaningful learning of globally discussed topics.

Zusammenfassung

Umfassende Veränderungsprozesse zu neuen Technologien, die dem globalen Wandel unterliegen, rufen in westlichen Nationen eine zunehmende Nachfrage an naturwissenschaftlich-technisch vorgebildetem Personal hervor. So scheint es wenig überraschend, dass sich die Berichte über den Nachwuchskräftemangel im MINT-Bereich in Ländern wie Deutschland, Israel oder den USA in den letzten Jahrzehnten zusehends häuften. Eine vielfach erwähnte Ursachenzuschreibung findet sich in der - aus Sicht junger Menschen - mangelnden Relevanz naturwissenschaftlicher Schulfächer für das eigene Leben wieder. Zu selten werden im Unterricht aktuelle und noch weniger praxisbezogene Aspekte mit Realbezug in den naturwissenschaftlichen Unterricht integriert, die der Schülerschaft deren alltägliche Bedeutung nahebringen.

Um diese Fächer attraktiver zu gestalten, haben sich in Deutschland und weiteren europäischen Ländern mit dem außerschulischen Lernort Schülerlabor den Schulunterricht ergänzende, erfolgreiche Lernumgebungen etabliert. Diese gewähren den Lernenden durch authentische Vermittlung aktueller und anwendungsbezogener Forschungsarbeiten Einblicke in die Wissenschaft. Auch wenn sich in der Vergangenheit bei der Untersuchung derartiger Initiativen häufig nur kurzfristig positive Effekte abbilden ließen, erweiterte sich dennoch das Angebot an Schülerlaboren hinsichtlich ihrer Rahmenbedingungen. So beschäftigten sich jüngste Arbeiten auch mit der Konzeption bilingualer Lernarrangements. Diese bergen enormes Potential interdisziplinäre Kompetenzen von Lernenden zu fördern, die in der naturwissenschaftlichen Grundbildung neben fachlichen und fachpraktischen Fähigkeiten aufgrund der globalen Vernetzung immer bedeutsamer werden. Der Einsatz der heute dominanten Wissenschaftssprache Englisch stellt dabei ein wichtiges Werkzeug für den Diskurs gesellschafts-relevanter Themen in den Naturwissenschaften und neuen Technologien dar. Die raren Studien aus dem Fachbereich der Biologie bestätigten den Erfolg, der sich durch den im Lernort integrierten interdisziplinären Lehransatz *Content and Language Integrated Learning* auf in der Schülerlaborbegleitforschung untersuchte Zielvariablen widerspiegelt. Bisher ist jedoch weder bekannt, welche Auswirkungen die Umsetzung eines derartigen Lernsettings auf den Fachbereich Chemie hat, noch ob diese nachhaltig reproduzierbar sind. Daher wurde in der vorliegenden Arbeit dieser Forschungslücke nachgegangen und untersucht, welche kognitiven wie affektiven Effekte das bilinguale Modul zum Forschungsgebiet der Nanotechnologie hervorbringt. Darüber hinaus wurde der Einfluss einer schulischen Einbindung des Lernorts

durch eine Vor- und Nachbereitung der im Schülerlabor behandelten Inhalte hinsichtlich der Langzeiteffekte benannter Konstrukte betrachtet.

Im Schülerlabor LMU*chemlab* standen somit für das bilinguale Modul *Modern Materials* drei Forschungsschwerpunkte im Fokus: Das Fachwissen (1), die tätigkeitsbezogene intrinsische Motivation (2) und das Fähigkeitsselbstkonzept im Fach Chemie (3). Neben eigens konzipierten wurden auch bereits erprobte Versuche aus dem Schülerlaborprogramm *klick!* der *Kieler Forschungswerkstatt* aus der Christian-Albrechts Universität zu Kiel angeboten. Überdies wurde in einer Nebenstudie am *Weizmann Institute of Science* ein ähnliches Setting geschaffen, um arabisch- und jüdisch-israelische Schüler*innen zu zwei (1,2) der drei genannten Ziele zu beforschen.

In einem quasi-experimentellen Design mit quantitativem Ansatz wurden die gesetzten Ziele evaluiert. Hierzu wurden 393 Schüler*innen der Sekundarstufe II in der Hauptstudie im Rahmen der Intervention untersucht. Das Modul wurde sowohl bilingual-Englisch als auch monolingual-Deutsch angeboten. Die Fragebogenerhebung erfolgte als Papier-und-Bleistift-Test, der jeweils vor (Prä-prä, Prä-test) und nach der Intervention (Post-test, Follow-Up) eingesetzt wurde.
In der am *Weizmann Institute of Science* durchgeführten Nebenstudie wurden in einer verkürzten Version des Settings 199 Teilnehmende in einem Prä-Post Studiendesign untersucht. Dabei fand die Intervention sowohl monolingual-Arabisch, monolingual-Hebräisch als auch bilingual-Englisch (Arabisch oder Hebräisch) statt.

Die Ergebnisse der Hauptstudie zum Forschungsschwerpunkt Fachwissen (1) lassen auf vergleichbare kognitive Zuwächse schließen. Demnach hatte der Einsatz der Fremdsprache Englisch keinen negativen Einfluss auf den fachwissenschaftlichen Wissenserwerb. Die hierzu angebotene Vor- und Nachbereitung führte jedoch zu vernachlässigbaren Effekten auf die Behaltensleistung teilnehmender Schülerinnen und Schüler. Weiterhin konnten durch eine hierarchische Clusteranalyse drei Lernertypen (sprachlich begabt (1), sprachlich und naturwissenschaftlich begabt (2), naturwissenschaftlich begabt (3)) ermittelt werden. Dabei erwies sich die bilinguale Intervention für Lernende mit sowohl sprachlichen als auch naturwissenschaftlichen Dispositionen als vorteilhaft.
Deutliche Unterschiede brachte hingegen die Messung affektiver Konstrukte zwischen den monolingual und bilingual instruierten Schülerinnen und Schülern hervor. Demnach ergaben sich für den Forschungsschwerpunkt Motivation (2) messbare Differenzen in der intrinsischen Motivation, die durch den Einsatz der Fremdsprache bewirkt wurden. Das bilinguale Setting stellte sich somit als weniger intrinsisch motivierend heraus und schien bis auf die Sub-Skala zur *wahrgenommenen Kompetenz* keine Langzeiteffekte hervorzurufen. Hier konnten zudem

die Vornoten im Fach Chemie, sowie die Sub-Skalen *Interesse/Freude*, wahrgenommene *Kompetenz* und wahrgenommene *Wahlfreiheit* als Prädikatoren der tätigkeitsbezogenen intrinsische Motivation ausgemacht werden. Hinsichtlich des Forschungsschwerpunktes zum chemischen Fähigkeitsselbstkonzept (3) konnten in der bilingualen Intervention unabhängig vom Lernertyp keine signifikanten Unterschiede gemessen werden. Lediglich in der monolingualen Gruppe ergaben sich schwache positive Effekte auf naturwissenschaftlich interessierte Schüler*innen. Hier konnte zumindest ein kurzfristiger Anstieg des chemischen Fähigkeitsselbstkonzeptes nachgewiesen werden. Weiterhin ließen sich in der bilingualen Intervention für die Vor- und Nachbereitung keine Einflüsse auf das Fähigkeitsselbstkonzept der Lernenden nachweisen. Ähnlich wie für die Variable Motivation konnte ein Zusammenhang zwischen der Chemie Vornote und dem Geschlecht der Lernenden zum chemischen Fähigkeitsselbstkonzept ermittelt werden.
Auch in der am *Weizmann Insititute of Science* durchgeführten Nebenstudie konnten, unabhängig von der Instruktionssprache, ähnliche Fachwissenszuwächse zwischen arabisch-israelischen und jüdisch-israelischen Schüler*innen im bilingualen Modul nachgewiesen werden. Die Untersuchung zeigte weiterhin, dass die arabisch-bilingual instruierten Schüler*innen ein signifikant höheres Druckempfinden nach der Intervention aufwiesen, wodurch die intrinsische Motivation der Lernenden negativ beeinflusst wurde.

Angesichts der Ergebnisse dieser Studie, lässt sich einschränkend festhalten, dass eine Implementierung des integrativen Lehransatzes in einem naturwissenschaftlich geprägten Schülerlabor das Potential birgt, interdisziplinäre Kompetenzen im Fach Chemie zu fördern. Des weiteren zeigt sich für das schulische Lernen, dass ein stärkerer Realbezug durch den authentischen Einsatz der Sprache Englisch im Fach Chemie gefördert werden kann. Dabei wird sinnstiftendes Lernen zu global diskutierten Themen ermöglicht.

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1. Introduction

In an information-driven age, ”Sciences, Technology, Engineering and Mathematics” - the so-called STEM fields - are regarded as the engine that fuel a country’s economy [1, 2]. It is therefore in every nation’s interest to sustain competitiveness by promoting its talented offspring to engage into related careers. Yet, an issue many Western countries currently face is a decreasing number of students to pursue a career in these fields despite better employment prospects [3]. One of the identified reasons which accelerated this development is students’ missing ability to relate the contents studied in school to globally relevant issues [4]. Traditional teaching approaches in classroom science still rather focus on the transfer of concepts than on social-scientific contexts [5] and lack to address application and functionality [6]. Key to the promotion of new talents then is to raise students’ interest by connecting scientific concepts stronger to everyday life [7].

Such considerations were already part of a German educational reform, in the early 2000s. There, informal learning settings were recognized as particularly valuable in improving students’ scientific literacy as they ”...have a significant potential to contribute to public’s understanding of, and engagement in the emerging fields of science and technology.” [8, p. 110]. In consequence to that, science labs for school students were established throughout the country. Due to their proximity to mostly science-related institutions, these distinct types of extracurricular learning venues proved to evoke a favorable attitude towards STEM-related fields. In these settings, learners are exposed to realistic and application-oriented hands-on activities provided in an authentic environment [9]. Science labs for school students thereby pursue experiential learning through haptic perception of real-world tasks [10]. Their primarily affective goals are mirrored in the examined target variables from accompanying research (e.g. motivation, interest, self-concept) [11]. Only recently, cognitive variables moved into the center of research. The now numerous existing studies in this field attest to positive, but largely short-term effects on participating students. [12, 13, 14, 15].

Nonetheless, today’s broad spectrum of science labs for school students in Germany and their extension to various European countries justify the success of the educational provision [16]. These learning facilities thereby mainly differ in their didactic approach and framework conditions [17]. Latest works in this field addressed the authentic use of English as part of a bilingual intervention. This trend does not seem to be far-fetched, as foreign language

competencies in scientific fields have become significant due to the change of the working language into English as the world's *lingua franca* in predominantly STEM-related companies and universities [18, 19]. As such, interdisciplinary skills have become all the more important along with subject-specific basic skills and practical experience. Exposing school students to English in a numerical domain to foster the goals of a modern society has taken a decisive role, since global competitiveness and future working prospects go hand in hand [20]. In the early 1990s, the European education policy took these developments as an opportunity and initiated educational reforms with the goal to politically approach the upcoming demands of the 21^{st} century from a language perspective [21]. The teaching style *Content and Language Integrated Learning* (CLIL) was introduced by the European Commission which aimed at the promotion of disciplinary learning in a foreign language [22]. According to its proponents, the instructional approach is highly suitable for the natural sciences as it is considered to "provide a pragmatic means to renovate science-education" [23]. Particularly application-oriented research areas such as the promising field on nanotechnology that are considered to have an impact on globalization benefit from such a teaching style. Integrated in science-outreach learning arrangements, CLIL offer opportunities to discuss these globally relevant topics in realistic settings [24].
First and fruitful attempts to implement the teaching style in an outreach activity have been made in the field of biology [25, 26, 27]. Time thereby seems to determine the success of CLIL. The longer students are exposed to this type of instruction the more they increase their competencies in both foreign languages and subject matter [28]. In chemistry education, so far, studies that investigate the impact of the instruction language on the effectiveness of a science lab for school students module are still missing. Furthermore, there is also a need for systematic analysis concerning the effects of a school-based pre- and post-processing, which examines an increased exposure to the CLIL teaching approach. The inclusion of these laboratory variables into an overall model that considers commonly examined target variables [14, 15] of science labs for schools students further allows an extrapolation to similar settings and contributes to a more general discussion on the impact of such learning environments [11].

Against this background, the present work wishes to contribute to the body of research on science labs for school students. Hence, the study at hand addresses the identified research gaps by examining the interaction between the laboratory variables *instruction language* and impact of a *preparation and post-processing in school* on three target variables (knowledge acquisition, motivation, self-concept) that describe classically examined constructs of accompanying research in science labs for school students. Similarly as in prior studies in this field, the analysis further incorporated the identification and comparison of different learner types based on students' dispositions [14, 26, 25] which allow for a more nuanced interpretation of the empirical findings.

To prove a replicability of the in the main study found effects from the designed learning arrangement, a side study was conducted at the *Weizmann Institute of Science* in Israel. Likewise, the influence of English as the instruction language was examined in a similar constructed setting in which two of the three target variables were assessed. The side study thereby focused on knowledge construction and motivation with regard to the use of English on Arab-Israeli and Jewish-Israeli students.

For this purpose, a bilingual science labs for school students module was designed and offered to secondary level II students who were registered by their teachers to participate with their class in this study. The investigation was executed at the LMU*chemlab* which framed the learning environment of this study. The offered module was composed of five experimental stations that illustrated the different research areas in the field of nanotechnology summarized under the term *Modern Materials*. The module further incorporated a school-based preparation and post-processing. To allow for comparisons, the module was offered in both bilingual-German and German (monolingual). The two treatments therefore only differed in the additional supporting language materials and scaffolding techniques in the bilingual group which aided in facilitating the conversation in English [29] during the laboratory phase.

Structure of this work

To frame this dissertation with regard to the constructs used therein a description to the structure of this work is presented. Following the opening remarks of the introduction, this chapter continues with the underlying theoretical foundation of the study. As laboratory activities are central to the structure and evaluation of the present work, the chapter proceeds with the views of a moderate constructivist learning environment [30, 31] in which hands-on activities, the general role of experiments in chemistry education and its implementation in the learning environment are covered (see Section 1.1). It follows a detailed description (see Section 1.1.1) and categorization (see Section 1.1.1) of science labs for school students as the here investigated learning environment. Section 1.1.2 is dedicated to the construct of authenticity which describes one of the main characteristics of science labs for school students. Purpose of this section is to bridge the gap between the learning setting itself and the here applied instructional method CLIL which allows the meaningful use of the language of science in a science-outreach setting. This is followed by the introduction to the interdisciplinary teaching approach CLIL itself. Section 1.1.3 covers the terminology and goals of the teaching approach (see Section 1.1.3) and offers insights to the existing implementation of bilingual-English teaching in Germany as well as its integration in chemistry education. Following previous studies of science labs for school students, the chapter culminates in the presentation of the three investigated target variables as part of the accompanying research in this field, all presented from an educational psychology perspective (see Section 1.2). Thereupon follows the introduction to the LMU*chemlab* (see Section 2) which outlines the investigated extracurricular learning setting and provides information about the five embedded experimental stations which are based on the methodological framework educational reconstruction by Kattmann et al. [32] (see Section 2.2). The theoretical and conceptual framework culminates in the presentation of the desideratum of research with its three research foci this study seeks to examine in the main study (see Chapter 3) as well as in the side study administered at the *Weizmann Institute of Science* (see Section 3.3). Chapter 4.1.1 gives an overview of the research methodology applied in this work. This includes the study design (see Section 4.1.1), the instruments (see Section 4.2) and the here applied statistical methods (see Section 4.3). The chapter further provides an overview of the administered pre-analysis for each testing instrument (see Section 4.4). Subsequently, the results of the investigated research questions are accumulated in Chapter 5. The study closes with Chapter 6 which interprets the empirical research results based on the three research foci. It further discusses the limitations of the underlying study project (see Section 6.4 and closes with a conclusion on this work (see Section 6.4).

1.1. Constructivist Learning Environments in Chemistry Education

In chemistry, experimenting is the key scientific method to knowledge production. Theories are proved, interpreted and discussed based on the outcomes of a conducted experiment. Practical experimentation takes over a major role as working independently allows students to understand the contents through subjective experience. This is especially important when considering that sciences such as chemistry are built upon abstract concepts that are difficult to understand [33]. Yet, the content-driven approach which most chemistry classrooms follow and the missing personal relevance are identified as some of the reasons responsible for the school subject's low popularity among students [34]. As opposed to this, practical experimentation is not affected from this rejection since studies in this field confirmed students' positive attitude towards hands-on practice [35] which often results in learners' increased interest in sciences [36]. However, hands-on practice alone does not determine students' interest but experimentation rather needs to follow an inquiry- or problem-based approach [37] where active learning is promoted through the creation of real-world connections thereby conducting methods and strategies similar to scientists [38]. Such an approach complies to the pursued goals in chemistry education which focus on the promotion of scientific literacy [39, 40].

Implementing more inquiry-based practical experience also aligns to the ideas of a constructivist learning arrangement which demands students' active involvement [41]. It is therefore not surprising that over the past decades, the moderate approach of the constructivist theory has become an integral part in research on science education [42]. There, experimenting is referred to as an ”interpretative process, [where] a new information is given meaning in terms of the student’s prior knowledge” [43, p. 198]. Incoming ideas are linked to an already established network on a specific topic. Thus, students construct knowledge based on their prior experience [44]. In constructivist learning settings, sufficient opportunities are offered that allow students the application of their newly developed knowledge [31]. The hands-on activity thereby defines the linking part between the practical experience and the interpretation of the outcomes [45]. Often cited in this context is the paradigm of the conceptual change. According to Posner et al. [46], the theory is based on learners’ everyday concepts which deviates from a scientific base. Students are confronted with a problem that challenges their mental representation. When new conceptions are considered as intelligible old assumptions are questioned and replaced by scientific theories [46, p. 216], even though believing these was justified in previous contexts from the past [47].

To a certain degree the conduction of scientific experiments as done in school, however, contradicts learning according to a moderate constructivist teaching. Some of the problems concern implementing scientific inquiry which lacks cognitive demanding tasks while experimenting [48]. Moreover, hands-on activities in chemistry classrooms are mostly designed for the verification of theories and don’t leave room to focus on more realistic aspects such as on vocational orientation [49, p. 463]. It is therefore not surprising that science outreach activities have gained more importance in science education since they have proved to fulfill most requirements of constructivist learning environments [15, p. 175]. Many of these extracurricular settings implement an inquiry-based approach which refers to the principles of a moderate constructivism. There, practical experimentation does not follow a strict ’cookbook approach’ but requires students to actively engage in the process and independently take action. Learning then results in the interaction between construction and instruction. This in turn promotes a high degree of autonomy within practical experimentation [15].

Engeln [14] and later Pawek [15] identified the following features as part of constructivist learning environments. In science outreach laboratories, these aspects are considered to have an impact on students’ affective state [1].

- **Authenticity**

  In education, the role of authenticity has long been recognized as a crucial factor for the success of students’ learning. From a constructivist perspective, such a learning

[1]The laboratory variable *degree of openness* has been purposefully left out here since Engeln [14] couldn’t prove its impact on students’ interest.

arrangement provides a scope of application and allows the contextualization of knowledge [31]. Accordingly, the stronger the information is embedded into a natural context, the more authentic it is perceived and the more the learners engage with the learning object [50]. Many science outreach laboratories meet this requirement as authenticity is considered as one of the distinct characteristic elements [15]. In her study, Engeln defined authenticity according to two aspects. The first refers to authenticity in the world of work. It focuses on the students' direct contact with scientist and their profession. The second factor incorporates students' living environment. There, authenticity is based on an accurate representation of the learning object [14]. Both factors are existent in science labs for school students. Thus, the learning arrangement with its scientific staff provides an authentic base for practical experimentation embedded in real-problem tasks [15][2].

- **Supervision**

  Teaching from a constructivist approach is defined by a fruitful interaction between students and teachers. The constant dialog enables a more student-centered learning setting where teaching aligns to the learners' abilities. At the same time, students themselves influence the learning process through immediate reaction. In such a setting, an atmosphere is created where learners voluntarily participate in the conversation and where the dialogue helps to overcome old beliefs in exchange to more scientific ideas [51]. Within a continuous reflection process, teaching adjusts to students' needs without dominating the learning process. Especially in practical experimentation, the relationship between student and teacher is regarded as influential for hands-on competences [36]. The few studies that examined the role of supervisors in science outreach laboratories confirmed the instructor's impact on the learning process [11, 13, 12, 15, 52].

- **Collaboration**

  Collaboration in constructivism describes an interacting process which takes place in a social context. There, construction of knowledge refers to the relation "between the individual and the social" [53, p. 9]. Together in the group, consensual meaning on new information is imposed [54]. Moreover, constructivist learning arrangements

[2] A more detailed description on authenticity with regard to the specific conditions of this learning arrangement follows in Section 1.1.2

foster the development of social skills and promote the use of language [55]. Facilitated through collaborative work, learners exchange thoughts by comparing and negotiating on the interpretation of the results [56]. Especially difficult contents are discussed and interpreted with other students [57]. In science outreach laboratories, the learner is constantly in touch with his or her environment including the peers and scientific staff. Through collective thinking a greater insight is achieved which enables solving given tasks within the group. However, a supporting learning atmosphere is decisive for collaborative work as only then contents and social skills are linked together [58].

- **Challenge**

  In a constructivist learning environment, knowledge is actively construed through cognitively challenging contents [31]. With regard to practical experimentation, hands-on activities must be adjusted to the learners' abilities to avoid overstretching their mental capacities. At the same time, the task should not be reduced but rather presented in its full context [50]. The learning object's degree of difficulty should thereby be selected according to the individual's need for collaborative work or assistance in order to master the problem.

- **Comprehensibility**

  Practical work in cognitive activating learning environments is designed in a way that allows students to experience a feeling of competence [15]. Consequently, tasks that are too difficult to handle would cause a cognitive overload resulting in frustration while learning is inhibited. In line with the self-determination theory and its concept of a person's basic psychological needs [59], a constructive learning surrounding promotes the feeling of autonomy as students are given the opportunity to develop knowledge independent of their environment [60]. Therefore, practical experimentation must invite learners for a conceptual change in order to give up their prior non-scientific firm beliefs.

- **Personal relevance**

  Personal relevance to the object of learning has also been attributed a decisive role in constructivist learning settings. In chemistry classes in particular, the notion that most contents remain unrelated to students everyday life is a frequently claimed aspect, and it is considered to inhibit the learning success [61]. As constructivism relies on one's individual experience, students have to put in context newly acquired contents from class by linking it to their prior knowledge. Otherwise this new information is regarded as inert knowledge of which students cannot make use of [15]. Learners' dispositions such as interest and motivation thereby play a crucial role since these affective aspect indicate one's expertise in a field. Accordingly, the more relevant the presented context is to the learner, the more they will engage with the topic [14].

Science education only recently started to align to the ideas of inquiry learning [62]. Especially science outreach activities, as a supplement to formal learning settings offer more or less intentionally these constructivist views and emphasize student's learning process by improving autonomous, active and creative learning [63, p. 117]. As such, science labs for school students also follow constructivist teaching principles. Given that the extracurricular setting is subject to the investigation of this study, the next section offers a more detailed description to science labs for school students.

1.1.1. Science Labs for School Students

Informal learning settings such as museums, science centers or zoos have long been recognized as enriching learning opportunities that enable the encountering of original artifacts in an authentic setting [64, 65]. Many of these outreach settings thereby incorporate hands-on activities that provide a problem-oriented contextualization of science contents. Especially school chemistry profits from activities that are offered additionally to school as experiments are crucial for knowledge construction [66]. Moreover, other than in classroom teaching, an extracurricular learning experience allows a stronger involvement with the topic by giving students the opportunity to engage with scientific methods for an extended period of time [67, p. 667]. Contents offered in such settings mostly produce a reference to everyday life. Hence, combining these with hands-on activities are considered to positively influence learners' perception on school chemistry [66].

Science labs for school students represent a recent development of informal learning that gradually found its way into some European countries such as Germany, Finland or Italy as well as in Israel [68, 24]. Most of these learning environments cover fields of classic STEM subjects such as physics, chemistry, technology or biology [69]. Such outreach settings provide learning in socio-cultural surroundings where students are offered the opportunity to construct meaning through social interaction and physical exertion [70]. As a ”bottom-up” movement [71], science labs for school students grew out of various different streams resulting in distinct executions. The following chapter refers to the predominantly German movement and gives an overview of the development, research and implementation of this particular form of science outreach settings with a focus on chemistry education.

Similar to the language education policy on CLIL (which will be discussed in detail in Section 1.1.3), the European Commission pursued the promotion of global skills to support a European lead in all STEM sectors [10]. In order to actively participate in a society, the development of a scientific literacy is required for all responsible citizens [72] which is understood as a collective goal [73]. Yet, Germany as many other Western nations struggled to fulfill these aforementioned objectives. In the 2000s, Engeln and Euler spoke of a ”crisis” in all STEM subjects [14]. The country had to face the outcomes of an errant science education policy. Large-scale international comparative studies such as TIMMS or PISA launched by the OECD revealed students’ weak understanding of scientific concepts and low scientific inquiry competences [74, 75].

On the premise of these findings, several initiatives had been implemented to counteract the decrease in the STEM sector. Although first implications of science outreach settings can be traced back to the early 80s [76], in Germany, their groundbreaking success came with the turn of the century as a reaction to students’ decreasing interest in sciences. Driven by the goal to break down latest scientific concepts thereby making complex research more approachable, science labs for school students proved to contribute to the effort [77]. Thus, an active participation was approached through the presentation of realistic problem situations that would result in learners’ higher engagement into science topics [78]. What followed was a nationwide implementation and science labs for school students mushroomed all over the country [14, 79]. In the beginning, the network was predominantly led by different operators who saw in this relatively new informal learning setting the potential to promote students’ interest in sciences while at the same time seeking for a platform to present their own research results [9]. It was only after the spurt when the German Ministry of Education and Research took over the patronage to support the 2004 founded *LernortLabor* project. Since then, the federation has counted more than 150 science labs for school students as registered members varying in their intention and form [67]. Even though these extracurricular settings are considered to be a predominantly German phenomenon, in the past decades, some countries have trailed the German model with operating science outreach laboratories now in countries like Finland or Switzerland [76].

Science labs for school students enjoy great public support as the integration of reasonable and planned outreach activities contribute to an achievement in natural sciences in school [80]. Many of these outreach laboratories report a brisk demand [10] that only a few perform to deliver promptly. Furthermore, schools request a stronger cooperation with the providers so that topics dealt in the laboratory are embedded into school curriculum. This incorporates the preparation and post-processing in school. However, due to the existing diversity and pursued goals not all designated science labs for school students are able to offer such a setting.

Terminology and definition

A growing diversity in existing informal learning settings has caused a heterogeneous field that finds its expression in varying definitions and terminologies circulating around the scenery. Even though among German-speaking practitioners some terminologies such as ”Experimentierlabor” [81] were founded simultaneously, ”Schülerlabor” still remains to be the most common designation [82]. Contrary, in the English-speaking environment, different streams of out-of-school hands-on activities reinforced a less uniform terminology. At present, there is no adequate international term that describes such a learning environment [76].

Figure 1.1.1.: Different established international designations of the German term ”Schülerlabor”.

Influenced from international publications, concurrent circumlocutions from ”out-of-school labs” [83], ”reach-out labs” [84], ”science center outreach labs” (SCOL) [85], ”science labs for school students” [86] to ”outreach labs” [87] (see Figure 1.1.1) have found their way into the debate, adding to a greater confusion. The well-established term ”science laboratories” also does not provide an accurate translation to ”Schülerlabor”. The concept refers to practical science experience that include both, informal and formal learning settings [88, p. 90]. In

Germany, these learning settings are mostly located outside school and are embedded in a non-formal class-event where formal learning takes place [76, p. 2]. As the title of this work reveals, the author decided to refer to such learning arrangements as ”science labs for school students” as Guderian first suggested [86, p. iii]. However, for variety reasons other fitting designations are here, too, used synonymous.

Similarly, attempts have been made to find a precise definition of science labs for school students. It is therefore not surprising that especially in the beginning, several definitions with varying specification co-existed. For simplification purposes, the here presented definitions only refer to STEM science labs for school students. The following definition based on Hempelmann and Haupt [76] has been one attempt to sharpen relevant features that allows learning environments to fall into the category:

> *”a subgroup of STEM out-of-school places to learn, namely those which enable direct contact and experience with up-to-date science and/or technology, provide well-equipped laboratories, allow young people to perform experiments hands-on, and have a regular periodical offer of practical courses.”* (p. 1)

Likewise, Dänhardt et al. [89] provided a different definition of the German ”Schülerlabor” that is determined by its ajar formal character. Thus, students experience hands-on practice in authentic STEM laboratories with their teachers and classes. Such learning settings are mostly operated by research institutions, science centers, museums or scientific enterprises and open their doors to classes on a regular base [89, p. 5]. Thus, some of the descriptions on science labs for school students exclude other similarly constructed learning environments. While Hempelmann and Haupt [76] also include construed extracurricular settings where single students voluntarily participate, Dähnardt et al.'s [89] definition is more exclusive, as it describes a specific form of science labs for school students.

Over the past decades, a continuing growing number of various science labs for schools students allowed for a more precise definition. Accordingly, in 2013, Haupt et al. [90] stated reoccurring elements which frame the concept:

- The learning environment is typically equipped as a laboratory providing authentic tools and materials
- Students perform hands-on activities on their own thereby practicing scientific working methods
- The laboratory is operating on at least 20 days a year
- The extracurricular setting is lead by scientific staff members that accompany students within their hands-on practice

However, it needs to be considered that due to the varying formation processes of different science labs for school students, there are some aspects that each learning setting more or less emphasizes as the categorization in the next section reveals.

Categorization

Intentions of various operators have found their expression in distinct secondary objectives different science labs for school students pursue [82]. Due to a continuously growing scene adding to the heterogeneous picture, a specific categorization has been left open. In the past, some publications sought to find criteria that would define already established science labs for school students either according to their operator organization [89], generation [91] or their function [82]. For the purpose of this study a division according to the preliminary works of Haupt et al. [82] will be described.

Classic science labs for school students

With 74.9% classic science labs for school students are the most pervasive of all. Learning arrangements that fall into this category aim on the broad promotion of all students through hands-on practice [92]. The designation "classic" refers to the generic form of science labs for school students' where in contrast to research science centers whole classes and courses are invited with their teachers to participate at a one-day hands-on intervention [82]. These laboratories are usually operated by universities that simultaneously promote the professionalization of pre-service teachers [93]. Most experiments focus on curricular-based topics and sometimes come with a preparation and follow-up in school as a way to overcome ongoing critics on missing long-term effects that a one-day participation entails [94].

Student research centers

Contrary to classic science labs for schools students, student research centers follow the promotion of excellence. In most cases, these facilities are affiliated to bigger research institutes, and regarded as a bonding bridge between scientifically interested students and the possibility to take up a study in a STEM subject [95]. Pre-selected, gifted individuals either work alone or in small groups thereby controlling their own progress [92]. Other than in classic science labs for school students, most of the offered hands-on activities have an open character without a comprehensive experiment instruction [96]. Contents are not curriculum relevant but adapt to real research projects [92]. Staff members offer students tools to acquire realistic scientific methods thereby fostering learners' independent working methods [97]. Many projects of these student research centers incorporate competitions where participants present their own scientific work [98].

Teaching and instruction based science labs for school students

As the acquisition of professional teaching competences has been regarded as a crucial factor for the learning output of students [99], these science labs for school students focus on teacher training in STEM subjects. Through a stronger assimilation of practical elements, pre-service teachers get the opportunity to connect theory with practice. Teaching methods are usually discussed within teaching seminars where professional development is regarded with respect to the learning environment [82]. In such science labs for school students, each step is accompanied by the analysis, reflection and planning in the process of the execution within the extracurricular setting [100]. At each experimental station, pre-service teachers get the opportunity to apply their potential knowledge on teaching the contents of an experimental station. Hence, in order to make these type of extracurricular learning settings become more sustainable, some of the operators count on a deeper implementation at different stages of teacher education and teacher training [94]. Moreover, such science labs for school students predominantly orient on the contents provided by the school curriculum.

Science labs for school students as part of scientific communication

There is general consensus on the beneficial effects scientific communication has on society [101]. Science labs for school students with an emphasis on science communication are pushing for a public understanding of societal relevant topics that research institutions are working on [102]. Universities and research centers give learners access to authentic materials and latest research [12, p. 5]. Moreover, these science labs for school students create individual incentives to promote students' interest on STEM-related academic and non-academic careers [82]. Winter [94] highlights the convergences between science education and scientific communication with respect to informal learning setting. Both have in common to raise the interest and motivation of children and young adults. Both aim on the transfer of relevant developments. As such, it has become one of the main objectives in science labs for school students as a significant number of gifted students decide against a career in STEM fields [94].

Materials and contents offered at the one-day intervention are not necessarily connected to school curriculum. The focus rather lies on the illustration of current research topics that are relevant to society. Scientist themselves mostly present their work to a broad audience thereby getting the opportunity to improve their own scientific communication skills [103].

Science labs for school students linked to the industry

These type of science labs for school students function as an interface between vocational education and training and allow students to engage with scientific careers in the enterprise [77]. Thim and Euler proclaim industrial based outreach activities as a form of ”learning by doing” [10]. Students get the opportunity to gain insight into a business enterprise where different work processes are reproduced. Science labs for school students that fall into this category closely cooperate with enterprises as well as with research institutions. Students of a class are split in small teams where parts of a product developing process are simulated. This allows to make operational procedures more approachable to school students. Furthermore, as part of the publicity work, enterprises take the opportunity to present their services and products in order to acquire new employees [82].

Science labs for school students for vocational orientation

The 2014 released report on STEM vocation indicated a deficiency of more than 117,000 skilled workers in Germany [104]. A reason, among others, for the low number of new entrants in STEM related working areas could be found in the negative image as well as the insufficient or wrong picture of STEM professions [105]. While first generation science labs for school students have primarily focused on scientific communication, newer founded initiatives aim on the promotion of career choices in sciences [77]. The profile of one vocational area is then contextualized through the deployment of experiments within the science lab for school students.

It still has to be recognized that many of the existing science labs for school students do not fall into only one category but represent hybrids of various categories as they follow different secondary goals. Furthermore, Haupt et al. [82] also concede that due to the ongoing process within the scene, the present categorization is not to be regarded as final but illustrates the current state of the movement.

1.1.2. Authenticity in Science Education and the Role of English in Science Labs for School Students

Regardless of its pursued goals, a characteristic found in any science lab for school students is the concept of authenticity. Its importance in these extracurricular settings has long been taken into account as they have the advantage over classic school lessons to convey a more realistic impression due to their proximity to a scientific environment [106]. One of the elements this multifaceted term authenticity mirrors lies in students’ opportunities for articulation. Authentic learning settings offer places for discourse so that learners can construct knowledge [107]. Applying English, the language of science, is then a natural approach as it not only facilitates ways to use the language in a purposeful way but allows the incorporation of realistic materials such as experimental protocols written in the original language. To give a broad overview about the concept with regard to the learning setting selected in this study, the following section first provides an overview of the term authenticity and subsequently relates it to the application of English in science labs for school students.

One of the obstacles school teaching is confronted with is the decontextualization of natural science contents in school [31]. The artificial learning environment adds to learners' incomplete or wrong perception of sciences in general and how scientists work [108, 109]. A reoccurring claim has been that regular science classes are alienated from what is called authentic science by following a linear investigation with a cookbook approach which falls short in resembling work processes as done in real science laboratories [110]. Such aspects for instance also include the reproduction of results which do not illustrate realistic scientific processes [111]. However, conveying an authentic understanding of the field lead to a stronger engagement in pursuing a STEM career [112]. Teaching methods and learning settings that evoke such a notion of authenticity consequently result in raising the interest in sciences [113].

Yet, although authenticity describes a reoccurring construct of different disciplines [114], considering its definition, there is still no consensus in its meaning from an educational point of view [115]. With regard to science teaching and learning, in his three-dimensional concept of authenticity Burgin [111, p. 81] defined three aspects that contribute to an authentic understanding of science. According to the author, (1) learning activities are considered as authentic when the action resembles the experimenting of scientists [116]. Moreover, (2) learners perceive tasks as more authentic when the work carried out is understood as profitable within specific contexts in society ([117] as cited by [111]). Lastly, Burgin refers to a student-centered authenticity where the activity must be meaningful to the learner and at the same time contribute to the solving of a problem within the discipline [118]. Merged therein are the three different constructs of sciences: *Nature of Science* (NOS) which is defined as the product through knowledge construction [119], *Nature of Scientific Inquiry* (NOSI) [120] describes an aspect that ”refer(s) to the concrete processes during scientific research activities” [121, p. 511] while *Nature of Scientist* (NoSt-) contains person-related aspects and the working field of a scientist [122].
Other definitions emphasize the interaction process between the learning arrangement and an individual's understanding of the concept. As according to Betz et al. [114], learners' knowledge and prior experience about the work routine of scientists also have an impact on their perception of authenticity. Consequently, the interplay between those two aspects construes the degree of what is perceived as authentic [114]. Nachtigall et al. [84] summarized

the relationship between those elements in their model of authenticity in teaching and learning contexts as depicted in Figure 1.1.2). Thus, a learner's pre-existing understanding, beliefs and interest of the learning context influences the creation of a domain-specific feeling of authenticity [84].

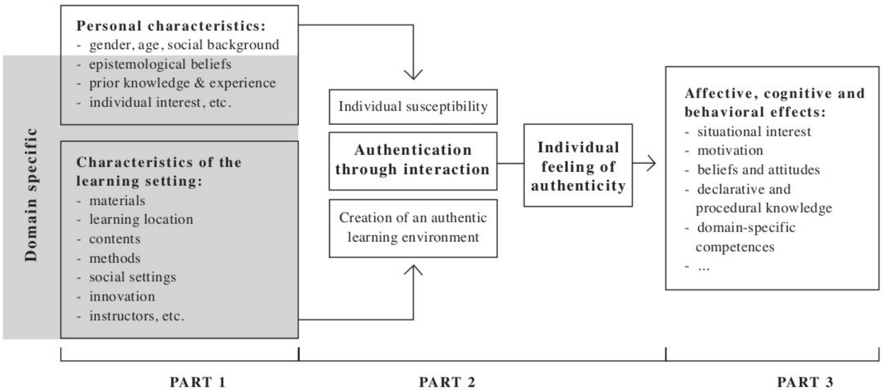


Figure 1.1.2.: Model of authenticity in teaching and learning contexts adapted from Nachtigall et al.[84].

To dispel these misconceptions, effort has been put into a more accurate illustration of the working field of scientists [123]. Science outreach activities have long been considered as a potential source for conveying an authentic understanding of sciences. The success of science labs for school students, for instance, can be attributed to the setting that goes beyond possibilities teachers have in a science classroom [124]. Learning settings which follow the goal of science communication are perceived as particularly authentic, as they act as gateways to current scientific topics and can thus paint more easily an accurate picture of a scientific environment [123].
Based on the existing corpus of studies on science outreach activities, in her work, Stamer [125] summarized six different characteristics that had been discussed in the past with regard to an authentic learning environment. Science labs for school students more or less intentionally fulfill most of these features [126]. Hence, what makes the learning environment so unique is (1) the access to different work fields of scientist and their use of scientific methods [127]. Other than linear investigations as done in science classes, chemistry outreach laboratories which follow an open-inquiry format offer (2) authentic use of scientific equipment while working with real measuring data on experiments that are close to research [15]. Nonetheless, the sheer application of scientific equipment does not foster authentic insights [111]. As according to Engeln [14], a learning environment is perceived as authentic (3) in which students are confronted with scientific phenomena from everyday life or by displaying and imitating working steps within professional practices. (4) Involving students with "real-world"

tasks allows experiencing work on purposeful problems [128]. Authentic learning settings thereby avoid classic knowledge acquisition but focus on the contextualization of cognitive input within a specific frame [84]. The presented problem should further contain a (5) degree of uncertainty in the solution which produces a feeling of authentic involvement in solving the task. (6) Without the interference of the teaching body, students feel empowered to solve the problem as learners act as the scientist who examines the problem [128, 123]. The so created autonomy lets students experience learning more meaningful as the learning process and performance steps are self-paced and self-determined [129, p. 377].

Although a growing body of research has been dedicated to the abstract construct within extracurricular settings in general, authenticity still remains ”an under-theorized design principle at the center of debates about the relationship of school activities to professional practices” [130, p. 405]. The situation is not different in science labs for school students where only recently a few studies have started to investigate this phenomenon (e.g. [131, 125, 84, 114, 132]). Moreover, previous studies have not been able to confirm a major relationship between the learning environment and an increase in authenticity. The studies of Schwarzer et al. [131] and Stamer [125] both also could not prove significant effects on students' perception of authenticity. Sommer [133] therefore questioned whether science labs for school students actually carry the characteristic and what actual impact it has on students' perception of authenticity.

Despite the lack of evidence on their actual potential to convey authentic scientific insights, science labs for school students with a focus on foreign languages open up another facet of authenticity [24]. As English is the dominant language in scientific discourse [134], its integration in extracurricular settings affiliated to research institutions features another input component of authenticity. The role of language and how it is used is also crucial in a science outreach context. As according to Puvirajah et al. [129] an authentic science experience is shaped by the participation in meaningful linguistic interactions which is situated within the scientific knowledge construction [129, p. 381]. Considering that language is a cultural product with its unique system, in a science context it is needed to create scientific knowledge [129]. Thus, science activities provide opportunities to apply English for authentic communication [135]. Engaging learners with scientific inquiry during the hands-on activity in the informal learning setting allows through different formats the authentic use of English [135, p. 157]. The collaborative work within the setting facilitates opportunities to use English in an authentic communication situation about scientific concepts [136]. These realistic STEM activities and practices encourage learners to apply their linguistic skills for the meaning making process. A realistic communication about scientific concepts and the application of science in such a learning environment fosters students' engagement into sciences [137].

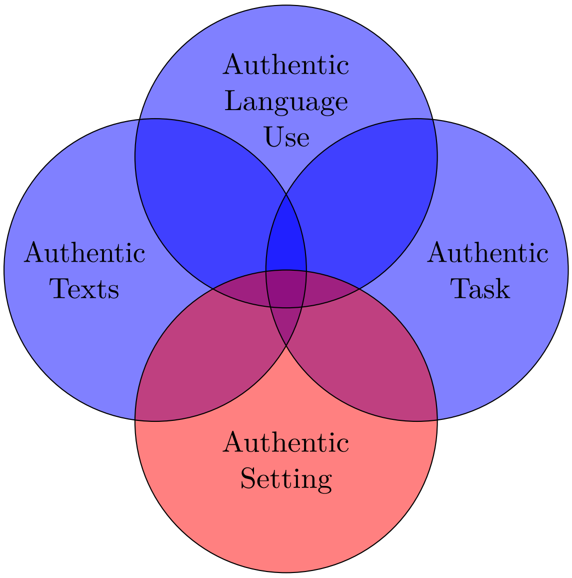


Figure 1.1.3.: Four domains of authenticity adapted from Hollweck and Schwarzer [24].

Moreover, the representation of real-world problems allows the promotion of interdisciplinary skills which is required for scientific work.

In the foreign language context, authenticity has been most discussed with regard to CLIL (see Section 1.1.3). The teaching style links the concept of authenticity to both, content and communication where the use of ”authentic texts” and the application of the foreign language in authentic situations lead to meaningful interactions (Coyle [138, p. 13] as cited by Pinner [139]). Accordingly, CLIL leads to ”authentic content learning where attention is given to both topic and language of instruction” [21]. Emphasizing authenticity is defined as a stated criteria relating relevant, societal topics to learners' everyday lives [140]. The relationship is explained according to an adapted model based on Pinner's three domains of authenticity in CLIL as depicted in Figure 1.1.3. Taking the implementation of CLIL in a science outreach context into consideration, Hollweck and Schwarzer added an additional domain to the model. Thus, the presentation of contents in a realistic learning setting combined with original tasks and texts in the language of science contributes to the creation of authenticity within science labs for school students [24]. Further, the setting requires participants own involvement in collecting and analyzing data in order to construct knowledge where authentic tasks are solved in group-working activities.
Although no significant studies exist on the importance of language in relation to authenticity in a science context, it can nevertheless be assumed that linking the English language to a numerical domain appears meaningful and has potential for the promotion of learners' interest in the field. It can be assumed that the authentic mediation of science illustrates

only one of the many positive aspects that an interdisciplinary link between language and natural science produces.

1.1.3. The Content and Language Integrated Teaching Approach as an Instructional Method in Science Labs for School Students

The importance of English in science education is growing visibly, as mastering the foreign language is considered a prerequisite for academic studies and the workplace. In recent years, a number of science labs for school students have also modified their objectives in this regard, as using the foreign language offers considerable potential for practical orientation and creates real-life opportunities for speaking in authentic situations. In 2010, for example, the Alfried Krupp Lab expanded its offerings to include English as a target language. This example has been followed by other laboratory operators [25, 26, 27] using CLIL as an instructional method.
Since the present study, too, investigates the effectiveness of a bilingual science lab for school students, the teaching style will be introduced more thoroughly. The section begins with an introduction to the interdisciplinary approach and continues with its implementation in Germany which is commonly known as bilingual teaching. Subsequently, its use in chemistry education will be discussed. Due to the teaching method's large intercontinental impact and the resulting amount of publications in this field only a selection of studies will be reviewed in this work. The goal is to provide a rather broad overview of its implications that specifically focuses on outcomes from science settings. Further, even though CLIL is not restricted to one language in particular, the studies and developments here presented almost exclusively refer to English as the foreign language [3].

As a reaction to ongoing internationalization process, European's language-learning policies had been adjusted to current demands in the educational field [142]. These measures were taken as students' foreign language competence level in traditional foreign language classes "continue(d) to be below expectations" [143, p. 1]. Consequently, in 1995, the European Commission released the White Paper on Education and Training following a '1+2 policy'. The resolution aimed at preparing its citizens for the upcoming challenges on the future labor market. Students should acquire skills in two more European languages other than their mother tongue [144]. Already existing and successful integrated language teaching programs inspired the European Commission to purse this goal [145]. Thus, Content and Language Integrated Learning (CLIL) was introduced as the European alternative to well established immersion programs as practiced in countries like Canada, and which aimed at fostering European students' language competences [146]. This new integrative approach

[3] The terms CLIL and bilingual education will be used interchangeably which follows the procedure of already existing studies in this field (e.g. [141]).

follows the teaching of a foreign language as the medium of instruction [147] in areas and domains that students will increasingly be confronted with in the near future [140, 142] by promoting students to eventually engage into the academic discourse [148].

Even though the concept of CLIL formerly did not mean any European language in particular, English is by far the most applied medium of instruction [149, 140]. This is quiet understandable as English is the world's designated *lingua franca* [150] and commonly used in academic discourse [134, 151]. It becomes evident how important bilinguality as a 21^{st} century skill for the future workforce is [152] when considering that in the international labor market its participants are expected to speak and communicate fluently in English [140, 142]. Moreover, especially branches like sciences, IT and law heavily rely on the language of science [153]. In 2000, Warschauer already emphasized its importance as in the age of *informationalizm* mastering English as the vernacular language will be more than ever needed by non-native speakers in European countries [2].

In 2006, Eurydice, the European Union's education information network released a report which documented the implementation of CLIL in public school systems in European countries. The majority of these propositions predominantly addressed primary and secondary school students [140] while only a few states started offering CLIL to children at the pre-primary level as well as to young adults at the tertiary level [149]. This number of participating states continued to increase as even more EU members presented the fruitful results of embedding the teaching style in their school system [149]. Its success has been widely recognized and appreciated as now countries outside the European continent started to implement CLIL into their school system. Thus, there has been a spread of the integrative approach across the continents from Asia to Latin America [153, 139]. Nonetheless, CLIL still lacks a methodology [154], and practitioners and educators are mostly left by themselves when implementing the teaching strategy into the classroom [155]. As a consequence, many different implications coexist that rely on the country's executions [140, 145] which complicates the evaluation on its effectiveness [156].

In the first decade after its launch, CLIL was predominantly in focus of foreign language teaching investigations [157, 158, 159]. Many programs from this field were transferred to subject content learning. Darn justifies this procedure by stating that foreign language teaching methods enable a higher engagement to improve students' critical thinking skills [160]. The integrative approach must than be understood as a way to foster critical thinking abilities allowing learners to independently construct knowledge by communicating in a specific domain [161]. In this context, the conceptualization of language proficiency in bilingual education according to Cummins [162] has been often applied on CLIL. It refers to the interdependence of learners' language proficiency and their cognitive achievement. Cummins distinguishes between Cognitive Academic Language Proficiency (CALP) and Basic Interpersonal Communication Skills (BICS). The former acronym refers to the language proficiency skills in academic discourse. It describes the positive correlation between students' cognitive competences and their academic achievement [162, p. 198]. BICS on the other hand relates to the fluency in informal conversations and refers to general language competences [163]. Due to the cross-curricular teaching style, an interplay of the conceptual pair is of particular importance as it presupposes the discourse in classroom to acquire higher-order thinking skills [164].

Terminology

When researching CLIL, it seems to be a common routine for educators in this field to add a section with a definition of the integrative approach aiming at a common understanding of the concept. Yet, undoubtedly, no teaching style has caused more confusion among practitioners due to its many definitions [165]. This section therefore provides a short overview of the most relevant terminological and educational developments of CLIL to which the present study refers to.
As an initiative in 1994, it's founder David Marsh and his team introduced Content and Language Integrated Learning at the University of Jyväskylä. According to Marsh and Mehisto, the teaching style is best defined as

> *"a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language".* [147, p. 9]

In 1996, after a successful testing phase CLIL was adopted by the European Commission thereby declaring its interest on a European wide embedding in different school systems [146]. The interdisciplinary approach highlights the role of language as the medium of instruction through which different curriculum-based contents are presented. In the Eurydice report of 2006, CLIL is further classified as

> *"a generic term to describe all types of provision in which a second language (a foreign, regional or minority language and/or another official state language) is used to teach certain subjects in the curriculum other than the language lessons themselves".* [140, p. 8].

Marsh clearly marks down the differences to regular foreign language classes when he states that CLIL is a "language pedagogy focusing on meaning which contrasts to those which focus on form" [166]. According to the author, the teaching approach rather emphasizes the acquisition of content knowledge than foreign language learning. Yet, by using any foreign language as a vehicle for content transfer language acquisition is unleashed [165].

Even though there is a general agreement on the core principle, its execution remained a matter of interpretation. As a result, after its launch, CLIL has been governed by various definitions and terminologies that accumulated over the past decades [165]. In 2006, the Eurydice report summarized 52 different terminologies associated to CLIL [140]. All of these expressions are used interchangeably [147]. Those discrepancies mirror the problems the implementation of CLIL still entails. The concept underlies many confounding variables since the realization has been left to its practitioners. CLIL therefore can either take place in a language classroom or embedded in a subject lesson depending on what the focus is [167]. Furthermore, the language influence of immediate geographical neighbors, varying educational systems, and similar forms of already existing teaching approaches contributed to more of these diverging executions [145]. As a result, alignments of CLIL instruction vary from country to country [146, 145]. The European Commission, too, does not give a clear directive but leaves the integration of CLIL into school curriculum open to the countries [158]. Reoccurring claims are then associated with the missing theoretical foundation and consequently the lack of a methodology [168]. Furthermore, there are just a few best practice implications on how the relation of foreign language use and content learning should be distributed [154] even fewer are applicable to specific contexts. It is therefore quite understandable that its advocates ask for its own didactics [169] in order to silent the skepticism of many critics that dismiss the interdisciplinary teaching style as an opportunity for extra foreign language lessons [170]. Moreover, the resemblance to other, similar pedagogical concepts cannot be denied [150]. A comparison to content based instruction programs as applied in countries such as the US is therefore justified [171].

Nonetheless, similarities and characteristics can be found in any CLIL implementation [150]. Urmenta describes the interdisciplinary approach by two identifying key features on successful foreign language learning. In her opinion, the increased exposure to a foreign language in a CLIL classroom enables students to interact more often as the additional time frame offers plenty of occasions to speak and communicate in the approached domain (1). Furthermore, acquiring non-language contents from real-life contexts by using the foreign language purposefully is qualitatively different from language learning classes (2). The implication of a foreign language is thereby considered as a vehicle to transfer meaning through authentic contexts where its use is adjusted to a students' language level [168, p.10]. Academic contents thereby provide the base in order to develop higher-order thinking skills, a feature that similar approaches cannot offer in that extent to its learners [165].

Goals

CLIL has been widely acknowledged as it ”has managed to win over politicians, families, educators and researchers in most European member” [172, p. 59]. A common associated goal is to meet the needs and expectations of the Modern times [157] as its implementation contributes to the individual and society alike [173]. Even though the initiative has been originally a European strategy, the fast prevalence over preexisting content-based instruction approaches highlight its global success. However, the missing directives on a national level eventually lead to different executions of the formerly pursued goals [174, 140].
The following provides an overview of the objectives that CLIL offers, namely the two elements that the interdisciplinary approach compromise: content knowledge and language learning. The section starts with the description of its basic goals that has led to the European global implementation and accumulates in the description of its conceptual framework based on Do Coyle's 4C model [175] for CLIL.

General goals

With the urge of an educational policy change early in the beginning of the 1990s, CLIL has been established as a way to prepare its citizens for the upcoming requirements of the Modern Times [140]. The European Commission's decision aimed at supporting a stronger identification with the European Union through the extensive realization of CLIL [176]. Thus, from a sociocultural perspective, its primary goal was linked to the education of intercultural awareness through multilingualism [164]. Learners should acquire a cultural understanding that allows the distinction and acknowledgment of cultural diversity when learning different languages [177]. The speaking of a common language in turn accelerates a broader worldview which increases students' awareness and tolerance for people of different cultures [140].

Another important aspect the EU's policy also addressed regarded socioeconomic needs. Since the progressing internationalization asks for measures to prepare its citizens for the global labor market, foreign language skills in different domains will be of importance [140]. With the promotion of bilinugal proficiency, the European Commission has made their intention clear as stated in the goals on education from 2012:

> *Europe's vision for 2020 is to become a smart, sustainable and inclusive economy. Therefore, improving the outcomes of education and training and investing in skills in general—and language skills in particular—are important prerequisites to achieve the EU goal of increasing growth, creating jobs, promoting employability and increasing competitiveness.* [178, p. 4]

Since a country's capital depends on its future workforce, the CLIL approach aims on youth development where students need to be able to communicate their ideas within an international working group. CLIL never referred to English as the one and only target language [179], however, the world's *lingua franca* has taken a leading position as every citizen will be required of English language skills in the near future [2].

Do Coyle's 4C model for CLIL

Even though CLIL is frequently associated with foreign language education, a comparison would be misleading as the former represents a holistic approach that is achieved through the interplay of its parameters [180]. CLIL's conceptual framework is based on the principles of Do Coyle's 4C model (see Figure 1.1.4) [175] which highlight the interrelation of four main parameters that influence students' learning in such a setting. The 4Cs refer to *Content, Communication, Cognition and Culture* and reflect the ideas of language learning theories, learning theories and intercultural learning [181]. Each of these factors will be briefly explained in the following:

Central to the approach is the *Content* that leads the way of teaching. It determines the context and the domain language where knowledge should be construed of. Understanding is then conceived through meaningful content [157].

Cognition describes the second parameter which refers to students' learning skills. Hence, for knowledge construction the offered *Contents* need to meet students' *Cognition* [182]. Both, students' content and linguistic level are crucial for the negotiation of meaning. This dual-focus of subject-content learning and language learning strategies address specific cognitive skills such as critical thinking or problem-solving that lead to a deeper understanding of the dealt contents [183].

The construction of knowledge further relies on its transition through *Communication*. Language is therefore considered as the medium to express opinions, ideas, thoughts or observations related to the *Content* provided that the language is accessible to students. Using a community's language enables learners to perceive authentic communication situations that justify the language change [157]. CLIL allows students to encounter subject-specific knowledge in the original language where in domains such as sciences, English has been predominantly used among the scientific community [134]. Accordingly, working language in texts and working materials function as a tool to transfer the intended *Contents*.

Figure 1.1.4.: The 4Cs framework for CLIL adapted from de Zarobe [164].

The interaction between the aforementioned C's influences a learner's perception of *Culture*. From a sociocultural perspective, CLIL gives students the opportunity to acquire contents that require them to understand the domain from the angle of an expert in this field as a means of global understanding [183]. These goals go beyond cultural awareness in society but relate to learning culture that is rooted in different learning strategies [184, p. 90]. Focusing on language enables the learning within a specific subject community through the immersion into domain-specific contents. A different perspective also helps students to obtain an intercultural understanding and enables to construct knowledge that is connected to culture [180]. Consequently, CLIL's teaching objectives go beyond regular subject content classes as the component of language allows a broader discourse of the learning content [174].

Different implementations of CLIL - bilingual education in Germany

Of all the co-existing executions the "umbrella term" CLIL entails, in Germany, "bilingual education" prevailed [185]. Yet, even though today's bilingual teaching is strongly associated with the cross-curricular approach, the country looks back to an older tradition where its first appearance resulted from the post-war cultural convergence with its neighbor France. First implementations in school curriculum were recorded in 1963 which were set down in the contract of Elysée [186]. In this Treaty of Amity, both countries agreed on a reconciliation that would draw Germany and France politically closer. One paragraph of the intergovernmental treaty regulated national education policies where intercultural awareness was promoted (cf. [187]). This led to a nationwide embedding of the French language in Germany's education system.

Aiming at a stronger Franco-German bilateral relation, bilingual teaching was mainly subject to social sciences and humanities [188]. It was only in 1978, when the Standing Conference of the Ministers of Education and Cultural Affairs (KMK) extended the framework and formulated guidelines and principles to anchor the European educational mandate in German schools [189]. For the first time, the country consciously promoted a European identity by offering further foreign language classes (ibd., [189]). Although the program temporarily became less popular, bilingual education has gained back its prominence after the German reunification [190] leading to the establishment of the vast currently existing bilingual programs. Subsequently, former political goals were replaced through socioeconomic demands as a response to a more globalized world [190, 191]. Thereupon followed a stronger promotion and integration of "bilingual content instruction" [192] which resulted in extending the program to all school subjects [188]. However, with the emergence of CLIL, and the focus on societal goals French's dominance as the language of instruction has vanished, and even though various European languages were introduced to school curriculum, English by far remained the most applied language in the CLIL context [193, 194].

CLIL's immense success resulted in a widespread introduction with a state-wise legislation that would regulate an embedding inside school [195]. As a consequence, the application of the cross-curricular approach has grown simultaneously from a bottom-up and a top-down movement [196]. Similar to other countries, various assumptions to the didactic approach exist mostly derived from foreign language education [195]. Moreover, Germany's historical genesis of already existing bilingual teaching programs further added to an incomplete didactics [197] where bilingual classes were mostly initiated from instructors [188, 198] with a foreign language teaching background [198]. It took decades until content didactics were included to the approach even though its incomplete state still remained.

Due to the nationwide installation of bilingual programs, teacher professionalization has recently gained more attention as it constitutes an essential part to successful bilingual education [199]. In the past, federal-state regulations impeded the integrative approach in especially science-related subject matters due to varying education policy objectives [194]. Even though bilingual programs need to be taught from subject teachers [194], ideally, only teachers who double-majored in both, a foreign language and a non-language subject are qualified [200, p. 33]. Recently, a stronger focus has been set on teacher professionalization by offering specific university programs which address teacher training and qualification programs aiming at a preparation for the dual-focused approach [201]. This becomes even more important when considering Do Coyle's 4Cs model where CLIL teaching goes beyond subject content but encompasses critical thinking and cultural awareness [180]. Thus, pre-service teachers need to bring these competences themselves in order to convey intercultural awareness to their students [157].

Despite its success and the expanding bilingual concepts, the majority of these programs still address students from higher secondary schools [191]. Bilingual education is therefore regarded as a talent program for gifted students [170]. This is even emphasized in the report of the KMK [202]. There, participation is often restricted to specific requirements that learners have to meet in order to be qualified [203, 204, 205]. A reoccurring claim is that bilingual education supports students that "tend to come from a strong socioeconomic background" [170, p. 272]. Yet, there is reason to believe that bilingual education has similar positive effects on non-gifted students as there is a general consensus about its necessity in the upcoming future [200]. Educators increasingly started to offer bilingual teaching programs to students from comprehensive and elementary schools, even though research in this field is barely non-existent [141]. In doing so, they draw upon equivalent immersion programs which proved to address learners' needs where the purposeful use of a foreign language in a subject matter did no impair learning [206].

Chemistry teaching in a bilingual learning environment

First attempts to implement CLIL in sciences had been undertaken in the early 2000s [203] where many critics eyed with suspicion the development of CLIL teaching. Persistent initial doubts about the eligibility referred to the missing relationship to culture [204]. Hence, a counterargument of its suitability refers to the nature of scientific texts. Contents in these fields are considered to lack the contribution to cultural differences due to their missing bear of primary cultural systems [207]. This assumption is out of date since chemistry has proved its high societal relevance, and the importance for each individual in many fields (e.g. environmental chemistry, nanotechnology, bio-inorganic medical applications) with numerous opportunities to teach intercultural awareness [208]. Bonnet provides the linkages to the intercultural goals of CLIL in natural sciences when he states that the

> *"Culture and/or nature of chemistry' can be understood as the discipline's naturally limited but specifically focused perspective on the world and its particular ways of creating, documenting and communicating knowledge, all of which are conventional. Intercultural learning in this sense deals much more with the question of how novices can be initiated into the language and the culture of a discipline".* [209, p. 153]

A second claim is based on the language that is applied to transfer content. Other than in social sciences, chemistry heavily relies on the knowledge of a specific register for science communication to what Cummins refers to as CALP [162]. Consequently, language use goes beyond students' general conversation skills as in the sense of BICS [162]. Its usability in everyday discourse is substantially reduced [204, p. 308]. This is differently viewed by various stakeholders as the scientific domain especially in the Anglo-American field, is rather oriented towards everyday language and therefore easier to understand [210]. Nonetheless, teaching science language should not replace everyday day language but enhance linguistic awareness so that learners are able to bridge different speech forms [211].

In 2012, the European Commission reinforced their demand to promote a stronger integration of CLIL settings in STEM subjects [22]. In response to that more bilingual programs were offered preferably in the English language [191]. Thus, most reports and publications come from CLIL settings in biology (e.g. [212, 26, 215, 83, 25, 216, 205, 217, 218, 213, 214, 27]). Less implications are to be found in chemistry which leaves research still practically in its infancy [219]. Moreover, the two didactics only slowly approximated each other, so that implications as according to an integrative approach are only about a decade old [208]. As a result, there are still some aspects left unresolved. This refers in particular to the application of the target language. Still, there is no consensus about whether the foreign language should be used either solely as is done in immersion programs (1), as a working language with the school language as the supporting element (2) or in equal shares with the school language (3) ([220, 210] as cited by [221]). Such inconsistencies make it even harder to draw valid conclusions due to the heterogeneity of the settings.

Teachers, parents and students alike share their concerns on the yet unfamiliar teaching practice. Surprisingly, it has been primarily the educators that have been skeptical about the effects on subject learning [222]. Many teachers argue that especially in natural sciences content suffers from the teaching style as learners' foreign language proficiency inhibits the transfer of knowledge which many teachers compensate through a reduced complexity [223]. Accordingly, the intense language focus would lead to a reduced time for content learning [224]. A similar observation was made among parents. Even though most parents are not familiar with the teaching style [225], they fear that the double-focus overstretch their children [226]. Overall, it seems not surprising that CLIL programs in chemistry belong to the least popular of all subjects (cf. [194]). At the same time, the additional teaching program is appreciated by many as it promotes their children' foreign language competencies [227].

Like any other subject matter, chemistry depends on the use of language in the meaning making process [228]. Verbalization in a chemistry discourse is often realized through the description and explanation of observations, chemical reactions, diagrams or graphs [229]. Such competences require the acquisition of specialized vocabulary that most standard-based frameworks for chemistry education include (cf.[230]). Accordingly, in each of the predefined domains in chemistry learning, the KMK defines teaching of implicit and explicit language skills that enable a specific and correct representation of complex chemical concepts students are obliged to master [231]. Yet, former studies in this regard proved that understanding difficulties of many learners are already located on the basic language level that is used in science contexts [232]. Students confuse concepts form everyday life and misinterpret these in the chemical context. In his study, Bonnet found that the use of English as the language of instruction helped learners overcome these misleading interpretations created from everyday language [233]. Further reports from practice proved that CLIL chemistry contributes to a stronger focus on language which helps students gain a deeper understanding of the technical terms embedded in the context [234].

As described in chapter 1.1.2, the teaching approach has recently also been applied in science labs for school students. Here, too, the advantages of CLIL teaching techniques are evident, as they enrich the learning setting and provide sufficient authentic speaking opportunities [24]. Since CLIL is also subject to the learning environment in this study, the next section introduces the variables investigated in this context from accompanying research in this field.

1.2. Target Variables Investigated in Science Labs for School Students

Although so far, accompanying research on science labs for school students focused on the investigation of various target variables such as interest [14, 15, 86, 13], motivation [81, 235, 236, 237, 25], self-concept [81, 238, 25], authenticity [125], image [238], job orientation [239, 238, 81], knowledge acquisition [124, 25, 237, 27], and acceptance [124, 95] [4], the following section considers only those that are subject to the study.

Hence, as this work investigates the three constructs cognitive achievement (see Section 1.2.1), motivation (see Section 1.2.2), and self-concept (see Section 1.2.3), the section begins with a brief introduction to each variable from an educational psychological perspective. Subsequently, the constructs are put into context of science labs for school students thereby considering the influencing factors which are summarized as laboratory-related variables [14] in this investigated setting (language of instruction, embedding of the module in school). Finally, their current state of research from a science labs for school students' perspective will be reviewed. Due to the still few studies that considered the CLIL teaching approach as the instructional method in this research field, relevant studies from foreign language didactics had also been taken into account.

[4] Only dissertations from German-speaking countries were considered here.

1.2.1. Content Learning and Academic Achievement

Following the goal of fostering students' scientific literacy, the acquisition of knowledge represents a primary societal educational objective. Yet, this extends beyond the mere learning of scientific concepts. It implies the contextualization of socially relevant topics in the field of sciences with the aim to educate students to become citizens who can reach responsible and comprehensible decisions [240]. At the same time, scientific literacy enables innovation of processes which require competences and dispositions that allow a participation within the scientific community [241]. With regard to chemistry teaching, it is the central task to familiarize students with the methods of acquiring knowledge and to promote scientific thinking in the process [242]. Science teaching in Germany thereby not only focuses on the purely content-related basic concepts, but also demands process-related competency areas that culminate in subject-specific teaching [230]. In the school context, the main indicators for measuring performance are subject-specific achievements, which are intended to provide information about the students' basic understanding of science. These are still proved solely by achievement tests, as they simultaneously verify the success of a teaching approach. The analysis in acquisition of subject knowledge in particular has always been prioritized before the evaluation of affective variables as an influence is directly visible in the examination.

Science labs for school students also pursue the educational mandate of knowledge construction. Such a learning experience is made accessible through an action oriented approach in the sense of a hands-on mentality in the laboratory [10]. Mostly working in groups, these settings allow a vital mutual collaboration where learners gain knowledge through direct exchanges with each other. Hence, the verbalization of knowledge takes over an important aspect which through active participation in the discourse, contributes to the development of scientific knowledge. Any learning process is dependent on verbalization and, in addition to imparting knowledge, also serves for the understanding of what has been learned [243, p. 176]. Similarly, the use of the foreign language for knowledge construction includes comprehension [244].

This section introduces two well-known theories that are frequently used in research on science labs for school students. First, the Levels of Processing Theory (LOP) [245] describes one way of explaining the assimilation and processing of newly acquired knowledge and its meaning for the bilingual science outreach context. Subsequently, the next section gives an overview of the Cognitive Load Theory (CLT) [246] which explains existing difficulties in this very knowledge acquisition.

The Cognitive architecture of the learner and the Levels-of-Processing Theory

Learning is the continuous change of already existing cognitive structures by embedding new knowledge presentations into old ones [247]. In the past decades, various models have been developed that describe how the brain processes incoming information. A theory that has prevailed and applied in most studies is the three-stage model of memory [248]. It relies on the transfer of a stimuli from the sensory to the short-term to the long-term memory in a linear sequence [249]. All stores differ in the way the information is encoded (visual, acoustic or semantic), with regard to its duration and capacity [248]. Hence, depending how existing knowledge is structured, new information is either memorized more shallow or deep. Yet, the multi-store memory system does not hold account on the encoding operations within the process which is why in 1972, Craik and Lockhart introduced their approach in learning and memory psychology [245]. The Levels-of-Processing theory (LOP) describes the ability of the human brain to process incoming information thereby allowing to make assertions how deep it is processed [245]. Accordingly, the authors assumed that not the long-term store in the short-term memory is dependent on when the information is saved in the long-term memory but rather at what level the item is processed. Unlike the multi-store model, it is based on a serial analysis which rather focuses on the process than on the structure [250]. Memory rehearsal is then seen as a by-product since the quality of the stimulus determines how well the information is memorized [245]. Craik and Lockhart proposed a hierarchical structure of the cognitive system where information is processed in three different ways as depicted in Figure 1.2.1. At what level the information is processed determines how intense the retention is. A shallow processing occurs when contents are encoded on a *structural* level which is restricted to the appearance of written words. Likewise, *phonemic* processing is defined as the auditory analysis of sounds. Deep processing refers to *semantic* processes, where the meaning of words is understood and which allows for an elaborate rehearsal. Thus, items are deeply processed when students have to put more cognitive effort in order to understand it.

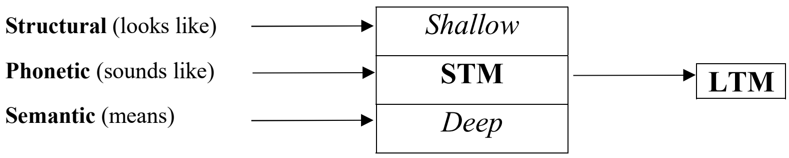


Figure 1.2.1.: Levels-of-processing adapted from McLeod [250].

When applying the theory to an educational context, it is assumed that students' achievement correlates to a deeper processing of the contents learned in school [251]. New information thereby easily accesses the long-term memory when cognitive strategies exist [247]. Especially science experimentation lessons require a simultaneous processing of the practical activity and content on different mental levels. In particular, open and collaborative learning environments in which students can control the learning process themselves allow for a more intense engagement with the contents [252]. The so obtained results negotiated in group work reflect jointly understood insights that ultimately promote semantic thinking structures [252]. Yet, the deeper processing depends on the quality of the contents that are connected to the

experimentation work. Pugh and Bergin [253] proposed that a deep-level processing is reached through practical experience where learning is connected to real-world problems. Moreover, a stronger in-depth processing can be achieved with a preparation and a follow-up of the topics dealt in the laboratory as learners are confronted with the material for an extended period of time. At the same time, additional information allows learners to experience a deeper processing [245].
Likewise, language, too, plays a crucial role in the acquisition of knowledge, as through the linguistic elaboration of the learned, new knowledge constructs are embedded more deeply into already existing ones [254]. As CLIL requires learners to assimilate and digest linguistic and abstract content information at once, the teaching approach is frequently examined with respect to the LOP theory. A common assumption had been that the processing among bilingually educated students occurs more deeply as it takes more effort to understand the contents [255]. The processing of the subject matter in the foreign languages demands a stronger reflection of the semantic content which eventually leads to a deeper processing [256]. In the context of bilingual science outreach laboratories, the hands-on component adds an another dimension which requires the processing of scientific concepts in a foreign language while running experiments at the same time. Even though the learning setting demands students' understanding in different domains, practitioners in CLIL science outreach approach settings assume that the learning arrangements fosters a deep-level-processing of information [214].

Nevertheless, an information intake does not exclusively lead to deeper semantic structures but depending on the form and presentation can become obstructive for the learning process. This may ultimately lead to an overload in the cognitive structures of the learner. In the following, the Cognitive Load Theory (CLT) will be discussed in this regard.

Cognitive Load Theory

In an effort to gain a deeper understanding of learning processes, researchers have engaged with the study of learning conditions that impede knowledge acquisition. A theory which also originated from memory research explains such phenomena through the cognitive architecture and its processing capacity. Frequently applied in instructional psychology in this context is the Cognitive Load Theory (CLT) which was developed by Sweller and colleagues [246]. The theory is based on the multi-component model of the human cognitive structure [257] and describes interacting mechanisms between the long-term and the working memory [5]. The long-term memory represents an unconscious storage where unlimited information is memorized for an extended period of time. The latter stores all the information of which

[5] The original term short-term-memory has ever since been replaced due to more recent theories to highlight its capacity to process information [258, p.105].

a human being is aware of. It involves problem-solving skills and information processing [246]. Most elements stored in the working memory cannot be converted all at once but need rehearsal to prevent them from deletion out of the system. As it is assumed that the capacity of the working memory is limited, overstretching through either time or duration could potentially lead to such a cognitive load [259, 260]. This ultimately results among other effects in losing information after a few seconds. Hence, learners need to learn house-holding with their resources to process incoming information in order to prevent inhibited learning.

The CLT thereby comprises three different types of cognitive load: the *intrinsic*, the *extrinsic* and the *germane* cognitive load [261]. *Intrinsic* load is caused through task complexity and depends on a strong element interactivity. As the elements of a cognitive construct (scheme) must be learned simultaneously, a learners' prior experience determines the magnitude of the cognitive load [262, p. 295]. Thus, learners with prior knowledge in this field can add up new chunks of information to a single element which is hold in their long-term memory. However, the more essential items interact with each other, and the less experienced a student is in a particular field, the higher the cognitive load will be [260]. *Extraneous* load is defined as the type of stress that relates to the instructional design of the learning environment. The way how information is delivered demands cognitive capacity which is not related to the complexity of the task [257]. Thus, poorly presented contents can hamper learning. Students have to filter irrelevant from relevant information as the *extraneous* load requires learners to put more effort in the understanding [263]. Therefore, the more structured the setting is, the easier the learners will intake the information and the less cognitive load they will experience. The third type, *germane* cognitive load refers to the processing and the understanding of schemes. The process that comprises a cognitive load begins with incoming information that passes through the sensory memory. A high *germane* cognitive load can lead to a better learning and understanding of the matter. It is therefore relevant for the construction of schemes and their automation in the long-term memory to increase the *germane* load [257].

Cognitive load is often applied in educational psychology aiming at the investigation of cognitive processes [264]. It is either measured directly through the use of a subjective self-reported rating scale on mental effort or difficulty ratings (e.g. [265, 266]) or indirectly by assessing students' performance. Taking the here selected learning process into consideration, there are different types of cognitive load to expect. Despite the fact that an open learning environment such as a science lab for school students explicitly promotes independent experimentation, the setting is not free from criticism, as it is likely to have a cognitive demanding effect [267] on learners especially when understanding is potentially limited [268, p. 49]. Scharfenberg [124] highlighted that students' prior knowledge affects the success of cognitive achievement in terms of comprehending the conducted experiments. Therefore, an adequate instructional

approach to experimentation is expected to have a beneficial effect on learning in science classes [267].
Likewise, in science outreach laboratories, the *extraneous load* also plays a major role. The unfamiliarity of the learning environment and its laboratory equipment, the instruction from mostly non-teachers and the structuring of work sheets might lead to this type of cognitive load [269]. Furthermore, the practical work in a laboratory can evoke an overload of the working memory due to the additional demands that arise in such a context. This puts in question whether experimentation as a whole can be regarded as conducive to learning [124].

Although it is assumed that a bilingual learning arrangement promotes a deeper semantic processing [256], critics expect a negative effect of the teaching style on content learning. Since learners' language proficiency determines their knowledge construction [270] and students' are required to process foreign language use and content knowledge all at once, the instruction style could induce a cognitive load. Delivering the information in a foreign language adds to the already complex contents and increases the cognitive load even further [83] as learning scientific contents through language goes hand in hand [271]. Transferring these findings to the bilingual laboratory setting, all three types of cognitive load are likely to occur [83] since it demands students to have higher mental capabilities to deal with the setting and all its requirements in this context.

Research position on cognitive achievement in bilingual science outreach settings

Even though science labs for school students have been gratefully accepted by many practitioners in this field, critics still question the effectiveness of such a learning environment with regard to knowledge acquisition. So far, only a few studies have focused on the learning output in these extracurricular settings with positive short-term results [124, 25, 26, 236, 272, 268]. Studies that tested for cognitive load found that the strongest learning effects could be observed at a moderate cognitive load [124]. Accordingly, learning arrangements that were neither too difficult nor to easy brought about the best results.

The question what long-term effects are caused has also not yet been clarified, since most science outreach laboratories offer a one-day program. Such a setting makes it questionable to expect long-term effects [94]. Consequently, more and more operators shift to a stronger integration of their program. One step has been followed through the implementation of a preparation and follow-up work embedded in school. Studies that examined the integration of the one-day experience in school confirmed the positive influence on knowledge retain [273, 86, 239]. However, others could not prove any long-term effects at all [13].

From a foreign language learning perspective, CLIL has been exhaustively researched with studies attesting its success on students' language proficiency [159, 149, 139]. Contrary, CLIL in science settings only recently have gained importance [212, 274, 233, 275, 216, 205, 217]. Unlike these rather unanimously results, evidence-based studies are contradicting. There is still no consensus about how subject content acquisition is effected by the teaching instruction [224]. Several studies found that secondary level II school students showed comparable results as their monolingual peers [274, 276, 277, 278]. Likewise, similar outcomes were obtained among secondary level I students in biology [244]. The authors of this study justified their findings through the use of *bridging* concepts (ibid., [244]) where students' prior knowledge is activated through known concepts and technical language that prepare them for the new session [29]. With regard to the study's intended learning arrangement, prior research confirmed that cognitive acquisition was not significantly impaired due to the foreign language use [24, 25, 215, 26, 83].

On the other hand, studies on subject knowledge intake demonstrated that foreign language resulted in longer response times and higher error-proneness in subject matters such as mathematics when instructional language and test language diverged [279]. Researchers assume that due to the translation process items are better recalled and deeper elaborated than when presented in the mother tongue [280]. However, there has been a battery of research that showed weaker learning outputs in the target language [281, 282]. This might be due to learners' unfamiliarity with new technical terms where the likelihood to have heard or used the word is lower than in the mother tongue [283]. Contrary, Piesche found that CLIL instructed students had acquired less knowledge than the monolingual ones [141]. Results of Cummins' study confirm these assumptions but she concedes that an exposure to the setting for an extended period of time could be beneficial as the indicated positive results were confirmed for both, content and language learning where learners participated for more than two years [28].

1.2.2. Motivation in Science Education

Although motivation is also a self-declared goal in chemistry education, the current stand proves that there is still potential to overcome its bad image as it has remained to be one of the least popular subjects in school [284, p. 6]. This had been confirmed by previous conducted studies where students' decreasing motivation in STEM subjects was demonstrated starting at a lower secondary school level [285]. As a consequence, fewer students graduate in sciences after school [286]. Motivation takes on a significant role here, as it influences learning-related behaviors in school subjects [287, p. 154]. Consequently, it would be useful to design learning environments that are both conducive to learning and motivating thereby aiming at long-term engagement all the way to career exploration (ibd., p. 154).

Learning situations are considered as motivating when students actively participate in the learning process. Open learning environments, in particular, are suitable for this purpose and their effect on motivation of participating students is already well known [14]. Science labs for school students bring about the potential to increase motivation in the natural sciences as most laboratories come with improved equipment and teaching structures compared to school lessons, which enable a constructivist learning situation as described prior in this chapter.

In the following, this section provides an overview of the construct motivation. It starts with an introduction to the self-determination theory (SDT) according to Deci and Ryan [288, 59, 289]. Thereupon follows a brief overview about the levels of behavior management which are illustrated by the quality of one's motivation [290] with regard to the here applied learning arrangement. In the final part, research on motivation in science labs for school students as well as bilingual education is presented.

Self-Determination Theory

In general, motivation is understood as an active orientation of the present execution of life towards a positively evaluated state [291]. It is always linked to a positive attitude from a learner's perspective. This is determined by dispositional characteristics and situational motivational stimulation [81, p. 10]. As a hypothetical construct [292] motivation defines the interrelation between a person and a situation [293]. Both intensity and perseverance to deal with the object describe motivation-dependent behavioral characteristics [287, p. 154]. In the subject chemistry in particular, the learning situation is characterized by practical work in the laboratory. The learning environment seems to have a special impact on the motivational output as other than classroom science students enjoy hands-on practice [36]. A positive learning attitude towards the subject can thus be achieved not only through critical questioning and autonomous use of scientific concepts [294, p. 262], but also through the independent performance of experiments [36] in an authentic surrounding while solving real-world problems. It satisfies students' need for competence. Hence, a crucial influence on motivation in chemistry comes with the design of the learning environment in order to facilitate meaningful learning [295].

A common theory that defines this relation between motivation and an object is Deci and Ryan's self-determination theory (SDT) [288, 289]. According to the authors, there is an intentionality behind each motivation resulting in the need to perform an action. Central to the theory is one's ”self” [289]. In this context, motivated action is considered a characteristic feature for self-determined behavior. The more self-determined an activity is perceived, the more willing and lasting the learning will be [289]. SDT grew out of Bandura's Social Cognitive Theory of human learning [296] which explains motivation solely from a cognitive point of view focusing on the outcomes [297]. Bandura's theoretical construct on self-efficacy expectancy, however, leaves out emotional and social aspects that further determine an individual's motivational base [298]. Deci and Ryan pay this aspect particular attention as according to the authors, motivation further involves self-regulated action which is defined by adaption mechanisms that are based on the a person's socio-cultural environment. These "primary psychological needs" [59] include the feeling of *(1) competence*, *(2) relatedness* and the feeling of *(3) autonomy* [289, p. 229] which will be described in the following.

(1) **Promotion of *competence***

As according to the authors, a person perceives herself or himself as competent when she or he complies with the requirements given in a specific situation. From an educational point of view, students only feel competent when knowledge is ready at hand to bring about the desired outcome in differentiated tasks [288]. Such a perception of competence occurs primarily through the presentation of content that is embedded in a practical situation with a concrete relation to everyday life [299]. Hence, it is important to take into account learners' prior knowledge and skills which are decisive for the accomplishment of the tasks [15, p. 30]. Likewise, prior academic achievement in these areas also implies a feeling of competence [300]. In science labs for school students, learners' capabilities can be promoted through independent experimentation, as they experience themselves in a positive way and feel a sense of achievement through their own actions. Accordingly, experiments that are successfully mastered lead to the experience of competence which also has a positive effect on learning [301]. Preparing students for experimenting in the laboratory therefore significantly influences this feeling of expertise [12]. Contrary, a task that is too challenging or the lack of confidence of the teacher towards his or her students could lead in turn to the loss of competence [15, p. 40].

(2) **Promotion of *relatedness***

The need for relatedness refers to a person's motivation to connect to the environment where one feels accepted and acknowledged in a social milieu [289, p. 229]. In the school context, relatedness is expressed through the learner's wish to engage with their peers and their teachers as positive relations also effect positive emotions with the learning object [302]. Especially in science outreach laboratories, working in small groups is promoted. This reinforces a sense of teamwork in a collaborative partnership whereby resources can be acquired. The individual experiences acknowledgment, a sense of belonging, and connection by contributing to solve the given task.

(3) **Promotion of *autonomy***

Finally, the need for autonomy describes an individual's desire to experience oneself as self-determined. This is dependent of what one regards as important [298]. Intrinsically motivated actions are reflected in a high sense of autonomy, as they are free from external regulation and are consistent with personal preferences [303]. In an educational context, autonomy is reached by giving learners the opportunity to choose from different options of learning contents which results in a feeling of personal responsibility [302]. This is especially the case for bilingual classes as in Germany, these tracks are elective [304]. Likewise, learning a subject in a foreign language mostly comes with a higher self-efficacy [305] as well as the desire to communicate in a another language [306].

Fulfilling these basic needs is considered a crucial goal in science labs for school students as motivation describes a control variable frequently researched [11, p. 30]. Most of these learning settings follow the approach of self-directed learning, in which students are given the opportunity to act like researchers in an authentic environment [49]. In this context, working independently on tasks is considered as a source for motivation. This requires learners to think about the planning, conduction and interpretation of experiments aiming at supporting students' critical thinking abilities. Such an approach runs contrary to German chemistry classes where experimentation is still often characterized by a very strong guidance. There, experiments are mostly delivered in a cookbook approach and activities that require independent action are taken over by the teacher. However, learners lose important perceptions during guided experimentation. In addition, students are not confronted with unpredictable events during experimentation resulting in a loss of competence, since tasks are not solved independently [307]. Consequently, solving the task cannot be attributed to their own talent [289].
Nonetheless, such a self-directed learning approach is determined by the level of instruction and varies among different science labs for school students. As extracurricular settings that focus on talent development allow students to freely work on their projects, classic science labs for school students offer a more directive setting due to the existing conditions within the laboratory and the limited time frame of visiting school classes. Still, the elaborate equipment of most science labs for school students offer a less restrictive learning environment. There, experimenting is conducted in small groups in which self-determined work is promoted [308].

Levels of behavior management - extrinsic and intrinsic motivation

One prominent aspect the SDT emphasizes is the differentiation of motivation based on its 'quality'. The theory relies on a dichotomous understanding of learning motivation which is determined by the motivational basis of the action. Hence, an action that expresses a person's free will and which illustrates one's interest, joy and curiosity is described as intrinsically motivating. Such an action is complemented by a person's needs for experiencing competence and self-determination [309, p. 42]. This self-determined action does not rely on influences outside the person but is inherently connected to the performed action [298, p. 59]. In order to experience intrinsic motivation, the fulfillment of an individual's basic needs is required

[297]. In their theory of interest, Krapp and Schiefele define intrinsic motivation out of the notion of interest that determines the relation between a person and an object [310]. A person's interest works as the driving force of an action which is internally produced [311]. Contrary, extrinsic motivation is linked to the individual's effort for the sake of the outcome or to avoid failure [289, p. 226] [6]. The action fulfills a purpose which is inherently connected to the consequences that result out of the behavior. Consequently, the performed action is not spontaneous but rather instrumental as with its execution the individual follows an agenda anticipating a reward [289, p. 225]. The assumption that the willingness to learn must be intrinsically motivated is far from the rule, because extrinsically motivated behaviors may also lead to the experience of self-determined action [289, p. 228].

From an educational research perspective, learning motivation takes over a decisive role as it describes an internal state that determines students' preferences in a subject matter [312]. It is therefore regarded as an accelerator for success in academic achievement [313]. There, intrinsically motivated action is the most desired form as it describes the learner's willingness to deal with a learning object without anticipating a reward from outside. Inspite of that, the motivational conditions given in the classroom are subject to institutional constraints that affect the quality of motivational development. Within the framework of school institutions, performance assessment, for instance, plays a decisive role, since it determines not only one's educational trajectory but also the choice of profession [81, p. 33]. These performance assessments have a high motivational value, which is reflected intrinsically and extrinsically in the behavior of the learner. Hence, based on a person's values and norms extrinsic motivated actions could be illustrated in the motivation to study an unfavorable subject in order to receive good grades. In addition, social motivation, competence motivation or competitive motivation are also expressions of extrinsically motivated action [314, p. 19]. In these cases, learning in the school context is orientated more towards efficiency rather than effectiveness considerations [315].

These insights gained from motivation research were harnessed to design time-limited intervention measures in addition to school lessons that benefit the promotion in motivating learners for sciences. It is also assumed from a constructivist perspective that motivational experience is better realized outside the school context [316]. Unlike in-school settings, extracurricular learning sites are not subject to institutional constraints, which can help avoid situations that hinder motivation [81]. Moreover, heterogeneous groups benefit from such informal environments as they are actively involved in the learning process [88]. But also students that are already motivated to study a particular subject area in greater depth, experience motivation through simple incentives [317]. A deliberate learning environment is offered due

[6] for a more detailed description of the four types of extrinsic motivation see [289].

to the degrees of freedom that allows learners to choose the direction in the learning process self-determined that eventually leads to the development of intrinsic motivation [318].
With regard to the studied learning environment, researchers in this field assume that working on tasks independently increases the intrinsic value of learning the subject [319]. Most of the contents dealt in the laboratory thereby relate to everyday situations enabling students to transfer learned concepts to solve tasks [253]. In addition, as most classic science labs for school students offer cooperative learning groups the feeling of social relatedness is promoted [238]. Likewise, authentic elements as part of informal learning opportunities can also positively effect students' intrinsic motivation in studying sciences [320]. The authentic use of English in a science outreach setting reinforces students beliefs in the field. Other than in classroom teaching where the use of the foreign language creates an artificial atmosphere, such extracurricular learning venues allow the purposeful application in an authentic setting [24].

Research on motivation in science outreach laboratories and CLIL

As previous studies already proved a positive correlation between motivation and academic achievement [313], its promotion especially in subject matters like chemistry is of importance when pursuing the goal to attract students back to sciences. So far, it has been found that the motivational effects are greater in science outreach laboratories than in regular school classes [317, p. 325]. Accordingly, practical experience in extracurricular settings has been shown to be a distinct factor in the promotion of motivation [321] that might have a lasting effect [322]. Studies that investigated science labs for school students indicated at least short-term positive effects on student's motivation [323, 81, 235, 236, 324, 238]. Scharfenberg [124] further found that participation in an out-of-school laboratory increases knowledge acquisition even without experimentation due to a higher learning motivation. Nonetheless, autonomous experimenting also has a positive influence on students' learning motivation [124, p. 199]. Other studies that examined the importance of school involvement in the out-of-school learning arrangement demonstrated that learners developed a higher intrinsic motivation from theoretical instruction, which led to the call for integrating these settings into classroom instruction [85]. This assumption was confirmed by Budke [324] who found that the integration of learning materials into the classroom had a positive impact on students' intrinsic motivation.

A similar situation arises concerning the influence of foreign language usage on the motivational experience in the subject matter. Even though CLIL is attributed a high motivational level due to its teaching style [140] the research base on this affective aspect remains sparse. So far, there are only a few studies that deal with the subject-specific motivation [141]. Most of these findings are anecdotal evidence from practice where missing research does not allow a

direct comparison [208]. Especially in science subjects, a lower motivational experience was identified among bilingually taught students among scientifically conducted research [325]. No significant differences were found between the monolingual and bilingual groups, but the teaching unit tended to be perceived as more motivating among the native speaker group [326]. Part of the reason why the learning environment is perceived as less motivating is due to the students' linguistic competencies. Research has shown that learners' motivation is directly linked to their foreign language competences [327]. Consequently, linguistically less gifted students find bilingual instruction less motivating than those who classify themselves rather as linguistically gifted. In addition, the time component also has an impact on motivation in bilingual education. Students who were exposed to a CLIL setting for more than two years indicated a higher motivation and a stronger feeling of engagement on content learning [328]. Therefore, it can be assumed that long-term interventions increase learners' motivation as they become more familiar with the teaching approach and readily apply technical terms associated with the subject matter.
With respect to CLIL integrated in a science labs for school students, Rodenhauser proved that her program positively impacted learners' activity based intrinsic motivation resulting out of the scientific contents dealt in the laboratory [25]. However, the outcomes did not significantly deviate from the monolingually instructed group.

1.2.3. The Internal Structure of the Self-concept

As described in the beginning of this work, the main goal of science labs for school students lies in enhancing the attractiveness of the natural sciences. Active participation in the laboratory plays an important role in this as it enables students to discover scientific working methods and to experience themselves in an autonomous way. This activity-oriented learning is a critical component in the development of the self-concept [329]. It is therefore little surprising that the construct has been studied frequently in the past, especially in science outreach laboratory research [15, 81, 13, 238, 83].

This subsection is intended to provide an overview of the self-concept as it is central to the investigation by representing one of the three research foci this study seeks to explore. First, a definition shall introduce the construct in more detail. This is followed by a description of its structure following the work of Shavelson et al. [330] and its later revision by Marsh [331]. The section continues by a presentation of the research body on students' academic self-concept in educational studies as a multidimensional and domain-dependent self-assessment of a person's own skills [332]. In this context, its significance in science labs for school students and specifically its impact within a bilingual intervention will be further discussed.

The development of the general self-concept

In educational-psychological research, the self-concept is characterized by significant personality traits. It is regarded as one of the most important psychological structures with a deep impact on learning processes and motivation [333]. It predicts one's past and future behavior in different domains. It is "the cornerstone of both social and emotional development" [334, p. 19] and regarded as a dynamic construct of self-perception that is subject to changes [335]. The self-concept involves "self-confidence, self-worth, self-acceptance, competence and ability" [336, p. 660]. Shavelson et al. describe the construct as a reaction to an individual's experience with the environment [330]. A person's self-concept evolves with age, moving from an initially differentiated to a stable construct in adulthood [335] determined by his or her self-belief. Influencing factors are thereby distinguished with respect to their quality. With regard to Marsh's internal and external reference model (I/E-model) [331], the perception of an individual's self-concept underlies comparisons with the environment (external frame of reference) and with self-concepts of other domains (internal frame of reference) [331, 337]. The intense dealing with the psychological structure has produced different definitions of self-concept, mostly addressing the self-concept construct [330, 331]. Accordingly, due to the interaction with several factors, the psychological construct is rather understood as a multifaceted structure of different hierarchies that becomes more divided when growing older [330].

Originally, research assumed the existence of a global self-concept, in which the abilities of an individual were evaluated globally. Based on the model of Shavelson et al. [330], at the top stands the first dimension which constitutes the individual's general self-concept. It describes "those attitudes, feelings, perceptions and knowledge about a person's own attributions which are indicated by the responses on a scale or instrument" [338, p. 196, cit.lit]. Thereupon follow the dimensions of an non academic and academic self-concept. The former determines the individual's self-beliefs on his or her relationship with other people (social self-concept), physical and sexual appearance (physical self-concept) as well as his or her emotional evaluation (emotional self-concept). It is related to motivational factors that will either hinder or facilitate the learning of a subject [339]. The academic self-concept describes "those attitudes, feelings and perceptions about a person's own intellectual or academic skills" [338, p. 196, cit.lit]. A detailed description follows in the next section.

The academic self-concept

The revision of this original model appeared in 1985, where Marsh and Shavelson added an additional abstraction level to the hierarchical structure of the self-concept. Based on research in cross-domain comparisons, a tendency was found for students to dichotomize their abilities in either being rather science-driven or language-driven [340]. The dimension distinguishes between two more higher-order academic facets: the verbal-academic and math-academic self-concept. With respect to school performance, the former refers to perceptions and abilities a learner has in language subjects whereas the math academic self-concept refers to non-language school subjects. One dimension below follows a more detailed representation of each academic dimension. In the verbal-academic self-concept this includes dimensions such as native language and foreign language self-concept whereas the mathematical self-concept entails dimensions of physical, chemical or biological self-concept. Some of the subsections represent both higher-order facets and overlap to form a third segment as depicted in Figure 1.2.2. In addition, the authors' extended subdivision of academic self-concept also describes a concrete situational self-concept that can undergo immediate change [339]. Thus, while the general self-concept is considered as stable, lower dimensions in the model of self-concept become increasingly situations specific and are subject to changes [339, p. 107].

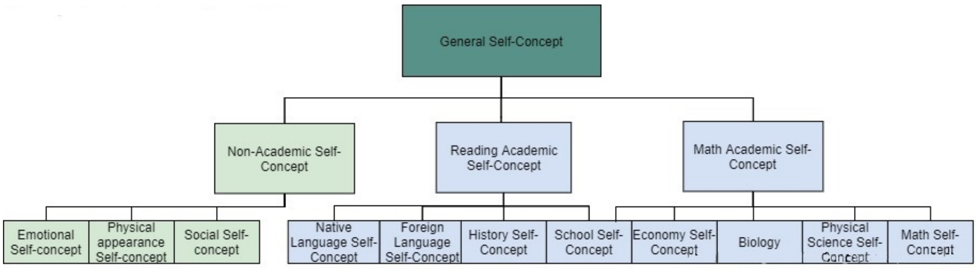


Figure 1.2.2.: Modified academic-self-concept adapted from Marsh et al. [339].

Based on this model, in education the self-concept of ability is considered as a cognitive representation of one's own abilities in terms of school achievements [341, p. 394]. In the school context, research always focuses on the subject-related formulation of instruments for assessing the self-concept. This makes it possible to measure the construct's degree of expression in different domains. With regard to the I/E-model [331], students' academic self-concept is formed from two ways of comparison learners apply to evaluate their preferences and abilities on different dimensions acquired in school. The self-concept develops, among other things, through the collection of competence experiences over time [342]. The external frame of reference thereby describes an inter-individual contrast where a student compares his or her performance of a particular subject with the achievement of their peers. The internal frame of reference illustrates a comparison based on one's performance in different subjects [331].

Taking the setting of the present study into consideration, the evaluation of students' academic self-concept is determined by two domains: chemistry (math academic self-concept) and English (verbal academic self-concept). Both dimensions are depicted with regard to the

I/E-model in Figure 1.2.3. Thus, based on their past experience and performance, learners will evaluate their self-concept in chemistry and English internally with respect to the grades they received in school and externally by comparing their performance in the laboratory with their peers.

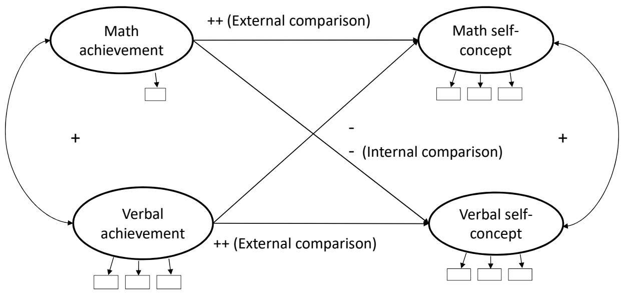


Figure 1.2.3.: Framework for the I/E-model adapted from Marsh and Hau [343].

The academic self-concept in education

For decades, studies have been conducted on the investigation of the academic self-concept which covers students' perceptions with respect to general school subjects. One important aspect literature has pointed out is the reciprocal relation between academic achievement and self-concept in which one influences the other [344, 345]. Thus, learners develop a stronger self-concept from high academic achievement in a school subject while weak results lead to a lower self-concept. However, learning success is defined individually, causing students in one class who share the same learning success to construct different self-concept beliefs in one and the same subject matter [346]. This suggests that self-concept is not only prone to academic achievement but can be influenced among others by affective reactions such as pleasure in the domain [347], attributions of success or failure in the subject matter [348] or by comparing their performances with other disciplines and classmates due to reference frame effects [331]. To a large extent, this relationship also influences the career choices of young learners [349]. Consequently, promoting students' self-concept is pivotal in future aspirations since the psychological construct predicts students' choice in science careers [350].

Similarly, gender based differences in academic self-concept have been subject to various studies in the past [351]. Thus, a very persistent assumption is the diverging perception of the self-concept in scholastic settings based on gender [352]. With regard to STEM subjects it is already known that there are tendencies of more positive self-concept beliefs in favor of boys [353, 354, 355, 356] who at the same time tend to form a lower verbal academic self-concept [357]. It is therefore little surprising that girls are underrepresented in STEM fields when it comes to career choices. Recent studies have shown that future aspirations are made primarily on the basis of self perceived competence rather than actual performance [358].

Consequently, girls tend to establish more negative self-concept beliefs in STEM subjects which affects their later career choice even though school performance is high [359] but as opposed to this tend to develop a stronger verbal academic self-concept.
Especially in the case of gender differences, social and dimensional framing as described in Marsh's [331] I/E model play an important role. Other than their male peers girls' assess their performances in school subjects more externally while boys frequently compare their achievement more internally [360]. As a result, within a heterogeneous class girls tend perceive themselves as less competent although having the same cognitive achievement as their male peers. This phenomenon is known as the Big-Fish-Little-Pond Effect (BFLPE) [361], and is even observable in higher education [362]. Kessels and Hannover [363] therefore attributed girls' lower self-concept in sciences to the learning environment since girls' in same sex classes showed a higher self-concept in the subject compared to their peers in heterogeneous groups [363]. As the promotion of girls' self-concept in sciences, would also improve their engagement in these subjects in school [364, 365, 360] it is a crucial goal of different educational institutions to create an engaging atmosphere for both genders [366]. The installation of science outreach activities as self-concept enhancing learning environments has proved to be a promising measure as research on science labs for school students indicates which will be presented in the next section.

Research on students' science self-concept in science labs for school students and bilingual education

Well aware of the self-concepts' influence on the learning process, numerous studies examined its change through the participation in a science lab for school students' program [81, 26, 272, 15, 83, 367]. Most research found at least a short-term increase in the self-concept of visiting students [272, 238, 214] or even confirmed a long-term rise [367, 15]. Others however, could neither prove any long-term impact [79, 81] nor any significant effects on learners' science self-concept at all [13]. These different outcomes are most likely attributable to the fact that setting and content of the operating laboratories differ, which in itself impairs comparability. Still, even though it cannot be expected that a one-day attendance causes a long-term alteration of learners' science self-concept, the mostly short-term increases nevertheless give reason to assume that these interventions may produce positive effects in such a short period of time. Moreover, there is at least a consensus that the extracurricular place of learning promotes girls and boys equally [14, 81, 15, 272]. Overall, while the role of the out-of-school learning setting on influencing the motivational factor has not yet been explicitly clarified, it can at least be assumed that participating does not lead to a decrease in learners' academic self-concept [15].
Likewise, it is indisputable that the self-concept does not allow any direct statements about

the abilities and skills of a person in a particular field. An empirical study of the given construct nevertheless allows predictions about future motivational readiness to perform actions [341, 342]. Within the context of science labs for school students where hands-on experience stands in the center of the intervention, the experiment-based self-concept is of particular importance. It is assumed that the high proportion of practical work has a positive impact on participating students' self-concept. In particular, learners are given the opportunity to experiment without any pressure while performing and acquiring scientific working methods [368]. Hence, by visiting a science lab for school students there is an opportunity to foster one's academic self-concept at the lowest level [15]. Again, it must be emphasized that the experiment-related academic self-concept addressed does not represent a construct that is stable over time [369] and need more than a short-term intervention to cause a long-term change.

With regard to the investigation of bilingual settings, research confirmed a higher verbal-academic self-concept for students who were experienced with bilingual education [370, 371]. Thus, as in Germany mostly gifted students attend bilingual classes [372], it can be assumed that those students already possess higher academic self-concept beliefs with girls in particular. Research from the subject matter perspective is mostly lacking. In the context of science lab for school students investigations, some studies already addressed learners' science self-concept. The authors found that the setting was especially beneficial for students' who perceived themselves as equally competent in sciences and languages [25, 26]. Similar to previous studies on science labs for school students, no gender effects were observed [25, 83, 26, 215]. Despite the current state of research, no clear conclusions can be drawn about the impact of the bilingual learning arrangement on students' science self-concept since again those interventions were framed in a biology context.

2. Conceptualization of the Interventional Setting: The LMU*chemlab*

As this study pursued to investigate the learning environment LMU*chemlab*, the present chapter focuses on the characteristics, concepts and conditions within the setting. It starts with a brief introduction and categorization (Section 2.1) according to the Lernort*Labor* [16] (see Section 1.1.1). Thereupon follows a description of the underlying methodological framework applied (Section 2.2) which is based on the model of educational reconstruction according to Kattmann, Duit, Gropengießer and Komorek [32]. The approach builds the foundation of the developed laboratory module on *Modern Materials* which covers the research field of nanotechnology (Section 2.3) mirrored in the five experimental stations (Section 2.4.1). The chapter closes with a description of the planning and organizational structure followed within the science lab for school students (Section 2.5).

2.1. Characterization of the Learning Environment LMU*chemlab*

Affiliated to the chemistry department of the Ludwig-Maximilians-University, Munich, the LMU*chemlab* first came into operation in March, 2018. With its two laboratories, it offers up to 36 students per class the opportunity to participate at a one-day event with the goal to experience interactive activities from latest research in the field of chemistry. Since its opening, more than 2700 students were recorded to have visited the laboratories with their classes. Its operators continue to expand their offerings and new modules are incorporated to the setting [373]. These various modules address both, secondary level I and II students. Registration is managed by the teachers who sign up their classes a few months ahead of the intervention.

Figure 2.1.1.: Logotype of the LMU*chemlab* [373].

As a member of the federal association *LernortLabor*, the LMU*chemlab* fulfills the required criteria [82] for science labs for school students (see Chapter 1.1.1). Apart from its main objective to raise learners' interest and awareness in sciences [82, p. 326], it follows more than one

secondary goal. Allocating the extracurricular setting to a single category as according to the classification of Haupt et al. [82] is therefore difficult to realize. On the one hand, the learning environment pursues the objectives of laboratories with a science communication focus. Due to its proximity to a research institution it aims at cooperating with disciplinary chairs within the department. This is reflected in new experimental stations that are constantly being developed deriving from latest research. A major effort in creating these experiments is put in meeting the skills of participating learners. Further, the learning environment is equipped with analytical tools such as atomic-force-microscopy (AFM) or UV/Vis-spectrometer which allows students to encounter rare materials in a natural surrounding. This gives learners the opportunity to get insights into different scientific job professions by working side by side with the staff while engaging with scientific topics. Accordingly, authenticity is approached through the presentation of different elements embedded in a realistic environment [133]. The LMU*chemlab* thereby adapts to the ideas of an extended theoretical model on authenticity based on Nachtigall [84] which describes the authentication process as an interaction between a learners' characteristics and the learning arrangement.
On the other hand, the setting further aims at the professionalization of teachers. Thus, all modules are embedded into seminars in which pre-service teachers are invited to optionally enroll for as part of their studies. Hence, student teachers are offered additional opportunities to practice, analyze and reflect their teaching skills through the work with participating school students. The LMU*chemlab* therefore calls the demand for teacher training by addressing the development of professional competences [99].

Bilingual module on *Modern Materials*

In the scope of this study and in parallel to the monolingual-German module *Moderne Materialien*, a bilingual-English setting was offered. Independent of school type, the module addressed secondary level II students from grade 10 to 13 which covered different aspects from the field of nanotechnology all summarized under the term *Modern Materials*. The interdisciplinary research field offers direct connections to topics on biochemistry, organic chemistry or inorganic chemistry which allowed a linking to the school curriculum (cf. [230]). At the same time, students could draw on their knowledge acquired from prior chemistry lessons. In small groups, learners collaborated at each experimental station to engage in conversations with their classmates and supervisors by using the instruction language English in a meaningful way. Hence, the setting was designed to promote the interdisciplinary competencies of students. Further, to increase the cooperation between school and university, the module also comprised a preparation and follow-up which was conducted by student teachers who visited participating classes in school before and after the intervention in the laboratory.

2.2. Educational Reconstruction as the Methodical Framework of the LMU*chemlab*

Visiting a science lab for school students can quickly become a balancing act between learners' concepts prevalent in everyday life and mainstream science. In order to make complex and latest research accessible to students, learning settings that, among others, pursue the goal of science communication, require a goal-oriented mediation of current research while taking into account students' perspectives. Similar to school science, the operators of these facilities are increasingly confronted with the question of how to arrange a suitably structured environment didactically and methodically with the aim to facilitate original encounters that are beneficial to learning.
When orienting on the practices of science education, one can quickly observe the linear structure exerted in most science classrooms. There, teaching still follows an instruction-oriented and receptive format by presenting contents only at the concrete state of research [374]. This procedure is realized through an increased degree of abstraction of the learning content adhered to the principles of didactic reduction [375]. However, simply relying on a more abstract representation while neglecting students' prior knowledge on the subject matter does not necessarily lead to the desired success. Recent studies in sciences proved that students' low interest and motivation in classic classroom science [376] is mainly due to the complexity of integrating newly acquired scientific theories into their everyday lives [377]. Consequently, in order to achieve a long-term success in the teaching process, it is essential to incorporate learners' pre-concepts to the learning setting [378, p. 41]. These ideas can greatly differ from the generally accepted theories and are often difficult to correct due to their persistence. However, by taking these concepts into account, instructors can improve learners' understanding of the science content [379].

An elaborated research framework followed by many science labs for school students that addresses learners' comprehension and is built on the phenomenological understanding of teaching and learning is provided by the model of educational reconstruction [32]. It is based on the epistemological considerations of a constructivist perspective [380] (see Chapter 1.1). Hence, learning is understood as a process in which content is developed and embedded in already existing mental structures. Kattmann et al. [32, p. 7] describe the learning process as the formation of new academic views by taking into account already acquired mental structures from the respective discipline and its associated application. In an iterative process, the ideas of researchers are contrasted with those of the learners. There, learning is not understood as the substitution of contents, but as a self-directed process where already acquired and internalized pre-concepts are modified [381].

In its core, the model pursues three objects of investigation, which are understood as interacting parts of a total system [382]. The three strands are regarded as complementary to each other. Thus, educational reconstruction describes a reciprocal relationship structure, whereby these individual tasks are not sequenced, but require repeated adjustment due to the recursive procedure [382]. Figure 2.2.1 depicts the model which illustrates the trinity of the holistic approach.
One of the strands in educational reconstruction describes the component of the *Clarification and Analysis of Scientific Content*. According to Kattmann et al. [32], disciplinary knowledge describes an analytical-critical examination of scientific ideas. It comprises the totality of all available content in a topic and defines the function and meaning of technical terms and scientific propositions used in different contexts. Conceptualizations, theories and methods are critically examined with regard to their relevance. According to the authors, both the current state of a field and historical theories are included, provided that it serves to clarify and delimit currently prevailing theories while making its contribution to the understanding of learning concepts [32, p. 11]. In addition, the limits of scientific theories are pointed out and ideas that promote or hinder learning are identified. Thus, a sound planning requires coverage by theory-based knowledge [99].

The second object is determined by the *Investigation into Students' Perspectives*. This component is concerned with capturing both, students' cognitive and affective beliefs on a particular topic. In general, according to Kattmann et al. [381], the acquisition of central ideas begins with the inclusion of all existing terms and concepts inherited by the learner. Previously acquired mental structures are localized as well as one's everyday language as the place of origin, in addition to everyday ideas [383]. By eliciting student conceptions, learners' mental constructs are made visible, allowing these conceptions to be embedded in broader contexts. This becomes even more important when considering that learners' conceptions can be heterogeneous and influence the process of learning by incorporating perceptual knowledge into pre-existing concepts [384]. Nevertheless, capturing learners' perspectives can only be understood as a qualitative research task, since a direct access to students' mental structures is not possible but rather relies on their interpretation [385].

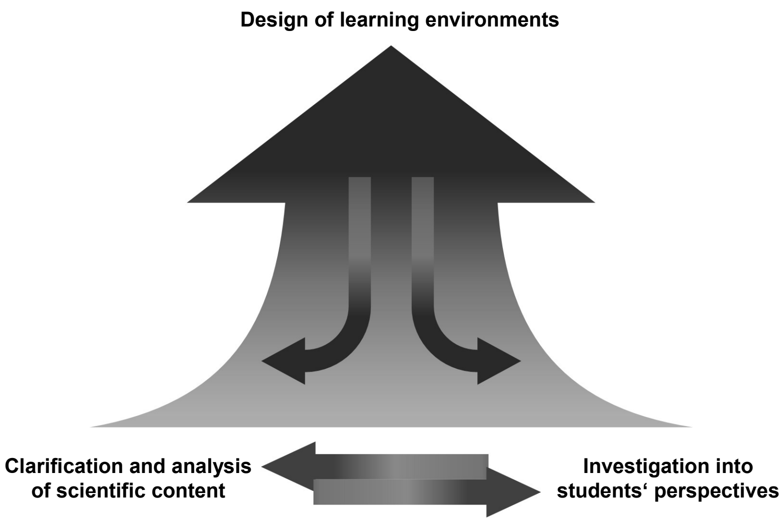


Figure 2.2.1.: The model of Educational Reconstruction adapted from Kattmann et al. [32].

The third objective refers to the planning process. There, decisions are made that comprise methods, objectives, and learning outcomes for teaching and learning sequences. Hence, the *Design of the Learning Environments* is based on the ideas of scientist and student alike where the two positions are brought into balance. Didactic structuring of the learning environment thereby ties to students' prior knowledge while at the same time these ideas are confronted with a scientific perspective. The juxtaposition of the two sides provides possibilities that take into account both perspectives [386]. Thus, a carefully designed instruction defines the goal, topic, scope and the degree of complexity resulting out of the two strands [377].

As already mentioned, the educational reconstruction approach has been used in the design and implementation of different learning environments in sciences [32, 387]. Conclusively, the practice-oriented model also provided the framework in this study following the goal on implementing, and evaluating learning opportunities at the LMU*chemlab*. In the context of a bilingual science lab for school students, language with its special registers takes on a significant position in students' perception process. In general, the meaning of language and the acquisition of it plays an important role with regard to the intake of learners' pre-concepts. The application of technical language functions as a communication tool within the scientific community and allows a distinction to other disciplines [388]. Thus, many of the terms used in the subject domain have a different meaning in students' everyday lives. This is due to the ambiguity of technical language which requires the awareness of colloquial language [374]. The fact that technical terms or scientific propositions are often misleading can be shown by simple examples from chemistry. The German word "Wasserstoff" (hydrogen) leads to misinterpretations and incorrectly indicates the composition of the element from the molecule water. Thus, one way to take advantage of the correct use of the technical language could be to replace it with the English term. This could circumvent misconceptions and at the same time promote the learning of the correct scientific meaning. Consequently, overcoming these language barriers can be accomplished through the use of the foreign language. This is especially possible when everyday language is recognized within the native language by contrasting its meaning in the foreign language.

Such considerations become even more important when it comes to teaching current research technologies. Accordingly, due to the high degree of complexity, scientific contents and experiments cannot be transferred unfiltered to the out-of-school setting. Rather, it requires an adaptation of the contents that take into account students' prior knowledge. However, with regard to learners' preconceptions in the field of nanoscience, there are hardly any ideas students can draw on. This is mainly owed to the educational curricula, which does not explicitly foresee the integration of the topic in the Bavarian curriculum on chemistry [230]. Although nanotechnology is of high importance in society (which will be reflected in Section 2.3), the field's potential for subject teaching has been little exploited. This is rooted in the difficulty of making these processes visible and approachable to the learner. The research field is thus limited in its tangibility. Consequently, students' ideas must be evaluated from their context, situational condition and function [377] which results in a synergy based on students' preconceptions and the scientific theories behind the experiments. Despite these obstacles still to overcome, the promising field of nanotechnology is frequently addressed in science labs for school students (cf. [16]) and is also the subject of this work. The upcoming section therefore gives a brief introduction to the research area.

2.3. Societal Relevance of Nanotechnology - Age of Modern Materials

Derived from the Greek word for "dwarf", the pre-fix "nanos" is defined as one billionth of a meter (10^{-9} m). The field of nanotechnology then encompasses the fabrication and manipulation of small objects at atomic, molecular to macromolecular scales that approximately reach up to 100 nm [389]. The change in size substantially alters the functional properties of materials allowing innovations in different STEM sectors [390]. It is therefore no surprise that nanotechnology is considered a fast-moving research area with a profound impact on different aspects of today's public life [390]. Yet, even though research in this future-oriented technology has first started to flourish among scientists of various traditional disciplines in 1996 [391], the fabrication and application of nanomaterials can be traced back to the fourteenth century BCE. Ancient artifacts were presumably colored with Cu nanoparticles to reach a red opaque tone on glass [392]. Today, the multidisciplinary approach encompasses areas from drug delivery, polymer sciences to electronics and has become one of the most influential research fields of the 21^{st} century. Fast moving developments emphasize nanotechnology's pertinence in many fields as it connects latest research relevant in everyday life to society [8, 393] indicated by the growing of application oriented branches [394]. Understandably, Laherto [8] pledges for a "nano-literacy" since future workers will inevitably come across the concept with its multiple applications.

Due to its high impact on industry, the conjunction between research and teaching has been widely promoted as students need to be prepared for societal developments indicated by the different work fields that incorporate the concept of nanotechnology [395]. Even though the progress in nanoscience and nanotechnology has started to inspire teachers and educators to implement contents into science classroom [396], it still lacks specific programs that offer students insights to the field [395]. However, such measures are important in order to recall its role in society as there is only a low understanding what nanotechnology means and what impact it has on learners' everyday life [397]. Consequently, to fulfill the educational goals and to attract students back to STEM fields, educators need to be prepared for the teaching of nanotechnology as the field mostly remains unconsidered in teacher education nor has it been extensively implemented in school curriculum [398]. Some countries initiated first steps towards the integration of nanotechnology. Whole projects were developed for teachers to adapt the contents to the syllabus since one of the major difficulties educators face is to place the topic into the curriculum [399]. Likewise, Germany only recently started to consider nanotechnology as contents of courses [396]. What is still left unacknowledged, is the potential that the broad field opens to the acting parties. From a whole variety of topics, teachers can offer a creative learning arrangement that goes beyond classic classroom science [390]. Past teaching experience has proved how the cross-disciplinary field promotes students' scientific literacy [400]. Its diverse scope thereby has the ability to attract girls and boys alike as gender has been said to have no specific influence on nanotechnology [401]. This would not only close the existing gender gap but fosters learners to engage in sciences, in general considering that students lose their interest at the secondary school level [402].

Hardly any other area of research is thus so well suited to be taught in a science labs for school students, partly as most schools lack the equipment to present the field in its entirety [403]. Furthermore, such learning environments offer a variety of possibilities to make the research area more tangible to students which allows other than in school an authentic presentation of the field. As nanotechnology represents the scientific background of the experimental stations from the designed bilingual module, their didactic implementation based on its research work will be presented in the following.

2.4. Introduction to the Experimental Stations on the Bilingual *Modern Materials* Module

This section illustrates the five experimental stations that were offered in the bilingual module on *Modern Materials*. Time frame and overview are provided in Table 2.4.1. Three of the experimental stations (station 2 to 4) were originally educationally reconstructed by Stefan Schwarzer as part of the *klick!*:labor at the IPN Kiel and were adopted with permission and translated according to the needs of the study. Content-wise, they follow the field of nanoscience [404] and are based on the works of Schwarzer et al. [405], Bethke et al. [406] and Baum and Schwarzer [407]. For the sake of completeness, a short introduction to the scientific background and didactical implication each are also included. Experimental stations 1 and 5 were newly developed. All instruction sheets are added to the appendix (see B).

Table 2.4.1.: Presentation of the five experimental stations from the *Modern Materials* module. Experimental stations that were adapted are marked with an asterisk*.

Station no.	Name	Time frame
1	Investigating sunscreens	50 minutes
2	Synthesis of gold-nanoparticles	30 minutes*
3	Generating micro- and nanostructured surfaces	30 minutes*
4	Determining the layer thickness of a soap bubble	30 minutes*
5	Production of a nano care	50 minutes

(*With permission taken from the *klick!*:labor program)

2.4.1. Experimental Station 1: Sunscreen Nanocomposites - Investigating Sunscreens

The first experimental station dealt with the mechanism of sunscreens and sun blockers in their function as skin protecting systems against damaging UV radiation. The basic principle behind sunscreens lies in the prolonged time of exposure to the sun. Currently, two basic principles are distinguished: absorption and scattering. Absorption is solely observed in organic filters whereas inorganic and broad-spectrum filters show both mechanisms.

Sunscreens with organic filters are considered as photon-absorbing active ingredients. Radiation is absorbed by chromophores based on aromatic compounds containing carbonyl groups. Organic UV filters thereby use the capability of delocalized π-electrons in their ground state (S_0) to absorb photons to reach an excited state (S_1). The process is reversible due to the relaxation of the molecule to the ground state. Many of these organic filters absorb energy at the UVB region [408].

Inorganic UV filters describe a group of metal oxides that are used in sun blockers. Currently, insoluble bulk ZnO or TiO_2 crystals are the two main active ingredients that are approved in Europe and the US [408]. Mineral UV filters like TiO_2 are small semi-conductors that absorb energy at the UV spectrum. Microsized TiO_2 crystals absorb energy at the UVB range or in combination with ZnO which covers the whole UVB and UVA range [409].
Broad-spectrum UV filters usually describe a combination of different organic and inorganic UV filters allowing for a uniform UV protection. Thus, they cover the whole range of ultraviolet light.

Experimental station 1 deals with the different mechanism of UV filters in which a fluorophore is applied to the UV compounds. In general, fluorescence is typically observed with organic and inorganic molecules where visible and UV light from the electromagnetic spectrum is absorbed. The raise in energy leads to an electronic excitation from the ground state S_0 to the first excited state S_1 or between any two energy levels with the same spin. To return back to the S_0, energy is released through heat and the emission of a photon. The emitted light energy is of longer wavelength than the absorbed radiation. This wavelength shift is observed as fluorescence (in the S_1) [410]. UV absorbing molecules have the ability to suppress the energy needed to excite the fluorophore resulting in the diminution of fluorescence intensity. This intra-molecular deactivation process is known as fluorescence quenching (see Figure 2.4.1).

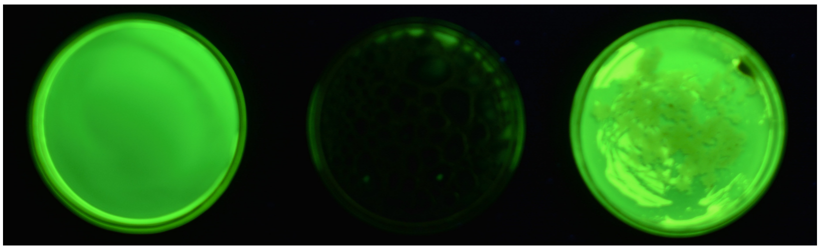


Figure 2.4.1.: Fluorescence quenching of organic UV filter under UV light. Left: blank uranine in polar medium; middle: quenching of uranine by organic UV filter (octocrylene); right: bulk, micro-structured TiO_2 inorganic UV filter in a fluorescent dye solution.

Premise for the quenching process is the molecular contact between the fluorophore and the quencher during the excited state life-time. Consequently, the fluorophore returns to the ground state without emitting a photon. The mechanisms that lead to the decrease of the fluorescence generally results from molecular interactions. Electronic energy of the initially excited molecule is removed by the quenching process [411]. The fluorescent dye and the organic UV filter form a non-fluorescent complex in the ground state. With its formation, the complex evolves a unique absorption spectrum.

As students qualitatively and quantitatively analyzed sunscreens based on their different modes of action their prior knowledge on damaging UV light from their everyday life was activated. In doing so, wavelengths with respect to the electromagnetic spectrum of light are classified. The effects of high frequency light were demonstrated through the exposure of UV light sensitive dolls to a UV lamp placed on top of a black box. Students' perceptions concerning the different types of radiation were addressed. One preconception that persists is the coloring of UV radiation as blue light. Many students are not aware of the hazards associated with UV radiation and estimate the risk depending on their prior experience. Hence, learners who are familiar with UV light as a safety feature on bank notes tend to assess UV light as less dangerous than those that know UV radiation from sunbeds [412, p. 123]. Subsequently, students are introduced to the fluorescent dye uranine, and its UV radiation absorbing abilities. The experiment continues with a constructivist approach and learners are asked to construct a model experiment which allows the testing of each sample with the supplied chemicals and laboratory equipment given in the work sheet. In order to do so, each of the unknown samples (see Figure 2.4.2) had to be brought into a homogeneous mixture with the fluorescent dye on a watch glass and were observed under the UV light lamp that radiates into a black box. Another aspect that allows the linking to students' preconceptions according to the educational reconstruction model [32] is the coating of inorganic UV filters. The well-known ”whitening effect” superimposes the main mechanism that like organic UV filter relies on the absorption of UV radiation.

Figure 2.4.2.: Set up of experimental station no. 1.

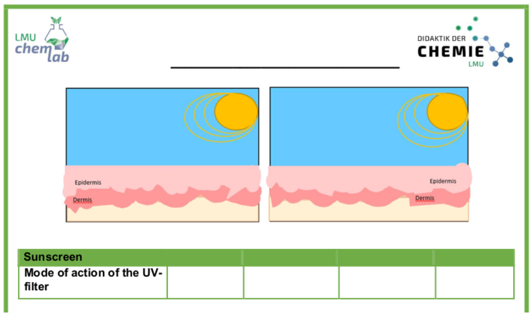


Figure 2.4.3.: Work sheet explaining the mode of action of organic and inorganic UV filter.

The phenomenon was used to introduce the nanotechnological application in sunscreens which enhance optical properties to overcome the cosmetically undesired white haze. One learning objective was to explain that the size of inorganic filters needs to be optimized at a nanoscale so that visible light can transmit and the application of the sunscreen becomes transparent [409]. Again, changing properties and functions of the material were used to link to students' prior concepts on the bulk transition metals. Subsequently, introducing students to further application fields such as paintings to drug delivery [413] allowed for a reference of these materials to everyday life.

Links to the nanotechnological implementation of sun protecting filters can be found in the Bavarian curriculum. These allowed to tie onto a predefined curricular acquisition of the stated competencies including the structure and function of organic and inorganic compounds (see Figure 2.4.3). Likewise, the station tackled functions and mechanisms of fluorophores and offered opportunities to promote students' acquisition of scientific working methods by reinforcing quantitative as well as qualitative methods within the investigation. This also opened up opportunities to foster learners' evaluation skills [414]. As such, the use of mineral filters in sun protecting filters was discussed with regard to the relevance of nanoparticles in everyday life. This included the interpretation of a presented study on the effects of nanoparticles on the human body.

2.4.2. Experimental Station 2: Synthesis of Gold-Nanoparticles

Experimental station 2 focused on the fabrication of gold nanoparticles (AuNPs) in water produced in a Leidenfrost reactor. The Leidenfrost effect describes a physical phenomenon which occurs at temperatures above 270°C. It is based on the heat conductive characteristics of H_2O molecules. In the reactor, on the down side of the drop water molecules begin to evaporate and form a steam cushion. When reaching the Leidenfrost temperature, the gas pressure in the vapor layer insulates the drop from the hot surface and promotes its levitating through an increase of its kinetic energy (Figure 2.4.4) which in turn prevents the drop from evaporating [415]. Conditions within the drop proved to be favorable for the synthesis of gold nanoparticles in a chemical reactor and allow a sustainable and eco-friendly production through the reduction of tetrachloroauric acid salt $HAuCl_4$ in the presence of the stabilizer molecule citric acid $C_6H_5O_7^{3-}$ added to a Leidenfrost drop [405]. It is assumed that through charge separation due to the occurring autoprotolysis of water (Figure 2.4.5), the OH^- ions deliver basic conditions that are needed for the nanoparticle formation which help to reduce the gold precursor to form AuNPs. At the same time hydronium ions begin to vanish in the vapor leading to the negative charge inside the drop [416, 417]. However, even though the OH^- surrounding promotes a fabrication of plasmonic AuNPs, a full conversion of the nanoparticles is difficult since the concentration of OH^-- ions depends on the dissociation of water [416]. The obtained AuNPs are finely dispersed in the solution where clusters of gold atoms are formed and protected by a stabilizing shell as schematically depicted in Figure 2.4.6. The experimental station therefore describes a 'bottom-up' synthesis in which complex structures are built up through small clusters of atoms that allow a selective control of the size, form as well as the dispersion of the nanoparticles.

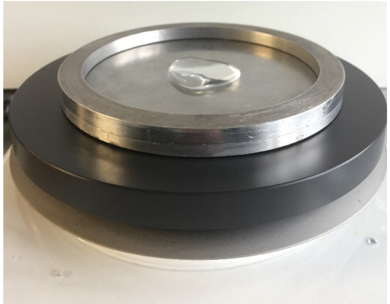


Figure 2.4.4.: Water drop levitating on a hot plate at Leidenfrost temperature.

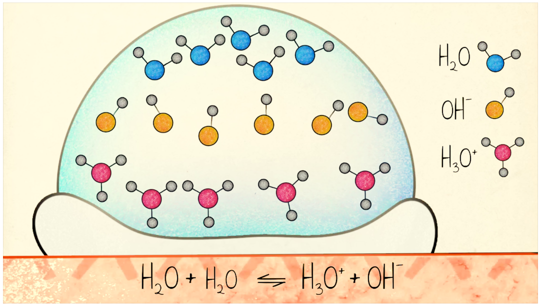


Figure 2.4.5.: Didactically reduced and animated representation of a charge separation within a water droplet caused by the Leidenfrost effect.

Goal of experimental station 2 was to fabricate different AuNPs varying in size and color. The reaction mechanism behind it becomes apparent by following the three approaches given in the instructional manual based on Schwarzer et al. [405]. In order to convey the necessary subject-specific scientific content, learners have to come with prior knowledge on the metal gold. With regard to the model of educational reconstruction [32] contents built on students' everyday conceptions of bulk gold with its optical and chemical properties. Appearance and size contradict learners' prior knowledge about the structure of metals and allow addressing the topic. Historically developed application fields of colloid chemistry provide a suitable starting point for pre-instructional connections [418] within this station. Students learn that nanotechnological application of gold can be traced back as far as the antiquities. Fabrication of relics, stained glass windows in churches or jewelry are a few examples that remind of the production of gold nanoparticles in the ancient times and their use for the coloring of stained glass [392]. Such connections offer opportunities to work out recent and more efficient ways and application areas of the production of AuNPs. Learners are then introduced to current application areas from medicine to tool technology.

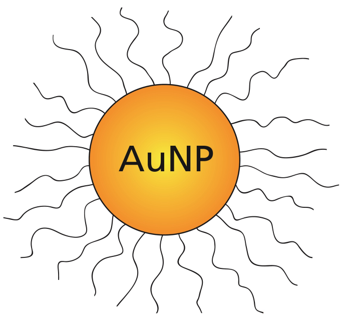


Figure 2.4.6.: Schematic view of citrate-stabilized AuNPs.

In the upper secondary level, the experimental station provides various links to classroom chemistry. Depending on students' grade level, these connections offer successful reference points to facilitate the understanding process behind the chemical reaction. The autoprotolysis of water, for example, allows to establish links to acid-base chemistry [414]. Furthermore, activating learners' pre-existing concepts on redox chemistry gives students the opportunity to understand the reaction mechanism that lies behind the experiment. The experimental station also focuses on the relationship between color and wavelength of the absorbed light.

2.4.3. Experimental Station 3: Bioinspired Surfaces - Generating a Micro- and Nanostructured Surface

Figure 2.4.7.: Lotus-effect observed on Indian cress.

Experimental station 3 followed the didactical implications of Bethke et al. [406] and referred to the concept of biomimetics where the lotus-effect was applied on a copper plate. This bio-inspired experiment describes the low wettability of surfaces. Its mechanism is named after the lotus flower [419], even though many other plants and animals show similar self-cleansing properties. When a water drop falls on the leaf of a lotus flower, surface conditions lead to the formation of a spherical drop that lets the water drip off. A characteristic known as *superhydrophobicity* is responsible for the self-cleansing effect. The term thereby describes a water-repellent surface where water drops nearly keep their spheric shape and roll off it [420]. Such a protection mechanism prevents the leaf from the cultivation of microorganisms or dirt particles that would impair the photosynthesis of the plant. At the same time, water repelling abilities help plants to survive long periods of rain, and protects them from flooding [421]. *Superhydrophobicity* is based on two criteria. The first refers to the rough structure on the leaf surface [419]. Little micro-papillae of mircostructres are finely but randomly dispersed allover the leaf. These microstructures are further covered with nanostructures that prevent from a direct contact of water and create an overall roughness on the surface. Furthermore, epicuticular waxes of mainly hydrocarbon crystals cover these evaginations and lead to hydrophobic properties [422]. Moreover, surface tension is determined by inter- and intra-molecular forces that effect the drop size. The former describe the interaction of molecules inside the drop. In a homogeneous liquid, forces of molecules inside the liquid are equally strong. Since the intra-molecular forces at the interface between liquid and air are less favorable for the molecules at the surface of the drop, the molecules are more attracted to each other. Consequently, the drop keeps its spherical shape.

A method to determine the degree of wettability on surfaces is the contact angle (CA). It describes the angle that is formed from the interface of a solid surface to the liquid phase of a water drop. The CA measures the point where the inter-phase ends. A high wettability is related to a small CA ($\theta < 90°$). The surface shows a low tendency to repel water with hydrophilic properties. Contrary, on a low wettability of a surface follows a high CA ($\theta > 90°$). Thus, the more hydrophobic the surface is, the higher the CA [423]. Measurements on lotus flowers have shown angles due to water repellent characteristics up to $\theta = 180°$. A schematic view of the contact angle on surfaces is depicted in Figure 2.4.8.

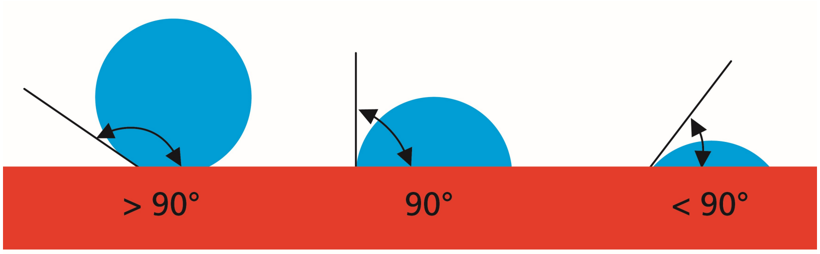


Figure 2.4.8.: Contact angle describing the wetting behavior of a drop on a surface.

In nanotechnology, surfaces are manipulated to obtain superhydrophobic features. Thus, the experimental station followed a two-step procedure to modify a copper-plate as based on the didactic approach of the experiment by Bethke et al. [406]. This requires the copper plate to be activated by removing the oxidized layer and dirt particles to improve the result. The first step of the experiment leads to a nano- and micro-structuring of the copper surface (soaked in a solution of NaOH and $K_2S_2O_8$). A measuring of the CA at this stage yields angles close to $\theta = 0°$ which is referred to as *superhydrophilic*. Due to the roughness created from the coating of the surface, wetting is increased which consequently yields higher polar interactions with the medium. To acquire the desired lotus-effect, in the second step, the copper(II) plate is soaked in a solution of lauric acid ($C_{11}H_{23}COOH$) in ethanolic medium. The long-chained fatty acid interacts with the exposed Cu^{2+} metal ions to form a unitary self-organized monolayer of $Cu(CH_3C_{10}H_{20}COO)_2$ agglomerates [406, p. 35]. The long-chained, non-polar alkyl rest faces up from the surface resulting in the desired repellent effect (Figure 2.4.9).

This experimental station requires students to understand the concept of biomimetic models. Based on learners' prior knowledge, the station begins with the observation of the phenomenon on Indian Cress (see Figure 2.4.7). Students' preconceptions on polarities are incorporated by asking for the properties of the plant's surface that enable a water-repellent effect. The self-cleansing behavior is briefly rehearsed and beneficial as well as influential conditions on the surface of the Indian Cress are discussed. Its functionality enables learners to understand biomimetic designs which describe one branch from the field of nanotechnology. Accordingly,

Figure 2.4.9.: Wetting behavior of a modified copper plate reproduced according to Bethke et al. [406]. Contact angle of the superhydrophobic copper plate reaches CAs around 158°.

as nature has inspired scientists to develop problem-solving technical innovations experimental station 3 offers students the opportunity to learn more about their relevance in everyday life [424]. Such new application fields reach from paints, textiles, anti-icing coating, anti-bacterial surfaces to "self-cleaning" windshields [425, 426].

The topic area offers several points of connection to the syllabus such as attractive forces between molecules, atoms and ions as well as their intermolecular interactions. In this context, already known terminology such as hydrophilicity and hydrophobicity are revised in order to describe the wetting tendency of the micro- and nanostructured material. By connecting to students' prior knowledge, the topic allows to study the relation between contact angle, surface tension and the resulting shape of the drop. Second, besides repeating organic compound classes, the experimental stations also offers possibilities to connect to students' knowledge on redox chemistry [414].

2.4.4. Experimental Station 4: Nano- and Microlayers - Determining the Layer Thickness of a Bubble

As soap bubbles are one of the simplest methods to visualize molecular dimensions [427], experimental station 4 deals with the chemistry behind the phenomenon. Its study has been the driving force for various research branches [428]. Yet, only recently soap bubbles have been encountered from a nanotechnological perspective. Soap bubbles consist of a bi-layer of mostly anionic surfactant particles that encapsulate water molecules and air. Due to their amphiphilic character, the hydrophobic part self-assemble towards the gaseous phase. Likewise, the hydrophilic carboxylate group end is pointing to the H_2O molecules thereby avoiding repellent forces that would occur between the two layers [429]. The bubble is held together through surface tension that arises at the outside interface between the surfactant and air. Inside the bubble, due to the alignment of the hydrophobic alkyl-chains outside the liquid, attractive forces between the water molecules increase whereas the surface tension decreases allowing to form the bubble [430]. The thickness of a soap bubble ranges around a few hundred nanometers up to a micrometer [427]. However, soap bubbles only have a short life span, and after a period of levitation gravitational forces lead to a sinking of the trapped H_2O molecules [431] (see Figure 2.4.10). This and the evaporation of water molecules over time cause a repelling of like charges between the inner and outer bubble layer resulting in a break of the vessel [430] (see Figure 2.4.11).

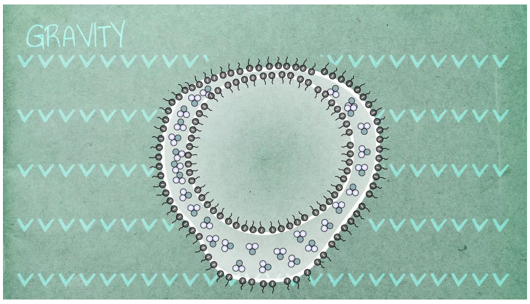


Figure 2.4.10.: Animated representation on the interaction of gravitational forces with the soap bubble.

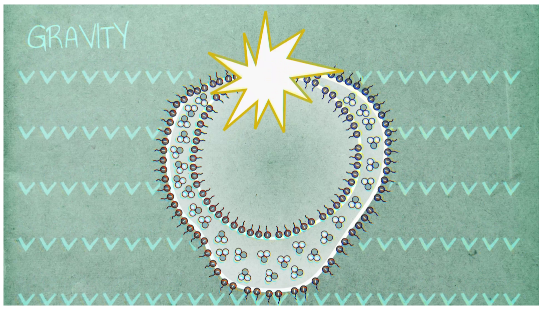


Figure 2.4.11.: Animation explaining the bursting of a soap bubble.

The thin film that keeps the vessel in its spherical shape describes the scientific background of experimental station 4. The intended goal is the mathematical computation of the bubble skin layer thickness and refers to an approximate calculation based on the work of Baum & Schwarzer [407]. The focus thereby lies on an in-depth explanation of the concept of ”nano”. Calculation is based on a simplification with respect to the layer. It is assumed that the inner layer of the soap bubble is considerably smaller than the radius of the soap bubble (h $\ll$ r_{Sb}). Hence, a simple calculation can be made when the layer thickness (h) is equated with the volume of the bubble layer and multiplied by the product of the bubble surface. The volume is defined by the mass of the soap bubble and the density of the soap liquid. Even though the calculation is susceptible to errors, it allows a narrow determination of the thickness of a bubble layer without applying sophisticated equipment [407].

Since soap bubbles are familiar to practically every student from childhood, an introduction to the topic of nanotechnology is an obvious choice. In the process, students are to record soap bubbles by conducting analytical measurement methods (Figure 2.4.12) and use the obtained data to indirectly calculate the layer thickness. The experimental station begins with the revision of students’ knowledge on surfactant chemistry. Building on this, their preconceptions on the bursting of soap bubbles can provide information about their chemical expertise behind the process. This can pave the way to understand the size range of the bubble layer as participants are demanded to conduct a small research on objects and living things ranging at the nanoscale. A comparison with other objects of the same size helps to classify the layer thickness and incorporates their prior knowledge of the concept ”nano”. In this context, learners are introduced to the importance of the size of materials and their areas of application. These reach from material sciences [432] to biomedical research fields [433]. Thereupon follows the preparation for the indirect measurement of the layer thickness of the bubble. Together with the instructor, students work out the needed variables which allow for the calculation of the soap layer (Figure 2.4.13).

Figure 2.4.12.: Video sequence explaining the indirect calculation method of a soap bubble layer reproduced according to Baum et al. [407].

Figure 2.4.13.: Set up of experimental station no. 4.

Experimental station 4 also provides sufficient references to the Bavarian curriculum. These include the influence of surface tension as well as the explanation of bond polarities and solubility with regard to interactions of molecular forces [414]. In addition, it is also possible to link to required competencies on scientific literacy as the experimental station provides opportunities to let students sharpen their evaluation skills. Hence, working precisely and organizing further steps is crucial to the tasks since the measurements are liable to errors. Further, detecting simplifications and discussing their influence on the accuracy of the measurement method cover expected skills required by secondary level II students [414]. As such, error calculations and finding methods that improve the quality of the measurement also include aspects that help students improve their scientific thinking.

2.4.5. Experimental Station 5: Functional Nanomicelles - Production of a Nano After Sun Care

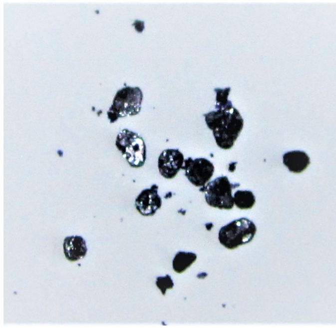


Figure 2.4.14.: Crystalline azulene.

Experimental station 5 incorporated the research work of Eberspächer [434] and Langhals and Eberspächer [435] and refers to the production of azulene loaded nanomicelles. Azulene derivatives can be found in chamomile, wormwood or yarrow - herbs that have long been recognized for their healing effects and which were traditionally used in aromatherapy. Accordingly, the bi-cyclic deep-blue hydrocarbon is widely recognized for its anti-inflammatory, anti-microbial and anti-spasmodic effect [436]. Although azulene has a wide application field, due to its hydrophobicity it can only be solved in a nonpolar medium. It restricts its use to only a few segments. Yet, for the treatment of sun burns, it needs to be transferred into a polar solvent. Due to their properties, surfactants are brought into use as a medium to solve non-polar substances in polar solutions. A frequently applied surfactant that a significant amount of personal care products in the cosmetics industry contain is cocamidopropylbetaine (CAPB) [437].

Recently, the zwitterion has been used as a carrier molecule as due to its positive and negative charge it is able to readily take up organic substances by forming nanomicelles in a polar medium. These tiny inverse bubbles show a typically spherical shape ranging in size between 5 - 100 nm. In aqueous solution, their amphiphilic monomers first arrange themselves with their hydrophobic tail in the air. After reaching the 'critical micellar concentration' (cmc), the colloids disperse at the interface of the solution where the molecules start to aggregate. As a result, each micelle is defined by a hydrophilic outershell that covers the hydrophobic inner layer. One application field encompasses the function of drug-loading where nanomicelles act as carrier molecules that encapsulate the active ingredient. Micelles thereby overcome the obstacles of many drugs that are insoluble in water as their biggest advantage lies in the drug delivery of lipophilic molecules. The incorporation of azulene in nanomicelles ensures a simple and non-hazardous way to solve the lipophilic organic compound in a polar medium and gives access to skin care products where the active ingredient is available on a water base [438]. This opens up the possibility for a wider range of products.
Experimental station 5 pursued the goal of producing an after-sun care where CAPB nanomicelles were loaded with the hydrophobic organic molecule azulene. The set up follows a problem-oriented approach. This requires the incorporation of learners' real-life experiences concerning the use and mode of action of after-sun lotions. A frequently existing pre-concept is found in students' knowledge about the composition of such after-sun products. Many

assume that these lotions contain fat, but when applied on the sunburn, they lead to counterproductive results. In groups, students work out relevant properties of an after-sun care. In this context, the anti-inflammatory, active ingredient azulene is introduced and the function of nanomicelles as the carrier molecule explained. The approach allows the link to the broad application field of nanomicelles which are considered to be the next generation of pharmaceutics in nanomedicine due to their improvement of *in vivo* therapeutic efficiency [439]. Furthermore, students learn that these dispersed colloids are used for different domestic purposes such as functional dirt remover that release any kind of surface from contamination or oil [440].

Students from upper secondary school are familiar with the concepts of polarity [414]. Based on that, prior knowledge concerning the solving process itself is tackled in particular within the experimental station. Thus, in the group, students discuss how the crystals of the anti-inflammatory ingredient could be solved (Figure 2.4.14). In addition, the station also builds on concepts from organic chemistry. Basic knowledge is repeated such as resonance or isomerism and applied to the reaction mechanism in the task. Further, the experimental station provides opportunities to sharpen learners' evaluation skills. From a text passage on the toxicity of nanomaterials in cosmetics students are offered opportunities to practice their evaluation skills.

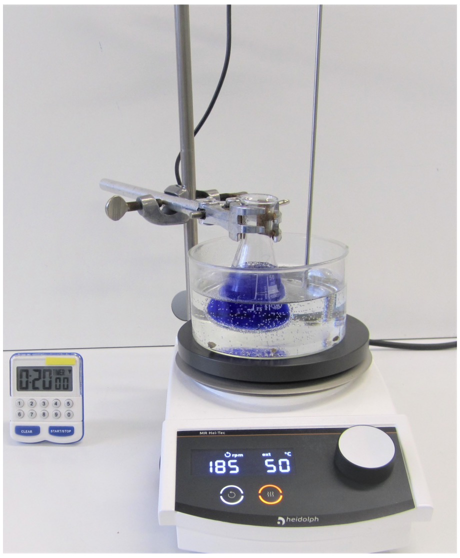


Figure 2.4.15.: Production of an after-sun care according to Langhals [441].

Figure 2.4.16.: Filtrate of azulene loaded nanomicelles.

2.5. Description of the Bilingual Module: *Modern Materials*

2.5.1. Objectives and Procedure

Although in most German states, nanotechnology is not an integral part of the school curriculum, the diverse research field still allows to tie to the syllabus of secondary level II education. Thus, experiments that are offered in the LMU*chemlab* comprise aromatic compounds, fatty acids, surfactant chemistry as well as redox chemistry. These topics are covered from grade 10 on in the Bavarian syllabus [442]. Furthermore, the laboratory's structure promotes the four core competencies that are pursued in chemistry classes: subject knowledge gain (1), knowledge production (2), communication (3) and evaluation (4) [230]. Experimentation in science labs for school students is a suitable environment for developing these core competencies. There, theoretical findings are put into practice which foster students' scientific thinking. This further allows the contextualization of the contents to a global dimension and its relevance for society [230].
Since subject content, too, relies on a verbalization process where the understanding of concepts is indicated through the language that is used [443], the application of a bilingual setting promotes students' judging and reflecting competencies. The Bavarian State Institute for School Quality and Educational Research (ISB) highlights the fruitful combination of the English language with the subject matter chemistry when stating that through the application of the teaching style CLIL not only accelerates motivation in learning the subject content but also leads to a deeper understanding and the promotion of students' verbal skills [230].

From a foreign language point of view the module, too, complies with the requirements of foreign language education [442]. According to the standards of the Bavarian syllabus, students' knowledge is reflected in the ability to deal with authentic texts and media that cover different aspects relevant to life. This implies learners' ability to interpret authentic data such as graphs or diagrams. Furthermore, students are obliged to master speech production [230]. The learning environment meets these criteria as it offers opportunities for peer collaboration and emphasizes a close work with the instructors. Moreover, the application of English within a scientific learning environment accelerates learning the target language due to the meaningful use in a realistic setting.

The bilingual module pursued one general goal that is composed of distinct learning objectives as depicted in Table 2.5.1.

Table 2.5.1.: Outlined objectives and learning outcomes of the module on *Modern Materials*.

Category	Objectives
Cognitive skills	• Students gain an increased sense of the size of nano materials and are able to draw connections to objects in their own lives • Students learn about biologically relevant materials and their diverse nanotechnological realization • Students manipulate the size of materials at the nanoscale and investigate the correlation between chemical and physical characteristics • Students test the effect mechanism of different nanosized cosmetic products • Students learn about the risks and benefits of nano materials and evaluate potential hazards in cosmetics
Hands-on skills	• Students learn to accurately weigh with a scale • Students train their problem-solving abilities and put their scientific working methods into practice
Foreign language skills	• Students use chemically relevant terms in English and German • Students are able to form coherent sentences in English to discuss with their peers the outcomes at each experimental station
Affective skills	• Students' interest on nanotechnology raises through the depiction of applied research in this field • Learners' gain insight in nanotechnology and are able to draw connections to their own lives • The laboratory environment, authentic language use and the up-to-date research field raises students' motivation and self-concept in the field of chemistry • Students acknowledge the meaning of English as the language of science in the scientific learning environment

2.5.2. Laboratory Environment

The following exemplary outline describes the procedure and organization of the module which incorporated a preparation and follow-up work in school. Table 2.5.2 presents the timeline of a regular intervention which considers place, contents and the applied medium. Experimental groups who were not prepared in school received a power-point introduction to the learning environment itself in the pre-laboratory phase (as will be described later in this section).

Table 2.5.2.: Module schedule *Modern Materials* at the LMU*chemlab*.

Time	Place	Activity	Medium
One week ahead of the intervention; 45 minutes	School	Administration of the pre-pretest; video preparation and formation of expert groups for each experimental station	Questionnaire
		LAB DAY	
09:20	Brief tour through the LMU building and storing students' properties in the lockers	Distribution safety coats and safety goggles	
09:30	LMU*chemlab*	1st experimental phase; Depending on the time frame	Experiments
		Lunch break	
12:30	LMU*chemlab*	2nd experimental phase; Finishing the experimental stations	Experiments
2:30	LMU*chemlab*	Feedback on the learning environment	Discussion
2:45	LMU*chemlab*	Administration of the posttest	Questionnaire
		End of the Lab day	
One week after the treatment, 90 minutes	School	Follow-up work: Expert groups summarize the learned contents of their expert station as well as a research on application fields for each experiment; Short presentation and discussion of each station	Concept Maps
Eight to ten weeks after the treatment	School	Administration of the follow-up test	Questionnaire

Preparation and introductory session at school

A week ahead of the intervention at the LMU*chemlab*, learners were prepared for the module at school. After filling out the pre-pretest, one of the instructors started with a very brief and general introduction to the learning environment by using a power-point presentation. The first slides contained information about the development and goals of the setting. In analogy to the prepared groups, the experimental groups without preparation were introduced to the local conditions in the laboratory. As the atomic force microscopy (AFM) has made the research on nanotechnology possible in first place and is considered as a unique feature to the research field [444], the instructor took over to explain the mechanism of the analytical tool (see Figure 2.5.2). Moreover, students were introduced to the model of educational reconstruction as conducted in the chemistry department (see Figure 2.5.1). Complementary, prepared classes were shown five videos that contained background information of each experimental station. The use of a digital medium thereby supports an authentic experience through the accurate presentation of the functional principle [445].

Figure 2.5.1.: Introduction slides on authentic equipment used in the laboratory.

Figure 2.5.2.: Introduction slides explaining the educational reconstruction behind experimental station no 5.

In the classroom, the videos were displayed over a video projector matching the language of the treatment. For the bilingual group, relevant terms were additionally visualized and appeared throughout the video. Furthermore, supporting sheets containing important technical terms, a translation and an English transcription were allocated beforehand. All videos were similarly structured and followed the findings of Orion and Hofstein on influencing factors for successful learning in a field trip [446]. The authors state that familiarizing with the *contents, the extracurricular setting and the framework conditions* enhance learning within the field trip [446]. Thus, to keep the novelty space experience low, the learning environment with its authentic equipment constantly appeared in the video (see Figure 2.5.3 and 2.5.4). Relevant contents that aligned to the students' prior knowledge were explained by researchers of the LMU chemistry department.

Figure 2.5.3.: Video sequence introducing the premises at the LMU*chemlab*.

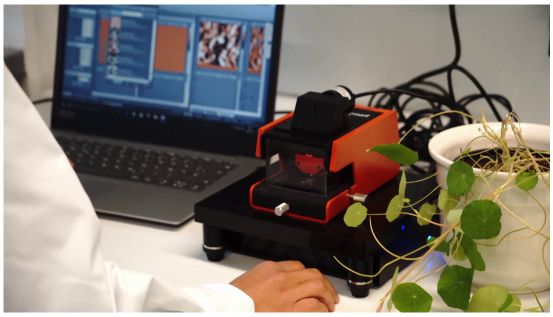


Figure 2.5.4.: Video sequence displaying a scientist working with an AFM.

Furthermore, different segments of the researcher's daily work were presented including experimenting in the laboratory, using analytical methods or doing research in the library. This is especially important, as one designated goal of science outreach laboratories is to convey an accurate picture of the job profile as a researcher [125]. As Lins et al.[447] acknowledge, teachers, too, act as "gate keepers" who influence students' later career choice. Therefore, it was also taken into account to present female and male research scientists in equal shares to support a more gender-neutral picture of the so-called "hard-western male science" [448, p. 83] as depicted in Figure 2.5.5 and 2.5.6.

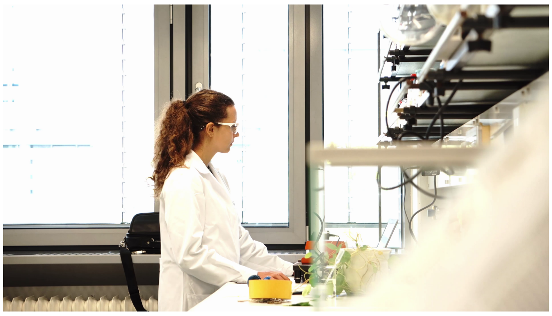


Figure 2.5.5.: Video sequence displaying a female research scientist at work.

Figure 2.5.6.: Video sequence of a male scientist in the laboratory.

For the sake of clarity, all videos contained animations. Different aspects of the nanotechnological contents were further animated. The additional visualization of technical terms contributed to a deeper understanding of the matter [449]. Furthermore, animations helped students to correctly apply technical terms relevant to the offered experimental stations as illustrated in 2.5.7 and 2.5.8.

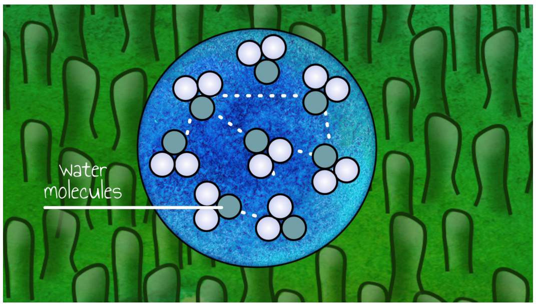


Figure 2.5.7.: Animation sequence of the lotus-effect.

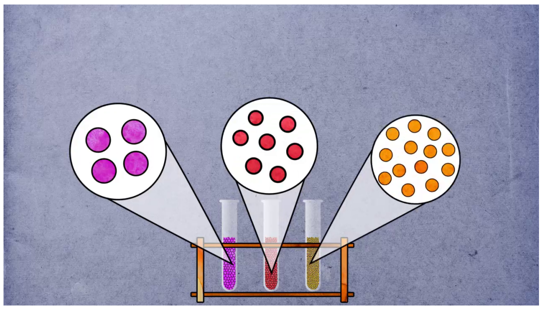


Figure 2.5.8.: Animation sequence displaying different sizes and optical properties of AuNPs.

Laboratory day at the LMU*chemlab*

On the day of the intervention, teacher and class met in front of the chemistry department where one of the instructors accompanied the participants to the seminar room. There, the laboratory supervisor welcomed the class and presented the organizational structure of the day. Furthermore, the chemistry department was briefly introduced which contained some background information about the LMU*chemlab*. Subsequently, the pretest was administered.

The second part of the introduction began with a safety instruction that gave learners a reliable basis for a correct conduct in the laboratory. The briefing entailed safety measurements and the proper handling of dangerous substances including the explanation of risk and safety phrases (R and S phrases). Finally, a small recap to the videos of the preparation was done to refresh the learners' memory on relevant aspects. Together with one of the instructors, the class briefly explored the chemistry department on their way to the locker room where properties were deposited. In the laboratory, each student was equipped with safety goggles, a lab coat as well as a workbook containing the work sheets for each experimental station. The intervention finished with the administered posttest.

Follow-up work in school

One week ahead of the intervention, one of the instructors visited the participating class in school. In a double lesson, learners recapitulated all experimental stations from the module. In groups of four, students created concept maps for each experimental station containing the chemical background as well as application fields for each experiment. These concept maps were presented to the remaining groups and were hung in their classroom. Eight to ten weeks later, the follow-up test was administered again in school.

3. Aims, Research Questions and Hypotheses

3.1. Desideratum of Research

As the study set out to examine the effectiveness of a bilingual module at the LMU *chemlab*, the chapter reviews the research gaps that derive from the theoretical foundation and its state of research summarized in Chapter 1. Consequently, the relationship between the laboratory variables and the examined target variables present in this out-of-school setting will be clarified. In respect to this desideratum of research, the chapter continues with highlighting the pursued research questions and hypotheses followed in this investigation. All hypotheses are based on prior results from accompanying research on science labs for school students as illustrated in Section 1.2.1, 1.2.2 and 1.2.3.

Influence of the instruction language on the effectiveness of science labs for school students

The importance of bilingual education continues to grow, especially in the natural sciences where competencies in English are now a prerequisite for professional life and university. Only recently, researchers recognized a greater potential for the interdisciplinary teaching approach in out-of-school learning sites [26, 25, 27]. This relationship is confirmed by foreign language research where extracurricular activities are found to promote students' English competencies [450]. Due to their frequent affiliation to research institutions, authentic language situations are facilitated that allow the meaningful use of English [24]. It is thus conceivable that by making current scientific topics and technologies accessible, such a science outreach laboratory can create a setting that engages content learning through foreign language use. Incorporating thereby personal characteristics more strongly allows instructors to design activities that are tailored to the addressee's needs. However, there is a lack of meaningful research to support a widespread implementation [224]. With regard to bilingual science labs for school students, only a few robust studies are available so far, all conducted in the subject matter biology. In view of the current state, it is worthwhile to understand the importance and intensity of a bilingual learning arrangement from both perspectives, a cognitive and an affective wise. A prediction of the possible causes that induce these changes would also be desirable so that recommendations for practice can be derived.

Longitudinal effects in science labs for school students

Although it is undisputed that science outreach settings have the potential to increase learners' interest while promoting young talents to engage in STEM areas [82], there is still no consensus on how much these programs produce sustainable effects [97, 13]. While some studies confirm partly long-term positive influence on learners' psychological state as well as on knowledge acquisition [451, 238], the majority reports on a fleeting impact [81, 15, 25, 26, 324, 272, 14, 86, 12, 11] or even no influence at all [452]. Critics therefore question the educational efficacy of the learning setting [238]. As a result, a reoccurring demand of many researchers in this field has been, among others, the integration of the laboratory programs in school [453, 14, 85, 15, 124]. In this context, conditions in the learning arrangement play a crucial role as contents and laboratory variables seem to determine what produces long-term effects. The aim should therefore be to narrow down these influencing factors through further research in order to be able to make more concrete statements in this regard.

Aims of this study

As the structure of the theoretical foundation reveals (see Chapter 1), this empirical project was driven by three target variables (see Section 1.2) that framed the investigated learning environment LMU*chemlab* with its influencing factors (1) language of instruction and (2) integration of the module in school. These two influential variables were brought into a model with the target variables (knowledge acquisition (1), motivation (2) and academic self-concept (2)) aiming to examine the effectiveness of the learning arrangement. For this purpose, the section continues with an introduction to the three main research foci investigated in this study. These were further separated in research-leading, underlying questions.

Knowledge acquisition

The first research focus investigated the impact the bilingual intervention had on learners' cognitive output concerning nanotechnological topics. Research on cognitive effects in science labs for school students is still not exhaustive [25]. It was therefore of general interest to understand what significance this research area plays when it comes to knowledge output. With regard to existing literature, a positive influence was expected since nanotechnological contents offer enough opportunities to connect to already known concepts in chemistry when provided in a natural and authentic context [454]. Still, even though the growing research field is considered as appealing due to its adaption to different aspects of citizens' everyday life [455] it is either absent or an afterthought in the Bavarian school curriculum [456, p. 47] and the general understanding of the topic is low [457]. Hence, this state of research indicated a need to understand whether the topics covered in the LMU *chemlab* generally facilitated learning or provoked a cognitive load since it is the content of school science that enhances learning due to its relevance for students' lives [458]. Moreover, considering that the unfamiliar surrounding can be distracting in the learning process [446], the setting itself was investigated with regard to knowledge intake.

What is more, studies which conducted students' cognitive output and which proved a short-term increase in learners' knowledge mostly refer to facts and concepts [459, p. 182] without linking to students' prior knowledge. For this reason, science labs for school students are repeatedly skeptically viewed. Reoccurring criticism is primarily directed towards the lack of long-term effects on the learner [81, 14, 15, 85, 235]. However, from the theory of knowledge-based constructivism it is known how crucial learners' prior knowledge is for the learning outcome [30]. Practitioners therefore demand the inclusion of a preparation and follow-up work as learning in an out-of-school context without embedding these contents in school would remain in short-term effects [460, 272]. Integrating extracurricular settings in the curriculum is even more readily established when the learning aspect becomes the center of the focus. Otherwise, extracurricular settings run the risk of learners having difficulties to relate to the relevance of field trips [461] as such learning environments appear mostly unstructured and therefore less engaging to students [462]. Based on this assumption, a preparation in school could deepen their understanding of the contents provided in the outreach activity [321]. Nonetheless, current data does not allow any clear conclusions to be drawn. The few studies that controlled for sustainable effects after the intervention indicated at least a mid-term knowledge acquisition [25, 272, 87, 462]. Others, however, couldn't prove any long-term effects at all [13]. Consequently, as field trips are often stigmatized as a one-day long entertainment event rather than a potential source for learning [86, 463], more research on sustainable effects in knowledge acquisition is needed.

Similarly, research to date has not yet determined the influence of the instruction language on subject knowledge acquisition. Even though studies in bilingual education increasingly started to focus on the subject content, literature on the integrative teaching style in sciences is still equivocal [221]. Often, the double burden seems to be a barrier to a widespread implementation. As according to Chandler and Sweller's CLT [464], bilingual teaching requires learners to process linguistic and abstract content information at once which could provoke different types of cognitive load [25]. However, current data does not allow any further conclusions to be drawn either. A few studies point to at least similar learning outcomes [274, 83, 215, 214] while others measured a lower cognitive output in the bilingual groups [141]. At the same time, literature suggests that the bilingual brain can process the information more deeply through additional scaffolding techniques such as specific documentation of the working steps, vocabulary with translations and paraphrases of relevant terms. As a consequence, important aspects are repeated and semantic processing is enabled [29]. This in turn would lead to the construction of knowledge [465]. However, as students' language proficiency determines their understanding, the bilingual intervention might inhibit the learning of the subject matter [270]. Therefore, it was of interest to understand whether an extended exposure to the contents allows for a deeper elaboration on a semantic level and how the preparation and post enhancement in the bilingual group further influences the output.

When considering a learning arrangement that promotes specific competencies, the inclusion of learner dispositions has also been found to be effective. Hence, different educational studies proved the impact of learners' personal, social and institutional variables on school performance [466]. In prior studies, a cluster analysis was deployed which grouped learners according to their preferences and interest [25, 26] in order to understand what impact learners' dispositions have on their cognitive output. Although in the monolingual science outreach context correlations with respect to the learners' characteristics are minimal [272, 124], studies in bilingual settings found a dependence between cognitive achievement and social variables [372, 25, 26]. Dallinger et al. [372] indicated selectivity processes in bilingual classes that determined learners' success in such settings. As mostly gifted students are enrolled in bilingual classes [370], their prior experience with the teaching style could supposedly have positive effects on knowledge acquisition in the science outreach laboratory. Taking existing research into consideration, it was therefore assumed that the monolingual treatment would not have an impact on students with any dispositions in particular but the setting facilitates learning among heterogeneous learner groups [467]. However, in the bilingually instructed group, it was reasonable to assume that especially high-achieving language-gifted students mostly profit from the treatment as was proved in former studies in this field [372].

Motivation

Motivational aspects within the extracurricular setting were in the center of the second research focus. As a frequently examined construct in educational studies, motivation has long been considered to be an influencing parameter for successful learning [288]. Literature on science labs for school students illustrated the success on an affective level, in particular, as these settings are regarded as an interest-creating source for sciences and technology [69]. Former research on field trips suggest intrinsically motivating effects of out-of-school settings on participating students [468, 25, 81]. Motivation thereby arises from stimulating learners' basic needs on autonomy, competence and social relatedness which according to Deci and Ryan's SDT [289] facilitate a voluntary confrontation with the object of interest for an extended period of time. Similarly, CLIL is considered to be a motivation creating source.

Studies that investigated the impact of the interdisciplinary teaching approach proved that motivation on subject content increased [216, 138, 140]. Based on these findings, this study was concerned with the influence of the bilingual teaching style on students' activity based intrinsic motivation taking the different learner types into consideration. Since Rodenhauser [25] proved positive effects due to practical experimentation and the presented contents rather than the foreign language use (p. 266), it was assumed that the learning setting would yield similar outcomes in the bilingual learning arrangement.

Furthermore, it was of interest to understand what factors influence learners' activity based intrinsic motivation in this regard. In her study, Röllke [268] found that students' *perceived autonomy, perceived competence* and the embedding of the module in school increased learners' activity based intrinsic motivation. As this study came with a language focus, it was of interest what factors would influence students' activity based intrinsic motivation and what role the use of English would take on in this regard.

Academic self-concept

The third research focus was concerned with investigating learners' academic self-concept. Although literature suggests the construct to be a relatively stable [331], research in science labs for school students indicated a short-term increase after visiting the laboratory [81, 272, 15, 13]. Hence, such outreach activities are indeed able to at least temporarily raise the academic self-concept of participating learners. Nevertheless, it has not been conclusively clarified whether a visit to the learning setting leads to the desired long-term change in self-concept. The present study intended to tie to this question and examined the special features of the present learning setting. In this regard, it was an appropriate question to ask, since the combination of a natural science subject with a foreign language addresses different dimensions of the academic self-concept ([337] as cited by Rodenhauser [25]). The few studies on bilingual science outreach settings confirm this assumption [83, 25, 26]. There, it was found that the setting was especially beneficial for students' with both a high verbal academic and science self-concept [26, 25]. Taking these outcomes into consideration, it was reasonable to suppose that such an extracurricular setting would evoke similar effects on learners' scientific self-concept in chemistry and would promote the self-concept of students who consider themselves as rather language-oriented. Furthermore, in order to get a more precise picture of the effectiveness of the science outreach laboratory, students' academic self-concept was investigated with regard to the identified learner types.

So far, little is known about the predictors that influence the academic self-concept of learners in such a learning environment. One variable that has been excluded in this context in the past is students' gender. Former studies proved that the variable did not play any role and even suggest a small correlation with learners' self-concept [14, p. 99]. However, from the theory on academic self-concept, gender-specific differences are known and have already been identified in studies on different school subjects [469, 363]. Since the present learning arrangement combined both linguistic and scientific domains, it was examined how gender would contribute to learners' academic self-concept and what other factors would influence the affective construct in this regard.

Following the goal to summarize the objectives pursued in the study, the target variables of interest were included in a model together with the laboratory variables present in the LMU*chemlab* and students' dispositions. Figure 3.1.1 illustrates the underlying model of this study.

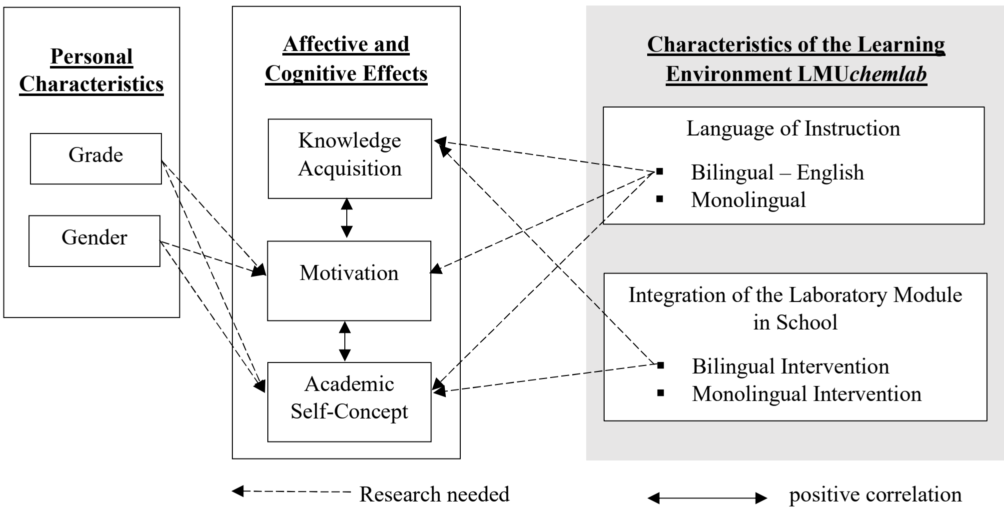


Figure 3.1.1.: Research model of the conducted study. Dotted lines indicate partly unexplained interactions.

3.2. Research Questions and Hypotheses Testing - Main Study

Taking the desideratum of research into account, the present study with the title "Assessing Cognitive Achievement and Outcomes on Chemistry-Related Activities in a Bilingual Science Lab for School Students" aimed at investigating the identified research gaps by answering the resulting research questions. First, the influence of the designed bilingual intervention on students' subject knowledge (R1) was examined. Secondly, affective components were also part of the investigation. This included students' intrinsic motivation (R2) and academic self-concept (R3). These constructs were selected based on the existing body of research in science labs for school students, allowing for comparability with previous studies.

3.2.1. Cognitive Achievement

The first research focus examined the effectiveness of a science lab for school students' visit with regard to learners' cognitive output. Initially, general knowledge intake was assessed (R1a). In a second step, the influence of the instruction language was recorded (R1b). It followed an examination of the long-term effects induced by the intervention. Here, it was of particular interest whether the bilingual-English module and the monolingual-German module would yield similarly high retention rates on students eight to ten weeks later (R1c). In a further step, knowledge acquisition was related to students' dispositions. For this purpose, similarly to the studies of Engeln [14], Rodenhauser [25] and Buse [26], students were clustered based on characteristics from collected data and investigated with regard to its impact on knowledge construction. Consequently, the following research questions on cognitive achievement were explored:

> R1a: DO THE OFFERED NANOTECHNOLOGICAL CONTENTS AT THE LMU*chemlab* GENERALLY FACILITATE LEARNING CHEMISTRY?

H1a: The contents behind the experiments lead to a knowledge intake right after the treatment.
H0a: The hands-on session has no influence on learners' cognitive achievement.

> R1b: HOW DOES INSTRUCTION LANGUAGE INFLUENCE SUBJECT KNOWLEDGE INTAKE?

H1b1: Applying CLIL in a hands-on setting on chemistry contents inhibits content learning among the bilingual participants as the setting leads to an intrinsic, germane and extraneous load.
H1b2: Bilingual learners show a deeper processing of the contents due to language change and therefore score higher in the knowledge test.
H1b0: There are no differences detectable based on the language of instruction in terms of their cognitive output.

> R1c: HOW DOES INTEGRATING PRACTICAL EXPERIMENTATION WITH SCHOOL-BASED PREPARATION AND POST-

ENHANCEMENT INFLUENCE COGNITIVE ACHIEVEMENT AND ARE THESE EFFECTS COMPARABLE IN THE MONOLINGUAL AND THE BILINGUAL GROUP?

H1c1: CLIL students who receive a preparation and follow-up work show a higher retention compared to their peers due to a deeper semantic processing.
H1c2: Retention is lower among CLIL students due to the extraneous load caused by the foreign language use.
H1c0: Independent of instruction language, integrating the laboratory module in classroom does not impact sustainable knowledge intake.

R1d: DO STUDENTS FACTORS INFLUENCE COGNITIVE ACHIEVEMENT?

H1d1: Students with both, a linguistic and a scientific disposition profit most from the bilingual intervention compared to those students who are either science-oriented or language-oriented.
H1d0 Knowledge acquisition in the science lab for school student is independent from students' preferences.

3.2.2. Activity-based Intrinsic Motivation

The second research focus examined what impact the teaching style had on students' activity-based intrinsic motivation in chemistry (R2a). In this regard, effects of the learning setting itself were assessed. In a further step, predictors of students' activity based intrinsic motivation were investigated (R2c). The research questions read as follows:

R2a: HOW DOES INSTRUCTION LANGUAGE IN A HANDS-ON SESSION INFLUENCE LEARNERS' ACTIVITY-BASED INTRINSIC MOTIVATION?

H2a1: The foreign language use results in a lowered activity-based intrinsic motivation among bilingually instructed students.
H2a0: There are no differences between the bilingual and the monolingual group with regard to their activity-based intrinsic motivation.

R2b: WHICH STUDENT AND SETTING FACTORS PREDICT STUDENTS' ACTIVITY BASED INTRINSIC MOTIVATION AT

THE LMU*chemlab*?

H2b1: Intrinsic motivation is predicted by the instruction language.
H2b2: Intrinsic motivation is predicted by perception of autonomy.
H2b3: Intrinsic motivation is predicted by perception of competence.
H2b4: Intrinsic motivation is predicted by students' chemistry grades.
H2b0: There are no predictors that influence students' activity-based intrinsic motivation.

3.2.3. Chemistry Self-Concept

The third research focus examined participants' academic self-concept in chemistry. Firstly, this work addressed the constructs' impact on the previously characterized learner-types (R3a). Secondly, it was of interest whether the bilingual science lab for school students' visit brings about changes when exposing learners to the bilingual intervention for a longer period of time (R3b). Thirdly, the research focus also investigated what predictors determine students' academic self-concept in the subject chemistry. The research questions read as follows:

R3a: TO WHICH EXTENT DO LEARNERS' DISPOSITIONS INFLUENCE STUDENTS' CHEMISTRY SELF-CONCEPT IN A ONE-DAY INTERVENTION AT THE LMU*chemlab*?

H3a1: Students with both language and science dispositions benefit most from the bilingual intervention.
H3a2: Chemistry self-concept shortly increases independent from the identified learner types.
H3a0: Independent of learner type and instruction language, students' chemistry self-concept remains unaffected from the treatment.

R3b: WITH REGARD TO AN INCREASED EXPOSURE OF TIME, DO SCHOOL-BASED PREPARATION AND POST-ENHANCEMENT IN A BILINGUAL SETTING CONTRIBUTE TO A SUSTAINABLE CHANGE OF LEARNERS' CHEMISTRY SELF-CONCEPT?

H3b1: A prolonged exposure to the teaching style allows for a deeper elaboration with results in a sustainable knowledge intage.
H3b0: Students' chemistry self-concept remains unaffected from integrating the module in school.

R3c: WHICH FACTORS PREDICT STUDENTS' CHEMISTRY

SELF-CONCEPT AT THE BILINGUAL INTERVENTION?

H3b1: Chemistry self-concept is determined by students' chemistry grade.
H3b2: Chemistry self-concept is determined by students' English grade.
H3b3: Chemistry self-concept is determined by students' English self-concept.
H3b4: Chemistry self-concept is determined by instruction language.
H3b5: Chemistry self-concept is determined by learners' gender.
H3b0: Chemistry self-concept remains unaffected from the bilingual intervention.

3.3. Research Questions and Hypotheses Testing - Side Study

Despite a long-shared history with an English-speaking culture during the British mandate era, most Israeli students first encounter English in foreign language classes at school [470]. In Israel, school language depends on the sector where the school is located [471]. Hebrew is the language of instruction in the Jewish sector. There, English is taught as the first foreign language. In the Arab sector, subject teaching is in Arabic while Hebrew as the dominant language of the country is taught as the first foreign language [472]. English appears as the second foreign language in Arab schools [473]. This might result in a lower English-language proficiency among Arab-Israeli students compared to their Jewish-Israeli peers [474]. However, proficiency in English becomes important when students decide to enroll in an academic-track. Admission to Israeli universities, for instance, depends on two aspects: the passing of a nationally administered psychometric test and applicants' scores in the matriculation exams. In this final high school exam, a separate English-language test is included [475]. Both sectors are subject to the same matriculation restrictions [476] and the same psychometric test for university admission. Nonetheless, inside universities, the situation concerning the importance of English proficiency is a different one. To date, the importance of English has not been reflected in Israel's tertiary academic institutions, where Hebrew remained the dominant language of instruction [477].

Against this background, the research objective of this side study was to examine students' cognitive achievement and motivation in a bilingual science setting that used English as the language of instruction for Hebrew- and Arabic-speaking students in Israel. The goal was to investigate the effects that the exposure to an authentic environment has on students' motivation and learning in chemistry where the language of science is used purposefully in a scientific institution. As Israel has not yet implemented any language integrated instruction programs [474], the study is therefore the first of this kind to be conducted in the Israeli context.

3.3.1. Cognitive Achievement

Due to the lack of preexisting studies on cognitive achievement within a science-related bilingual setting, the question arose whether using English as the instruction language would yield similar outcomes among Israeli students. Relying on positive outcomes of prior bilingual science outreach settings [215, 83], it was possible to assume that a bilingual hands-on practice at the *Weizmann Institute of Science* would create similar effects on heterogeneous groups. Yet, however, it is not sufficiently clarified what role the English language plays in Israeli students' lives. With respect to knowledge acquisition the study sought to answer the following research questions:

> R1e: DOES A BILINGUAL APPROACH IN A CHEMISTRY OUTREACH LABORATORY IMPAIR COGNITIVE ACHIEVEMENT COMPARED TO THE MONOLINGUAL INTERVENTION?

H1e1: Combining CLIL with a hands-on activity on chemistry contents inhibits content learning among the bilingual participants as the setting leads to an intrinsic, germane and extraneous load.
H1e2: Bilingual learners show a deeper processing of the contents due to language change and therefore score higher in the knowledge test.
H1e0: There are no differences detectable based on the language of instruction in terms of their cognitive output.

> R1f: ARE THERE ANY DIFFERENCES IN COGNITIVE ACHIEVEMENT RELATED TO THE CLIL INTERVENTION BETWEEN HEBREW-SPEAKING AND ARABIC-SPEAKING ISRAELI STUDENTS?

H1f1: As English is the second foreign language Arab-Israeli students study in school, learners in this bilingual group score lower than their Jewish-Israeli peers.
H1f0: There are no differences detectable with regard to the cognitive output between the two groups.

3.3.2. Activity-Based Intrinsic Motivation

The third research question dealt with the motivation of students participating in the out-of-school learning site. In particular, the research question focuses on the perception of the setting itself along with the impact of the foreign language use.

R2c: BASED ON THE TREATMENT, HOW DOES A HANDS-ON SESSION AT A RESEARCH INSTITUTE INFLUENCE STUDENTS' ACTIVITY-BASED INTRINSIC MOTIVATION IN CHEMISTRY?

H2c1: Students who participated at the bilingual intervention show a lower activity-based intrinsic motivation compared to those learners who were instructed in their mother tongue.
H2c0: There are no differences between the bilingual and the monolingual group with regard to students' activity-based intrinsic motivation.

4. Research Design and Methodology

4.1. Study Design

Study design main study

The empirical study was conducted from October 2018 till April 2020 in the LMU *chemlab* located at the Ludwig-Maximilians-University, Munich. A quantitative approach with a quasi-experimental 2x2 factorial design was adopted to assess the effectiveness of the bilingual module. The evaluation was planned as a pilot feasibility trial following a pre-pre-, pre-, post-, follow-up design. Anonymous pencil-paper tests were administered at four reference times taking about 20 minutes each. The pre-pretest T0 was conducted in school a week before the treatment and was supervised by student teachers who guided the whole study process. Pretest T1 followed right before the treatment while posttest T2 was conducted after the experimental phase. Both surveys were performed in the Ludwig-Maximilians-University. Eight to ten weeks later, the follow-up T3 was again administered and supervised by student teachers in school.

Secondary level II students were registered for the module by their teachers to participate within the scope of their chemistry class. Assignment to the four different treatments followed a randomization procedure in which classes were allocated to one of the four treatments independent of their school profile. Due to the composition of these classes, all groups were treated as cluster samples. Such cluster samples are interpreted as a form of random sampling. There, the population is divided into sub-populations [478]. A clustering further allows the analysis of context effects. Nonetheless, the present sample design was liable to a higher sampling error which might result in a less accurate estimation [479].

Two treatment groups received the intervention bilingual-English while the remaining groups were instructed monolingual-German. Accordingly, from the bilingual and the monolingual treatment, one group each received a preparation and follow-up work in school before and after the intervention. Students who did not receive a preparation were generally introduced to the laboratory and its main goals. The study setting is depicted in Figure 4.1.1. The bilingual treatment was not radically different from the monolingual one but in order to facilitate communication, all bilingual learners were additionally provided with vocabulary sheets and English labeled laboratory equipment that would enable semantic processing [24].

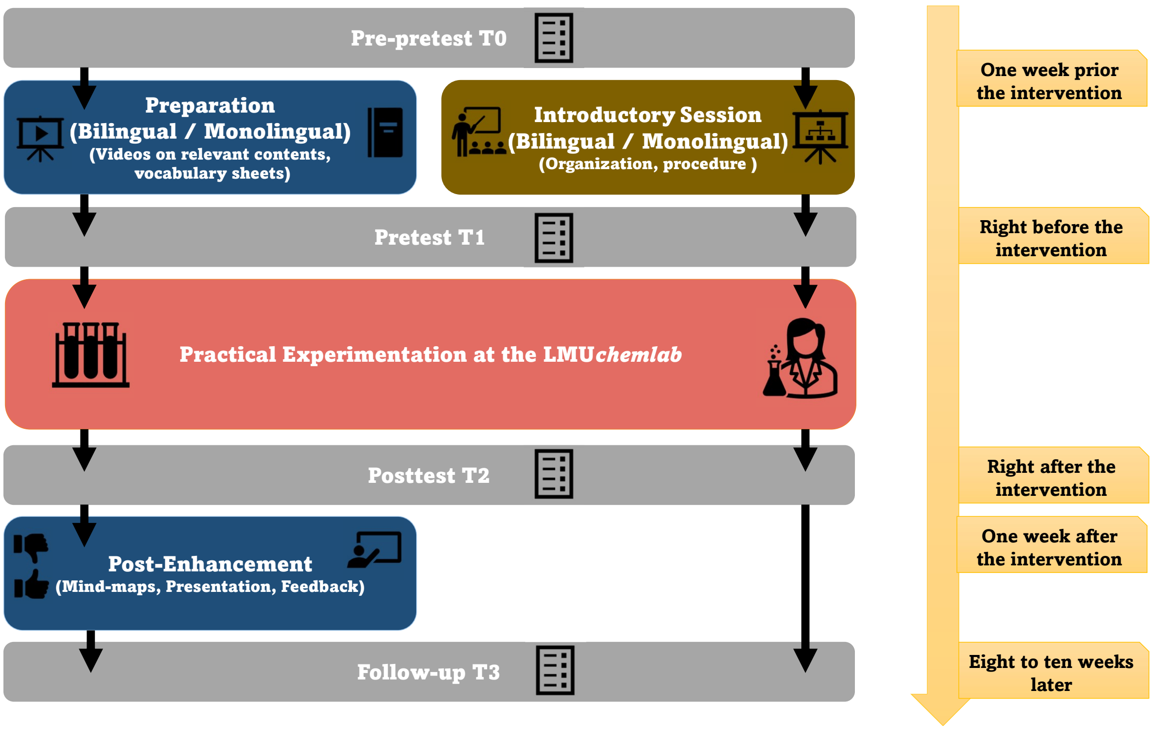


Figure 4.1.1.: Main study design. Outline of the implementation procedure followed in the intervention study. The graphic illustrates how the survey was conducted in the prepared bilingual and prepared monolingual group (blue boxes) as well as in the bilingual and monolingual group (brown box).

Piloting

In April 2018, a pilot was conducted to test the measurement instrument and the materials used in this study. Most of the assessed cognitive and affective constructs were already established testing instruments as they came from accompanying research on science labs for school students. The pilot had been completed by a cohort of five classes ($n = 98$). Both teacher and student comments were considered for the revision, resulting in an editing loop where questionnaires and experimental instructions were changed according to the needs of the study. Overall, only a minor adjustment was required, allowing the results to be included into the main study.

Study design side study

Funded by the German Academic Exchange Service (DAAD), the side study was approved by the research ethics committees at the *Weizmann Institute of Science* and the Ministry of

Education in Israel. It followed a quantitative approach with a quasi-experimental design. Again, anonymized pencil-paper tests were administered in a pre-post test design. Due to organizational aspects, long-term effects were not considered. Participants were divided into four treatment groups (Arabic-English, Hebrew-English, Arabic and Hebrew) as depicted in Figure 4.1.2. All questionnaires were administered in Hebrew or Arabic to ensure that language did not impair understanding of the questions. This required a translation from German into both Hebrew and Arabic. The pretest T1 was conducted right before the intervention. The posttest T2 followed right after the hands-on practice.
Questionnaires and work sheets in the monolingual groups were translated into the students' school language. Additionally, in the CLIL treatment, learners were provided with scaffold methods such as vocabulary sheets, labeled laboratory equipment and paraphrases enabling the learners to freely communicate in the English language.

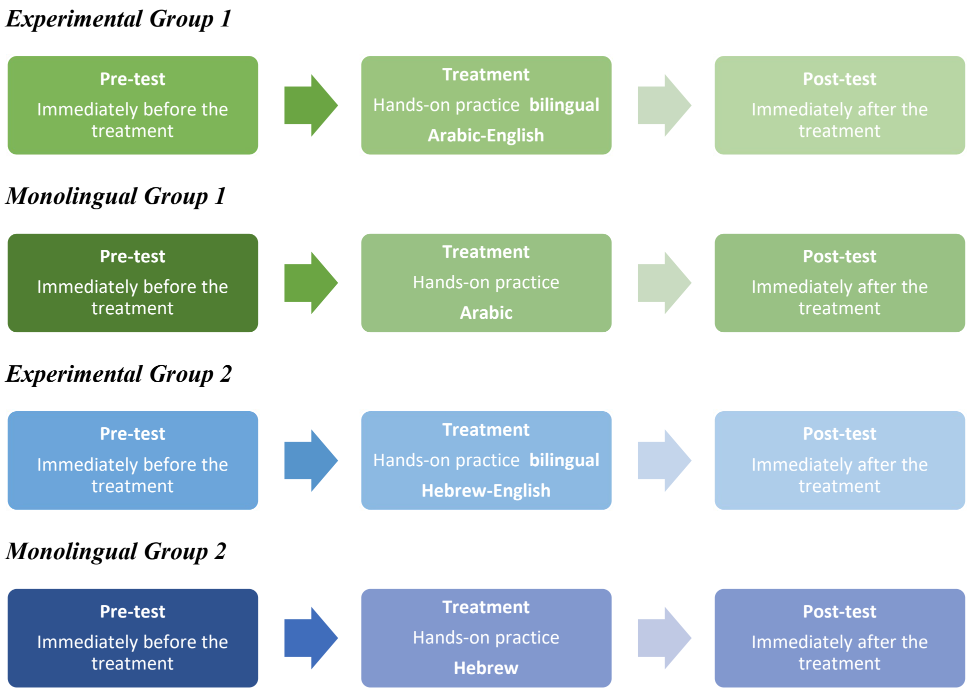


Figure 4.1.2.: Side study design at the *Weizmann Institute of Science*, Israel.

4.2. Overview of the Applied Quantitative Testing Instruments

In this section, the applied scales that measured the investigated constructs are presented. Data relevant to the analysis were collected via questionnaires across all reference times. Four different questionnaires were used to assess the intervention which were completed by all students independent of treatment group. The general structure of each questionnaire provided information about the study. The flyleaf contained a short welcoming text, an introduction to the study, the inquiry period and the reference times. Furthermore, in a confidential statement the anonymity of the participants had been ensured. Students were further asked to create a code consisting of four letters that would allow a clear allocation to the questionnaires of each participant without violating privacy concerns.

The following Table 4.2.1 summarizes the investigated measuring instruments which are based on the stated research questions of this work [1]. The majority of the applied scales were adopted from former studies in this area of research [14, 219, 25, 12, 26, 468, 15, 81, 481, 480, 12] or were modified accordingly. The questionnaires used at reference time T0 and T1 contained 117 items with a varying order. Respectively, T2 and T3 had an equal set of 173 items but again, with a varying order. Psychometric items were rated on 4-point Likert-type scales (*1 = strongly disagree* to *4 = strongly agree*). The items on cognitive achievement were newly developed. A set of 44 items with closed questions in a multiple choice setting measuring the content knowledge were used. This required a change in the order of the items appearing in the questionnaires with the goal to prevent systematic answering [482]. For research economic advantages, the multiple-choice format was preferred [483]. Response options were designed according to a forced-choice decision where strong tendencies were collected [484].

Items that were adopted from former related studies are indicated accordingly (see Section 4.4). Negative items were re-coded which allowed for an analysis and evaluation together with the remaining items of the scale. Each scale was tested for reliability through the calculation of Cronbach's α values and were indicated in the tables of the scales. Items that show a low reliability were removed from the scale (indicated in the tables where items are crossed out). After introducing all deployed scales, a factor analysis for the newly invented instrument was conducted.[2]

[1] The questionnaires contained further constructs which were not subject of the present study.

[2] In keeping with the scope of this paper, only selected instruments of the questionnaire used are listed here. The entire questionnaire including the reliabilities of the remaining instruments are provided in the appendix.

Table 4.2.1.: Overview of the in the study applied items.

Type	Construct	Source	Reference time
	(Dependent Variable)		
Knowledge Test	*Modern Materials*	Self-development	T0, T1, T2, T3
Likert Scale	Interest/Enjoyment	[468]*	T2, T3
Likert Scale	Perceived Pressure	[468]*	T2, T3
Likert Scale	Perceived Competence	[468]*	T2, T3
Likert Scale	Perceived choice	[468]*	T2, T3
Likert Scale	Intrinsic motivation chemistry	[81]	T0, T1, T2, T3
Likert Scale	Extrinsic motivation chemistry	[81]	T0, T1, T2, T3
Likert Scale	Intrinsic motivation English	[485]**	T0, T1, T2, T3
Likert Scale	Extrinsic motivation English	[485]**	T0, T1, T2, T3
Likert Scale	Self-concept Chemistry	[14]*	T0, T1, T2, T3
Likert Scale	Self-concept English	[480]	T0, T1, T2, T3
Likert Scale	Pressure foreign language use	[26]	T0, T1, T2, T3
Likert Scale	Preparation perception	[26]	T0, T1, T2, T3
	(Independent Variable)		
Single Item	Age		T0
Single Item	Gender		T0
Single Item	Mother tongue		T0
Single Item	Experience Bilingual classes		T0
Single Item	Experience study abroad		T0
Single Item	Grade Chemistry		T0
Single Item	Grade English		T0
Single Item	Advanced Placement Choice		T0
	(* changed to the needs of the study)		
	(** translated from English)		

4.3. Quantitative Statistics

In classical test theory, results that are obtained from scientific measurements depend on a confirmation through consistency tests. Methods for statistical analysis rely on already established procedures [486, 487, 488, 489].

Before analyzing the obtained data, preparation and processing needed to be done. Analysis of the resulting data was performed via SPSS software 25 to 28 as well as *R*-4.1.3. Data from the main study was typed in manually into the program. Before statistical methods could be applied, additional preparation was conducted. Missing values were detected and excluded from the study. From the original 596 data sets only 393 were considered for this study. Response rate was only 65.9% which is due to the increased number of the applied questionnaires. Subsequently, an item analysis was conducted. In general, descriptive and analytical statistics were applied as will be described in the following.

4.3.1. Quality of the Measurement

In order to validate the applied instruments, measurements that ensure the repeatability of the used scales had to be executed beforehand. As a basic principle, methods of investigation were employed that prove the quality of the testing instruments. This section provides a brief overview of the elements to evaluate the accountability of each measurement.

Reliability coefficient

The reliability coefficient describes a quality criteria that produces consistent and repeatable results of an item or scale [489, p. 632]. One degree of reliability is determined by the Cronbach's α coefficient which is defined as the internal consistency [489, p. 632]. In science education, Cronbach's α values are uniformly reported in studies as a measure for reliability [490]. As a common practice, measured values at around $\geq$ 0.7 are considered to be sufficient whereas scores around 0.8 and 0.9 are usually regarded as reliable values. However, in some papers the alpha value is determined differently where depending on their number of items scores around 0.5 are still accepted [488]. Items lowering the alpha coefficient below the given standards need to be dropped in order to increase reliability [491].

Validity

Validity has been a prevailing test quality instrument in statistical analysis. It refers to the accuracy of the test results. Validity can be measured at various points in the research process. Oluwatayo [492] distinguishes four different types of validity: a subjective assessment of the presentation (face validity), how much the items reflect the topics covered in the setting (content validity), the relationships and correlations among the variables (construct validity), and the accuracy of a measure predicted by the relation to the outcome (criterion validity) [492, p. 392ff]. It still needs to be considered that validity might suffer from selective effects. These compromise the definiteness of the interpretation on the obtained results [15].
As the study incorporated four reference times, selective effects of the measured variables can be excluded [487]. Moreover, the majority of the instruments used in this work were already established and effectively deployed in former comparable studies where a validity can be assumed [493].

Item difficulty

Item difficulty refers to a statistical probability of a participant to choose the correct item out of different options [487]. It presents an index that is calculated by the number of the correct given answers divided by the total number of possible answers [487]. Ideally, items with a difficulty index around 0.5 are considered to be not too difficult and at the same time not too easy to answer. With respect to the here applied knowledge test, items with a difficulty index at around 0.3 to 0.8 were used for the questionnaires. Items less than the suggested values describe a poor difficulty and were excluded from the study.

Item discrimination

In classical test theory, item discrimination has been a current method to evaluate the quality of the deployed items. Thus, item discrimination measures to what extent the used test item differentiates between participants with a high and participants with a low degree of a certain characteristic [494]. A high item discrimination usually indicates the high contribution of a single item to the whole scale. Values range between -1 and 1. Test items with an index of 0.4 and higher are regarded as high whereas items with a 0.2 and lower value are considered as low and therefore need to be excluded from the questionnaires [486].

4.3.2. Statistical Methods

Cluster analysis

Cluster analysis is a reduction technique that allows to group the sample data according to similar patterns. Generally, a distinction is made between hierarchical and partitioned cluster analysis. As in this study the hierarchical cluster analysis was applied, the following description is only restricted to this type. In order to reduce the number of variables in a data set, homogeneous clusters with similar objects need to be formed. The hierarchical cluster analysis either follows an agglomerative or a divisive analysis. In the former, first individual clusters are formed until in the second step similar cases are grouped together into one cluster. Contrary, the divisive analysis begins with one large cluster that over time is gradually separated into cluster groups with cases of similar individual characteristics [495, p. 9].
As the present study followed a hierarchical agglomerative cluster analysis, distance measures had to be predefined. The distance measure for interval scaled variables is based on similarities between cases. The distance between two clusters can either be defined by the minimal distance, the maximal distance or the average distance. The measurement is referred to as squared Euclidean distance measure [14]. Accordingly, in order to define the distance of the pairs, linkage measures needed to be applied. In this study, the complete linkage has been the method of choice. It refers to a measure that is determined by the furthest neighbor. The complete linkage defines the distance between two clusters as the maximum distance between a case from the first and a case from the second cluster [495].

The in the main study conducted analysis followed the procedure of former studies on science labs for school students [14, 26, 25]. Based on the collected affective dispositions on the subjects English and chemistry, students were grouped into three different learner types with the goal to further analyze cognitive and affective outcomes in this regard.

Nonparametric approaches

Frequently used for the analysis of smaller sample sizes are non-parametric statistics. In this procedure, calculated rankings and frequency information are compared without taking into account the different distances between individual values [496]. Unlike parametric statistical methods, no specific distribution form of the recorded characteristic is expected here; instead, nominal-scaled or ordinal-scaled characteristics are often used. Nevertheless, there is a possibility that by omitting scores effects are not detected [488]. Despite the criticism of their use, nonparametric statistics are considered to be equivalent to their parametric counterpart as they are seen as more robust overall to violations of model assumptions [497]. Moreover, parameter-free methods reach 95 percent of the significance of parametric statistics [12].

Although the large sample size would allow for an evaluation using parametric procedures as well as criteria such as the normal distribution by its fuzzy nature would allow for a violation [498, p. 168], the main study refrained from using parametric statistics and instead relied on less restrictive, non-parametric analysis as in similar studies [214, 141, 218]. Reasons for this were found in the increased number of reference times and the resulting fluctuating sample size, a violation of the normal distribution in the research focus sections (Shapiro-Wilk test $p < .001$), different sample sizes in the respective treatments, and the use of Likert scales that do not allow for clear interpretation of relative distances ([487] as cited by Roth [27, p. 42]).

In addition, the study sought consistency in the applied statistical methods, and therefore parametric procedures were disregarded for the main study. The following is a brief explanation of the procedures used in this study. At this point, it should be remarked that there is no claim to completeness and therefore reference is made to further literature in this regard [487, 497, 499].

Wilcoxon signed-rank test

The Wilcoxon Signed-Rank Test is considered a parameter-free analog of the t-test for paired samples. It is based on the difference between the median values of two paired samples [499]. Symmetrically distributed differences are a requirement to the test. Moreover, the dependent variable should be at least ordinally scaled. First, the difference between the dependent values is determined. The ranks are then formed from the absolute values of the differences, in order to form the sum of the ranks. Subsequently, it must be calculated how high the probability is for the resulting test value or for an extreme value in the direction of the alternative hypothesis.

$$\mu_W = \frac{n(n+1)}{4} \tag{4.1}$$

The calculated values are z-standardized for the test of significance as shown in the formula. This is followed by a comparison with the critical value of the standard normal distribution.

$$z = \frac{W - \mu_W}{\sigma_W} = \frac{W - \frac{n(n+1)}{4}}{\sqrt{\frac{n(n+1)(2n+1)}{24}}} \tag{4.2}$$

Mann-Whitney U test

Inter-group differences are assessed by conducting a Mann-Whitney U test. The test describes a non-parametric procedure used to identify differences with respect to the central location of distributions in two independent samples [499]. Instead of mean values, rank sums are used which reflect the central tendencies of the groups. As a complement to the independent t-test, the variable under investigation must be at least ordinally scaled, but does not require a normal distribution. In this approach, the rank of each case is taken to test whether the groups were drawn from the same population [500]. The Mann-Whitney U test procedure begins by determining ranks from the sample. This is followed by the calculation of the rank sum for the two groups that are required to calculate the rank values. The calculation then proceeds according to the following equation:

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - T_1 \tag{4.3}$$

where n_1 describes the number of participants in group 1, n_2 the number of participants in group 1 and T_2 the sum of ranks in group 2.

This requires z-standardization of the calculated U-value as indicated in the formula. The obtained z-value allows to control for significance, which corresponds to the critical value of the standard normal distribution for the applied significance level. If this exceeds the critical value, it can be assumed that the tendencies between the two groups under investigation are overly random. Accordingly, the formula reads as follows:

$$z = \frac{(U - \mu_U)}{\sigma_U} = \frac{U - \frac{n_1 \times n_2}{2}}{\sqrt{\frac{n_1 \times n_2 (n_1 + n_2 + 1)}{12}}} \tag{4.4}$$

Kruskal-Wallis test

To test central tendencies of more than two independent samples, the Kruskal-Wallis test is used as a nonparametric approach. In this procedure, the ranks of the dependent variable are tested for significant differences. The Kruskal-Wallis test is considered an extension of the Mann-Whitney U test, which, however, is limited to the calculation of differences between two independent groups. Three conditions are required to perform the test. First, the response variable must be either ordinal or continuous. Likewise, the observation in each of the groups must be independent from each other. Finally, a similar shape in the distribution of the groups is required. Significance in the Kruskal-Wallis test suggests that at least one group differs from the other groups, without, however, indicating where and which differences were determined [501].
To perform the test, the individual values of all samples must first be placed in an order. This is followed by an assignment of the rank according to its position. The sum of ranks is then calculated separately for each sample in order to determine the test statistic H. The formula for calculating the test statistic reads as follows:

$$E_R = \frac{n+1}{2} \tag{4.5}$$

E_R describes the expectancy value of the rank whereas $n+1$ determines the total sample size. Further, rank of variance is needed:

$$\sigma^2 = \frac{n^2-1}{12} \tag{4.6}$$

Subsequently, this allows the calculation of the test statistic H for the Kruskal-Wallis test:

$$H = \frac{n-1}{n} \sum_{i=1}^{k} \frac{n_i(\bar{R} - E_R)}{\sigma^2} \tag{4.7}$$

Friedman test

The Friedman test is used to test three or more paired samples (k) with respect to their medians in order to determine whether they derive from the same population. This non parametric procedure is the equivalent of a parametric two-factor analysis of variance with repeated measures [502]. However, in this case the rank numbers are considered rather than the actual measured values. Both factors are assessed simultaneously. For this purpose, each block must be ranked first and summed together for each columns and squared columns total. This is followed asymptotically by a chi-square distribution with (k-1) degrees of freedom which results in the computational formula [503]:

$$\chi^2 = \frac{12}{nk(k+1)} \sum_{j=1}^{k} R_j^2 - 3n(k+1) \tag{4.8}$$

where R_j describes the sum of the ranks for sample j, n determines the number of subjects and k is the number of ranked measurements.

Parametric approaches

Parametric approaches were used for the side study. This method was selected since data were normally distributed and measurement was performed at only two reference times.

T-test

T-test analysis is a statistical inference test that compares means of two groups. In the side study, two types of t-tests were conducted: independent and dependent t-tests. The paired (dependent) t-test is used for inter-group comparisons where one sample was tested twice on variables with values that depend on each other. Cross-sectional comparisons of different groups are calculated by independent t-tests where findings of two or more treatment groups are compared at one measuring point. Accordingly, independent t-tests require a normal distributed variable, homogeneity of variance and independent samples. T-tests are robust against violations based on normal distribution where samples sizes are larger than 30 [487].

In this study, dependent t-test were conducted to draw conclusions within the treatment groups. Means of variables were compared at two reference times. Independent t-test were conducted for the comparison between the treatment groups.

Analysis of variance

A statistical method that is commonly used to measure influences in a learning environment in educational research is the analysis of variance (ANOVA) [504]. ANOVAs measure the influence of independent variables (such as gender, age) on dependent variables (e.g. interest, knowledge). Depending on the number of factors examined, a distinction is made between one-factorial or multi-factorial ANOVAs (MANOVA) [505]. One-factorial ANOVAs investigate single variables (factor) with respect to group differences of three or more groups. Hence, multivariate ANOVAs measure the influence of two or more factors on an independent variable. Similar to the dependent t-test analysis, the repeated measure ANOVA allows the investigation of one group at two or more reference times. It further enables the analysis of interaction effects between different factors. As for all parametric approaches, ANOVAs require the data set to be normally distributed and a homogeneity of variances.

In the side study, the factor language was investigated with respect to cognitive and affective aspects using a two-factorial repeated measure ANOVA. Accordingly, intra-group comparisons based on different reference times were analyzed with a repeated measure ANOVA. A distinction was made between main effects and interaction effects. Main effects describe the influence of a factor on dependent variables whereas interaction effects present the influence of two factors on a dependent variable. Due to the underlying study design, this work mainly reports of interaction effects.

Rasch analysis for subject knowledge items

Opposed to the classical test theory stands the Item Response Theory (IRT). IRT is primarily used in the field of performance diagnostics for the development and evaluation of psychometric tests. One of the models that are based on the IRT is the Rasch model. The measurement procedure follows an indirect approach, whereby observable behavior represents an indicator for a latent trait. Hence, the center of investigation is described by the answers to the items given by the participants [484]. One of the IRT models Rasch developed is a measurement that is based on the analysis of dichotomous items. It describes the relationship between the measurement of items and test takers with respect to the extent these items truly measure students' ability [412]. This probabilistic test evaluation is based on the assumption that the latent ability of the test taker determines the expression of the task processing. If the latent ability is low, the respondent solves only a few tasks, whereas a high latent ability is associated with the solving of many tasks.

The Rasch scaled test allows testers to indicate both task difficulty and proficiency on the same scale. In this method it is assumed that different levels of difficulty of the subject knowledge are recorded. Thus, a suitable measure of a person's capability is task difficulty. Local stochastic independence is mentioned as a prerequisite for the validity of the Rasch analysis. The probability of solving an item depends on both the person's ability and the difficulty of the task. These must both be one-dimensional.

In addition, the Rasch model considers the *fit* of items. According to the model assumption, these indicate whether a particular construct is recorded on *a more or less than* scale. The *fits* are divided into infit and outfit. The former indicates the unexpected responses to items close to the person while the outfit makes statements about outliers. These values are presented as mean-square (MNSQ) and as z-standardized (ZSTD).

Linear regression analysis

As part of the multivariate analysis methods, the linear regression is used to test relations between two or more interval-scaled characteristics. For this purpose, the influence of one or more independent variables on a dependent variable is predicted based on a linear equation. Regression analysis distinguishes between univariate simple linear regression, univariate multiple linear regression, and multivariate multiple regression [506]. To quantify the observed values, the coefficient of determination (R^2) is introduced for this purpose. In linear regression, a linear model is assumed. The slope is determined by the values of the dependent variable when the independent variable changes by one value. This is described by the regression coefficient beta [507]. It indicates the dispersion of the values for the dependent variable and is described as the sum of squared deviation [507]. The corrected R^2 results from the ratio of the scatter to the total scatter. These can take values between 0 and 1. The test of the regression function is performed via the F-value. The latter indicates a significant correlation if the empirically determined F-value is above the theoretical value [506]. For the interpretation of the coefficient of determination R^2 in Table 4.3.1 is given by Bortz [487]:

Table 4.3.1.: Classification of the coefficient of determination R^2.

Coefficient of determination R^2	Interpretation
$R^2 > .02$	weak effect
$R^2 > .13$	moderate effect
$R^2 < .26$	strong effect

Bivariate correlation

Spearman's correlation

The correlation coefficient measures the linear statistical relationship between two variables. It presents "the strength of the putative linear association between the variables in question" [508, p. 69]. For nonparametric measures, the correlation coefficient Spearmans's ρ is used. The rank correlation coefficient Rho describes a method that determines correlations between two variables that are at least ordinally scaled. It examines the non-direct linear relationship between two variables. This means that the correlation coefficient makes no statements about which of the two variables is the dependent and the independent one. Furthermore, it does not clarify whether the two variables are mutually dependent. The correlation is calculated by assigned ranks. For this purpose, the values of the variables are sorted in an ascending order of magnitude, and differences are calculated for each value pair. The correlation coefficient can take on values between -1 and 1 and is computed with this equation:

$$\rho = 1 - \frac{6\sum_{i=1}^{n}(R_{xi} - R_{yi})^2}{n(n^2 - 1)} \tag{4.9}$$

R_{xi} represents the rank position within the variable x while R_{yi} refers to the rank position within the variable y. n is the number of cases compared. The strength of the correlation coefficient is also based on the interpretation given in table 4.3.2 according to [509].

Pearson's correlation

Frequently applied to the correlation analysis for a sample statistic is the correlation coefficient Pearson's r. Both variables need to be non distributed and both need to be interval or ratio variables. Pearson's r is calculated by the following formula:

$$r = \sum \frac{[\frac{x_i - \bar{x}}{s_x}][\frac{y_i - \bar{y}}{s_y}]}{n} \tag{4.10}$$

x_i and y_i describe the variables and $\bar{x}$ and $\bar{y}$ stands for the means of the two variables. n refers to the number of cases. Values range between -1 (perfect negative correlation), 0 (no correlation) to +1 (perfect positive correlation). Thus, positive values point to a positive association between the two variables whereas a negative value point to a weak and 0 to no relation between the variables [510]. Table 4.3.2 displays the strength of the correlation based on the interpretation according to [509]. A weak correlation is obtained for values around 0.1, medium for around 0.3. Large correlation sizes are indicated for an r more than 0.5.

Table 4.3.2.: Correlation size Pearson's r.

r **Values**	**Correlation Size**
$0.1 \geq r < 0.3$	weak
$0.3 \geq r < 0.5$	medium
$r > 0.5$	strong

4.3.3. Determining the Level of Significance

The significance level tests the probability of an observed difference between two samples with respect to the predetermined null hypothesis [511]. The p-value is commonly used as the level of marginal significance, and it is calculated based on the null distribution. Therefore, it allows to draw conclusions on effects that were found in the sample to also occur in the population. Differences that are reported as statistically significant in scientific journals usually show p-values $< .005$ [512]. Common levels of significance are indicated in Table 4.3.3. In tables and figures, statistically significant values are given in an asterisk rating system.

Table 4.3.3.: Level of significance.

Significance value	Definition	Annotation in figures or tables
$p > .05$	no evidence against the null hypothesis	
$p < .05$	weak evidence against the null hypothesis	*
$p < .01$	strong evidence against the null hypothesis	**
$p < .001$	very strong against the null hypothesis	***

4.3.4. Effect Size

A quantification of the findings from statistical significance tests can be made through the computation of effect sizes. Effect sizes for dependent variables are calculated by r with the formula

$$r = \frac{(Z)}{\sqrt{n}} \tag{4.11}$$

Table 4.3.4.: Effect sizes for the interpretation of r.

Values	Effect size
$0.1 \leq r < 0.3$	weak effect
$0.03 < r < 0.5$	medium effect
$r > 0.5$	strong effect

4.4. Pre-analysis

In this chapter, pre-analysis results of the applied instruments are presented. The section begins with the results of the Rasch-analysis for the items on knowledge acquisition of which the raw data were transformed into linear data sets. Thereupon follow the reliability results of the quantitative instruments. Independent of the treatment, the questionnaires were administered in German since the application of a foreign language might have influenced the response of the participants [513].

4.4.1. Rasch Analysis on Subject Knowledge Items

The knowledge test measured students' performance on the covered topics that related to the various field of nanotechnology. Contents were newly invented for the module and were presented in a multiple-choice format. This type of test is regarded as an informative method which reflects the intended learning goals [514]. 44-items from eleven questions assessed learners' knowledge before and after the treatment. Each of the questions consisted of four items with one correct answer and three distractors. Figure 4.4.1 gives an example of the question that were assessed to test cognitive achievement. Every correct answer was rated with four points (choosing the right answer out of four items). Zero points were given for the wrong answer. Consequently, a high score portrayed a high cognitive capability resulting in an increased knowledge gain whereas a low score indicated a low performance. The same test was applied in a varying order at four reference times.

FL 1.1 The so called "Leidenfrosteffekt" can be observed when a water drop falls into a hot pan thereby starting dancing. The effect…	
O	already occurs at temperatures around 100 °C in the pan
O	is based on the rapid vaporization of the water drop resulting out of a heat conducting layer underneath the drop
O	is based on the poor heat conductivity of water which delays the evaporation of the water drop in the hot pan
O	depends on the high boiling temperature of water

Figure 4.4.1.: Example question of the applied knowledge test translated into English.

The validity of the instrument was determined based on the Rasch analysis which first required an examination of the reliability values. As described before, reliability requires knowledge items to meet the criteria on item difficulty. Too simple and too difficult items were discarded from the questionnaire. Values over 0.9 reflect the simplicity of the item as more than 90% of the students were able to answer the question correctly. In contrast, a p-value of 0.2 highlights how difficult the item had been recognized by the learners [515]. Calculation of the item difficulty was executed for the posttest and items that belonged in each of this two categories were discarded from the test. Furthermore, the discriminating power of the multiple-choice test had been determined. Generally, item discrimination lies between 0.0 and 1.0. The higher the discriminating item, the more correct answers the examiners produced [515]. Accordingly, a negative value in item discrimination is discarded from the test whereas indexes above .2 are regarded as satisfactory ([486] as cited by [516]). The values for item reduction of the knowledge test are presented in Table 4.4.1.

Table 4.4.1.: Item difficulty, item discrimination and Cronbach's α value knowledge test.

Test	Original no. of items	Item no. after item difficulty	Item no. after item discrimination	T2 α
Modern Materials	52	52	44 .	.62 .

After calculating item difficulty and item discrimination, a total of 44 items remained for the final analysis with a Cronbach's $\alpha = .62$. Further, criterion validity was measured based on students' final chemistry grades as indicated in the first questionnaire and the scored points in the posttest. The calculated p-value (r(393) = -0.24, $p < .001$)[3] indicated a high correlation.

In addition to the reliability values, the fit values and the person-item map were further examined in more detail to verify construct validity. Table 4.4.2 illustrates the infit and outit of the mean square residual statistics. A closer analysis of the MNSQ scores reveals that both the values for the *outfit* and the *infit* show an acceptable range of $0.5 \leq \text{MNSQ} \leq 1.5$, which is productive for measurement. Consequently, a closer examination of the ZSTD values was not performed as fit statistics are compatible with data fit of the model [517]. The analysis of the model indicated an adequate measurement accuracy and goodness of fit of the data. In the next step, the person-item map was determined to measure the endorsement of the items to the test takers.

Table 4.4.2.: Fit statistics from Rasch analysis of the knowledge test.

	Outfit		Infit	
Item	MSQ	ZSTD	MSQ	ZSTD
FA1.2	0.99	-2.75	0.84	-2.56
FL1.2	1.03	0.35	1.02	0.46
FK1.1	1.05	0.63	0.98	-0.39
FL1.1	1.29	1.55	0.96	-0.32
FS1.1	1.22	1.74	0.99	-0.03
FA1.1	0.98	-0.31	0.99	-0.11
FK1.3	0.89	-1.28	0.90	-1.96
FA1.3	0.93	-1.12	0.96	-0.97
FA1.4	0.84	-2.67	0.89	-2.74

The person-item map in Figure 4.4.2 illustrates the location between a person's ability and the difficulty of the item plotted in logits along the same latent dimension. Items that were rated as difficult are shown further right in the diagram, whereas items that students perceived as easier appeared further left in the map. One explanation for the distribution of the items within the dimension can be ascribed to the complexity of the content. Item FL1.1, for example, which was found as the most challenging task, deals with the underlying physical phenomenon of the Leidenfrost effect. The question reflects physicochemical processes which contradict known laws from the learners' everyday experience and which are usually deeply rooted in their everyday understanding. As a result, it is possible that the underlying topic content was covered too briefly or appeared too complex [517]. Subsequently, this question was also rated as difficult.

A large number of items are located around 0 logit in the middle of the map with a tendency to the left. These items were easier to endorse for participants. In general, the distribution of

[3] due to the grading system in German schools, the indicated correlation is negative.

these items suggests an overall homogeneous item difficulty, so that the question construction was classified as neither too difficult nor too easy. Overall it can be stated that item saturation was represented at an average level.

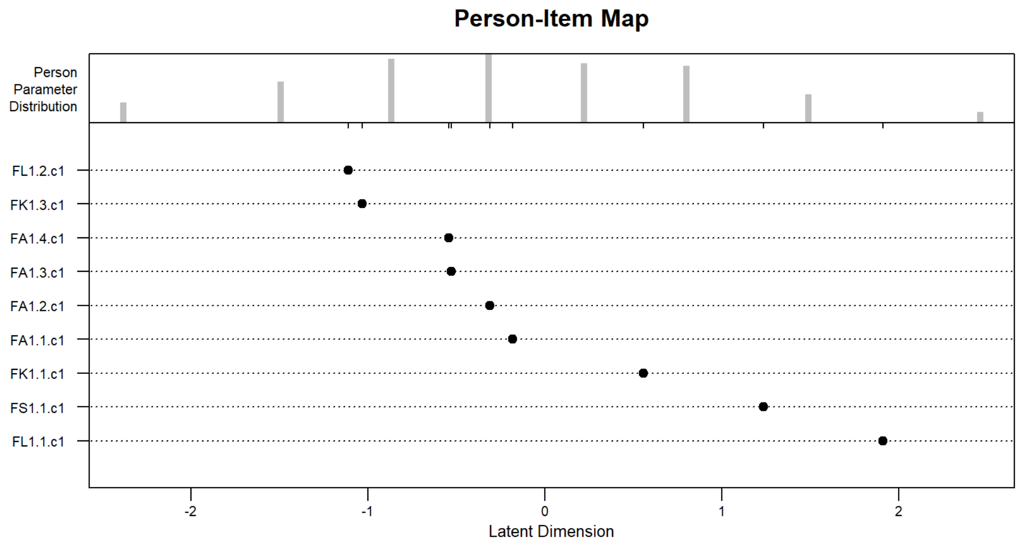


Figure 4.4.2.: Person-item map for the 44-items used in the subject knowledge test.

4.4.2. Motivation

Motivation chemistry

The in the study investigated construct of motivation is based on Deci and Ryan's SDT [288, 59]. Both scales for intrinsic and extrinsic motivation in chemistry were taken from Brandt [81] and were modified accordingly. Cronbach's α values for the intrinsic and extrinsic motivation in chemistry were sufficient for the posttest. The results for both scales are depicted in Table 4.4.3 and 4.4.4.

Table 4.4.3.: Items and Cronbach's α values on intrinsic motivation chemistry.

	When you involve yourself in a chemistry class for what reasons do you do that? Because I...				
Variable	Item	T0 α	T1 α	T2 α	T3 α
imc1.1	want to understand these things				
imc1.2	like to participate in the chemistry classroom				
		.74	.74	.76	77
imc1.3	like solving tricky problems in chemistry				

Table 4.4.4.: Items and Cronbach's α values on extrinsic motivation chemistry.

	When you involve yourself in a chemistry class for what reasons do you do that? Because I...				
Variable	Item	T0 α	T1 α	T2 α	T3 α
emc1.1	don't want to get bad grades in chemistry				
emc1.2	am expected to pay close attention	.67	.71	.73	.71
emc1.3	want them to have a high opinion of me as a student				

Motivation English

Intrinsic and extrinsic motivation in English were taken from the study of Noels et al. [485] and were translated for this purpose. Cronbach's α values for the intrinsic and extrinsic motivation in English were sufficient for the posttest. The results for both scales are depicted in Table 4.4.5 and 4.4.6.

Table 4.4.5.: Items and Cronbach's α values on intrinsic motivation English.

	I actively participate in the English classroom because...				
Variable	Item	T0 α	T1 α	T2 α	T3 α
ime1.1	I think the class is good for my personal development				
ime1.2	I like to be informed on the culture and history of the languages' country	.71	.72	.70	73
ime1.3	I like to solve difficult problems in English				
ime1.4	It feels right to use English				

Table 4.4.6.: Items and Cronbach's α values on extrinsic motivation English.

	I actively participate in the English classroom because...				
Variable	Item	T0 α	T1 α	T2 α	T3 α
exm1.1	I want to get a reputable job				
exm1.2	It becomes more and more important in the working world to speak in English	.70	.77	.75	.77
exm1.3	Many people in the world speak the English language				
exm1.4	I want a good grade				

Pressure due to foreign language use

As the setting of this study is similarly constructed to other CLIL science outreach laboratories [25, 26, 214], it was of interest to examine whether the use of English influences motivation. Therefore, pressure due to the foreign language use in a science learning environment was measured. The scale with its three items was adopted from Rodenhauser [25] and Buse [26] and was modified for the present study. The items were deployed at all four reference times. For the monolingual group, the scale were formulated in the conjunctive. Cronbach's α values were sufficient (T0, T1) to satisfying (T2, T3) (see Table 4.4.7).

Table 4.4.7.: Items and Cronbach's α values pressure due to foreign language use.

	As the LMU*chemlab* was bilingual...				
Variable	Item	T0 α	T1 α	T2 α	T3 α
de1.1	I was worried if I could master the class linguistically				
de1.2	I couldn't achieve my full potential in chemistry	.79	.79	.84	.83
de1.3	I felt under pressure to perform in chemistry while using English				

Short scale on the activity-based intrinsic motivation inventory (IMI)

A shortened version of Deci and Ryan's Intrinsic Motivation Inventory [289] was applied to the study. The multidimensional scale measures the activity-based intrinsic motivation in an extracurricular setting [468]. The four sub-scales *interest/enjoyment*, perceived *competence*, *pressure/tension* and perceived *choice* relate to a person's basic needs [289] and are considered as relevant components for the creation of intrinsic motivation [468, p. 35]. The items were modified according to the learning setting within a CLIL science outreach laboratory in order to "better reflect the situation of interest" [518, p. 49]. Hence, the sub-scales were only inserted in the posttest and the follow-up. Overall, internal consistency was rather low (α = .61).

Interest/enjoyment

Three items measured students' enjoyment based on the practical experience within the science lab for school students. Table 4.4.8 presents the Cronbach's α coefficients right after the treatment and eight to ten weeks later. The results point to satisfying reliability values at both reference times.

Table 4.4.8.: Items and Cronbach's α values on *interest/enjoyment*.

	As the LMU*chemlab* was bilingual...		
Variable	Item	T2 α	T3 α
tiv1.1	I enjoyed experimenting		
tiv1.2	the activity was very interesting	.81	.84
tiv1.3	I perceived the activity as very entertaining		

Perceived competence

The dimension on perceived competence measured learners' experience of competence within the extracurricular setting. The scale is composed of three items. Cronbach's α values indicated a high reliability of the sub-scale (see Table 4.4.9).

Table 4.4.9.: Items and Cronbach's α values perceived *competence*.

	How far do you agree with the following statements:		
Variable	Item	T2 α	T3 α
tik1.1	I am satisfied with my performance in the lab		
tik1.2	I felt very competent executing the lab activities	.82	.82
tik1.3	I think I did well in experimenting in the lab		

Perceived choice

As students' feeling of autonomy is crucial for the development of intrinsic motivation [519], the dimension investigated what influence the science outreach laboratory had in this regard. The sub-scale on *perceived choice* consisted of three items that were modified with respect to the present study. The analysis showed a high reliability at both points of measurements (see Table 4.4.10).

Table 4.4.10.: Items and Cronbach's α values on perceived *choice*.

	How far do you agree with the following statements:		
Variable	Item	T2 α	T3 α
tiw1.1	I was able to control the going of the experiments on my own		
tiw1.2	Other than in school chemistry I was able to choose how to execute the experiment	.82	.82
tiw1.3	Other than in school I was able to choose how to proceed		

Pressure/tension

As a negative predictor for intrinsic motivation, the dimension on *pressure/tension* relates to a subjective experience of the learning environment that lowers the perceived competency of the participant. The sub-scale is measured by three items that relate to the work in the science outreach laboratory. Here, again the scored Cronbach's α coefficient indicate a satisfying reliability of the sub-scale for the posttest and the follow-up as depicted in Table 4.4.11.

Table 4.4.11.: Items and Cronbach's α values on *pressure/tension*.

	How far do you agree with the following statements:		
Variable	Item	T2 α	T3 α
td1.1	Due to the activity in the lab I felt under pressure		
td1.2	During the activity in the lab I felt tense	.74	.73
td1.3	I had some concerns if I could manage the tasks and the experiments in the lab		

4.4.3. Academic Self-Concept

To understand the relationship between self-concept and academic achievement, the here applied instruments was based on Marsh et al. modified structure of the academic self-concept [337]. Academic self-concept of both domains was assessed. The scale of the chemistry self-concept was already approved in similar former studies on science labs for school students [14, 81, 25, 26, 272, 15, 12]. It was slightly changed to meet the subject chemistry. Items and calculated Cronbach's alpha coefficients are given in Table 4.4.12 for all reference times. Values around .79 indicated a satisfying reliability.
Accordingly, the academic self-concept in English was measured with three items that were adopted from the PISA study [480] and aligned to the subject. The self-concept in English was measured at all four reference times and showed high Cronbach's α values as depicted in Table 4.4.13.

Table 4.4.12.: Items and Cronbach's α values on self-concept chemistry.

	How would you assess your learning on the following school subject?				
Variable	Item	T0 α	T1 α	T2 α	T3 α
fc1.1	When I don't understand something in chemistry I know one thing for sure I will never understand that				
fc1.2	Even though I put much effort chemistry is difficult to me	.79	.78	.79	.79
fc1.3	I think it is important to deal with chemical topics				
fc1.4	I don't do well in chemistry				

Table 4.4.13.: Items and Cronbach's α values on self-concept English.

	How would you assess your learning on the following school subject?				
Variable	Item	T0 α	T1 α	T2 α	T3 α
fe1.1	I do well in the English				
fe1.2	I do well in most English tests	.93	.92	.92	.93
fe1.3	I'm a quick English learner				

4.4.4. Population Main Sample

Based on the contents covered in the treatment, students from grade 10 to 12 were invited to participate in the study. For the main study analysis, 393 data sets were included from students that completed all questionnaires. A distribution according to the treatment is depicted in Table 4.4.14.

Table 4.4.14.: Student distribution according to treatment.

	Treatment with preparation	Treatment without preparation	Total
Bilingual	124	82	206
Monolingual	98	89	187

On average, participating students were 16 years old (ranging form 15 to 20; *M*= 16.5, *SD*= .942). Overall, gender distribution was almost equal with 52.8% boys who took part in the study. A detailed break-up based on gender for all experimental groups is depicted in Table 4.4.15.

Except for one, all participating classes came from Bavarian schools. Likewise, only one school offered bilingual courses. 89.5% of the participating classes followed a classic German

Table 4.4.15.: Student distribution according to gender.

Gender	Treatment: Bilingual+ prep.	Treatment: Monolingual+ prep.	Treatment: Bilingual	Treatment: Monolingual
Girls	63	49	36	38
Boys	61	49	46	51

Gymnasium track where students regularly pass a 12-year school system. The remaining schools were either from higher professional schools of a private or official organization. A distribution of the type of school with respect to the treatment is given in Table 4.4.16. Depending on the type of German Gymnasium the learners attended, the subject chemistry

Table 4.4.16.: Student distribution according to school type.

Type of School	Treatment: Bilingual+ prep.	Treatment: Monolingual+ prep.	Treatment: Bilingual	Treatment: Monolingual
Gymnasium	109	86	67	89
Higher vocational school	15	12	15	

was either taught at grade 9 for two hours and three hours weekly in grade 10 (focus on humanities, music or modern languages) or up to three hours per week from grade 8 on to grade 12 (focus on natural sciences Gymnasium) [230]. Accordingly, in higher vocational schools chemistry classes are offered two hours a week from grade 11 to grade 13 (technical track) or two hours a week in grade 11 (social sciences track). The classes were assigned to the treatment independent of their prior knowledge and type of school they visited. With respect to the treatment, the distribution of the participating grades is presented in Figure 4.4.3. About 70% of the students attended the 11th grade during the time of the visit. 7.6% were in 12th grade and the remaining 22.4% attended the 10th grade.

Students were asked to indicate their advanced placement which they usually choose in secondary level II after completing $10th$ grade. Participants from higher vocational schools were asked to indicate the track in which they were enrolled in. Table 4.4.17 provides the students' orientation towards the indicated school subjects. As for the purpose of this study, a general distinction was made between STEM subjects and language-related subjects. Courses that don't fall into one of these categories are marked as 'others'. Of all participants, 40.7% of the learners chose a science-related subject. 13.9% specified in chemistry. More girls (8.3%) than boys (6.2%) chose the subject chemistry. Only 2.4% marked English as their advanced course. Likewise, more girls (1.7%) than boys (0.7%) chose the subject English. Twice as much boys (17.3%) than girls chose physics to specify in and twice as much girls (5.2%) were enrolled in an advanced biology course.

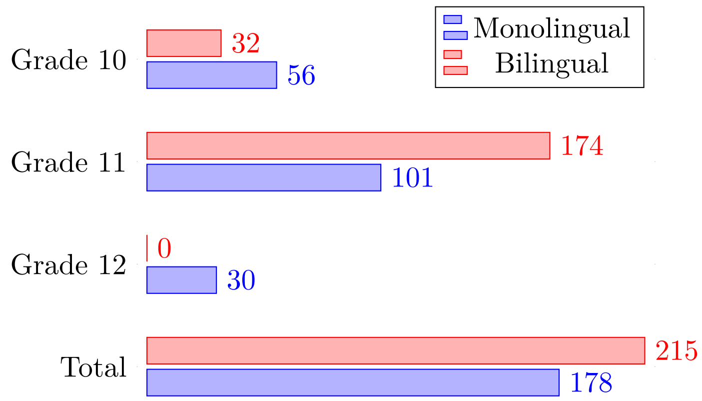


Figure 4.4.3.: Overview of descriptive statistics according to grades and language of instruction.

Table 4.4.17.: Distribution according to gender and advanced placement choice, $n = 287$.

Advanced Placement	Girls	Boys
STEM-related subject	53	63
Language-related subject	17	8
Other	78	76

Students were further asked to indicate their last grades in chemistry, English, biology and German in order to get a general knowledge about their competencies in both fields. The grades are depicted in Table 4.4.18 and Table 4.4.18 with respect to the treatment. Grades are denoted according to the German school system where 1 marks the highest possible grade and 6 the lowest. Based on the observed data, girls outperformed their male peers in all four disciplines. Girls' mean grade in chemistry was$M = 2.22$; $SD = .986$ in English $M = 2.34$; $SD = .856$. Boys' average chemistry grade was with $M = 2{,}56$; $SD = 1.136$ lower than those of girls. In the subject English, too, boys' average grade was lower $M = 2.61$; $SD =.880$. Comparing the overall average grades in science-related subjects (biology, chemistry), girls ($M = 2.18$; $SD = .858$) outperformed their male peers ($M = 2.48$; $SD = .874$). Similar findings were obtained for the overall language-related subjects (English, German) where girls ($M = 2.40$; $SD = .694$) again scored higher than boys ($M = 2.79$; $SD = .738$).

In total, of all participants 26 different native languages were gathered. The majority of students indicated German as their mother tongue (83.8%). Other languages that were more frequently recorded in the T0 were Turkish (2.3%), and Vietnamese (1.8%). The distribution of the most frequent languages are captured in Table 4.4.19.
Students prior experience on bilingual education was also collected in the first questionnaire. Almost all classes came from schools where no bilingual tracks had been installed. However, some students indicated a prior experience from previously attended schools. One class came

Table 4.4.18.: Distribution of students according to grades in chemistry, English and language of instruction, $n = 393$.

Grade Chemistry	Bilingual group	Monolingual group	Grade English	Bilingual group	Monolingual group
1	38	45	1	22	26
2	72	74	2	89	63
3	64	46	3	69	83
4	26	21	4	21	22
5	3	1	5	1	2
6	2	0	6	0	0

Table 4.4.19.: Distribution of students according to native language and treatment, $n = 393$.

Language	Treatment: Bilingual+ prep.	Treatment: Monolingual+ prep.	Treatment: Bilingual	Treatment: Monolingual
German	103	85	84	64
Turkish	7	2		
Vietnamese	4	1	2	
Croatian	1	3		1
Arabic	3	1		
Other	7	5	3	17

from a private school where bilingual classes where offered in different subjects on a regular base from grade 5 on. Due to the randomization process beforehand, the class with the bilingual experience didn't receive the bilingual treatment but was assigned to a monolingual intervention. Apart from that, none of the students had participated in a bilingual program for more than two years. The distribution within the treatment groups is presented in Table 4.4.20. According to the proportional distribution of the treatment groups, about 77.9% of all participants were inexperienced in bilingual education. Within the bilingual groups, about 44.8% stated to have attended at least one bilingual class in a non-science subject. 41.0% of those students who were bilingually educated indicated to have had at least one year experience in this regard.

Table 4.4.20.: Distribution of students according to their prior CLIL experience and treatment, $n = 392$.

Experience	Treatment: Bilingual+ prep.	Treatment: Monolingual+ prep.	Treatment: Bilingual	Treatment: Monolingual
No Experience	104	67	63	81
1 year	10	18	7	4
> 1 year	9	14	13	2

Students were further asked to indicate whether they had been in an English-speaking country for more than six months. In the bilingual group, 21.8% of the students marked a stay abroad. The distribution according to the experimental group is shown in Table 4.4.21.

Table 4.4.21.: Distribution of students according to study abroad experience abroad and treatment, $n = 393$.

Experience	Bilingual+ prep.	Monolingual+ prep.	Bilingual	Monolingual
≥ 6	46	36	41	41
Without experience	77	56	41	51

4.4.5. Population Side Study

The side study was conducted between October 2019 and December 2019 and was located in the laboratories of the Science Education Department at the *Weizmann Institute of Science*. Data was collected from 203 Arabic-speaking and Hebrew-speaking Israelis who participated at the one-day intervention. Six questionnaires had to be excluded from the study resulting in a mortality rate of 2.9% and 197 remaining data sets. A sample distribution is depicted in Table 4.4.22. The average age among Hebrew-speaking students lied around 17 years (M = 16.71; SD = .95) whereas in the Arabic-speaking group the average was 16 years (M = 16.39; SD = 1.01).

Table 4.4.22.: Distribution of students according to the language of instruction, $n = 197$.

Treatment	Arabic-speaking group	Hebrew-speaking group
Bilingual	62	33
Monolingual	61	41

With respect to gender, both Hebrew-speaking groups were unevenly distributed. In the monolingual group 56.1% girls participated in the program whereas in the bilingual group 75.8% of the learners were female. A similar picture was found in the Arabic-speaking groups where only 30.7% of the monolingual group were boys. In the bilingual group 26.2% were boys.

All participants were enrolled in an advanced chemistry course. Regarding the question of whether any of the students had had prior experience with bilingual education, 6.5% of the Arabic-speaking monolingual group stated that they had attended at least a one-year bilingual program. Likewise, 6.8% in the Arabic-speaking CLIL group had had experience with bilingual teaching. In the Hebrew-speaking groups, 6.1% of the CLIL group and 5% of the monolingual group stated that they had attended some form of bilingual education for at least one year. In the Hebrew-speaking monolingual group, 29.2% of all students indicated that they had spent at least six months abroad in an English-speaking country; in the Hebrew-speaking CLIL group, 12.5% indicated this. Only 6.7% of all Arabic-speaking students had been abroad for over six months; none of them were in the CLIL group.

5. Empirical Research Results

The following chapter provides an overview of the obtained results from the main and side study. These findings were aligned to the research questions formulated in Chapter 3 and resulted from the theory-driven measuring constructs elaborated in Chapter 1.

Since proponents of bilingual education attribute a deeper semantic processing to the teaching style [256], the study wished to contribute to the debate by assessing the effects of a bilingual science outreach setting. Analysis was conducted according to the two investigated factors of the study design: (1) language of instruction and (2) integration of the contents in school. The first set of questions aimed to measure students' cognitive achievement. Besides general knowledge intake, retention effects of the contents were central to this study. Moreover, the in the pre-pretest collected person-related data were also considered which allowed an in-depth explanation of demographic influences on the participants' cognitive output. Based on students' preferences and interests, a cluster analysis was performed of which the relation of knowledge acquisition and students' dispositions was determined.

The second part of the analysis dealt with the research questions on an affective level. As former studies on science labs for school students already proved the positive impact of the learning environment [81, 14, 15, 272], the findings in this study were interpreted with respect to the language of instruction. Constructs that were applied in this work link to the aforementioned studies in this field and investigated motivation and students' self-concept in chemistry and English.

5.1. Main Study Results on Cognitive Achievement

5.1.1. Overall Knowledge Intake

As the module on *Modern Materials* was newly developed and covered contents of different aspects on nanotechnology, it was of interest to examine whether the intervention generally facilitated content learning independent of the instruction language. For this purpose, intra-group analyses were deployed by using the Wilcoxon signed rank test at three reference times. As demonstrated in Figure 5.1.1, the findings point to an increased knowledge output and retention rates from pretest to follow-up. Overall, the intra-group comparison showed highly statistically significant increases in knowledge gain from T1 to T2 and T1 and T3. A significant decrease was detected between T2 and T3. *Z*- and *p*- values between the three reference points are depicted in Table 5.1.1. Overall, both short-term and mid-term increases in learning were obtained for the R1a. Students cognitive achievement increased after the treatment but dropped in the follow-up T3. Yet, scores never decreased below T1.

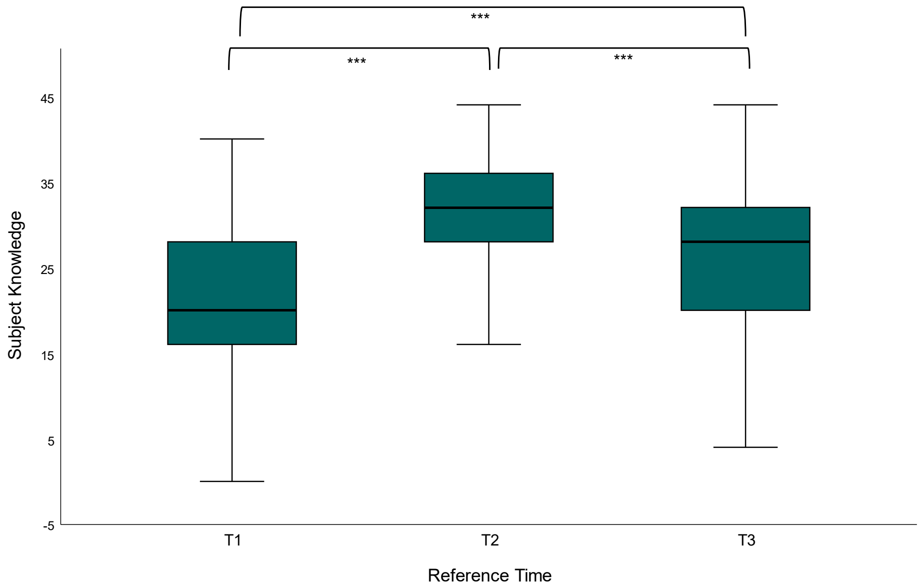


Figure 5.1.1.: Overall average knowledge score independent of treatment at three reference times. Significance values are indicated with ***$p < .001$.

To obtain students' net knowledge gain, actual learning success and long-term learning success were assessed by subtracting pretest scores from posttest scores [124, 218] for short-term knowledge gain (T2-T1) with respect to the maximal attainable score (44 points)(T2-T1) x (T2/44). Calculation of the long-term effects followed the same procedure accordingly (T3-T2) x (T3/44). The findings are indicated in Figure 5.1.2. Students' actual learning success was significantly higher compared to outcomes for long-term learning success.

Table 5.1.1.: Wilcoxon signed-rank test for intra-group comparisons on cognitive achievement at three reference times.

	T1/T2		*T1/T3*		*T2/T3*	
	Z	*p*	*Z*	*p*	*Z*	*p*
Total $n = 393$	-14.11	$p < .001$	-8.969	$p < .001$	-7.09	$p < .001$

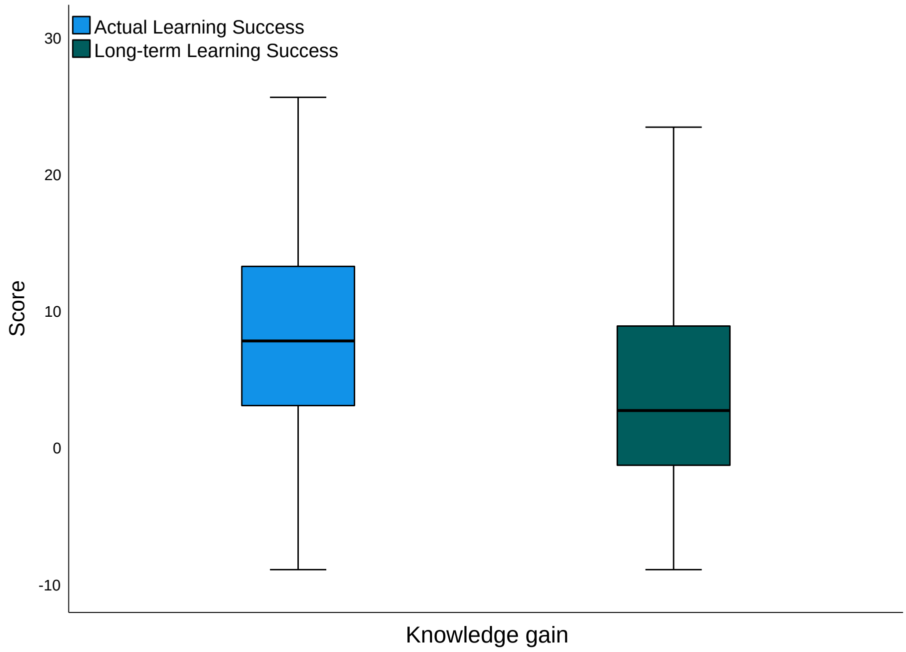


Figure 5.1.2.: Calculated actual learning success (T2-T1) x (T2/44) and long-term learning success (T3-T1) x (T3/44) independent of instruction language. Lowered scores in the follow-up indicate a drop in the long-term learning success.

Further, correlations were calculated to analyze the relation between knowledge score and reference time. A substantial relationship was found for T1 and T2 indicated in a medium correlation (r_s = .32, p < .001). Weak correlations were measured between T1 and T3 (r_s = .15, < .001) as was the case between T2 and T3 (r_s = .15, p < .01). Thus, students who scored high in the pretest also scored high in the posttest. Due to low retention rates eight to ten weeks after the intervention, students' performance on the posttest only weakly correlated with their results from the follow-up.
Furthermore, the impact of prior school grades on the acquisition of subject knowledge was investigated. A negative moderate relationship was obtained between students' grades in chemistry and the outcomes in the posttest (r_s = -.38, p < .001) as well as in the follow-up (r_s = -.46, p < .001). The reciprocal relationship is due to the German grading system where good grades illustrate a high cognitive output whereas bad grades in chemistry correlated with low outcomes in the knowledge test.

5.1.2. Instruction Language Impact

Controlling for preconditions

To exclude prior influences within the groups, person-related data as well as learners' dispositions in chemistry and English were tested for significance values. There were no differences detectable in terms of grade in English, chemistry, students' elective module or native language. Accordingly, controlling for pretest differences also did not show any statistically significant values between the two groups (Md = 20.0 bilingual group vs. Md = 24.0 in the monolingual group, U = 19,003.00, p = .148, Mann-Whitney U).

Intra-group differences on knowledge acquisition

Total scores for T1, T2 and T3 were calculated with the goal to answer the research question what impact the language of instruction had on learners' knowledge acquisition. Further, short-term cognitive output due to pretest and posttest differences (T2-T1) were assessed as well as long-term retention effects by calculating differences between the follow-up and the posttest (T3-T2). In a first step, intra-group differences were examined applying the Wilcoxon signed-rank test. Table 5.1.2 depicts Z-scores and p-values for the bilingual and the monolingual group. The findings point to significant increases between T1 and T2 in both groups. Yet, scores decreased significantly between T2 and T3. In Figure 5.1.3 within group outcomes on cognitive achievement for both, the monolingual and the bilingual group are summarized. Hence, both groups showed highly statistically significant changes over the reference period. A decrease in knowledge acquisition was observed in both intervention groups in the follow-up test.

Table 5.1.2.: Cognitive achievement of bilingually and monolingually instructed group using the Wilcoxon signed-rank test at three reference times.

Instruction language	*T1/T2*		*T1/T3*		*T2/T3*	
	Z	p	Z	p	Z	p
Bilingual, n = 206	-10.42	$p < .001$	-4.95	$p < .001$	-6.69	$p < .001$
Monolingual, n = 187	-9.54	$p < .001$	-5.11	$p < .001$	-5.93	$p < .001$

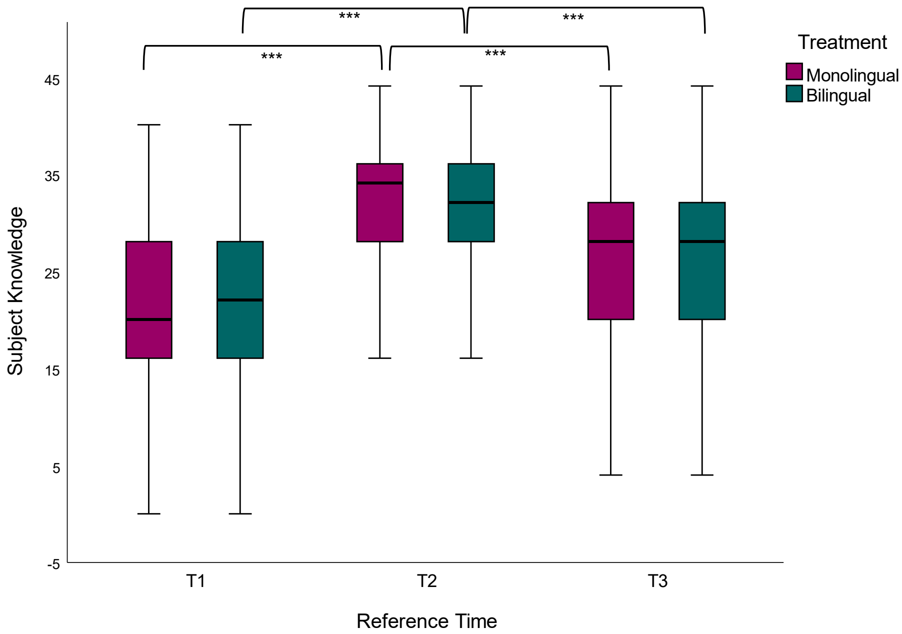


Figure 5.1.3.: Within group comparison of students' performance on the knowledge test in the bilingual and monolingual group at three reference times. Significance values are indicated with $^{***}p < .001$.

Inter-group differences on cognitive achievement

Inter-group differences were calculated using the Mann-Whitney U test with a Bonferroni correction [488]. When comparing cognitive output between the bilingual (Md = 25.0) and the monolingual group (Md = 20.0), it becomes evident that the test scores for T1 were not statistically significant (U = 19,003.00, p = .887, Mann-Whitney U). The same is true for T2 (Md = 32.0 bilingual vs. Md = 34.0, U = 17,190.5, p = .152, Mann-Whitney U) and T3 (Md = 28.0 bilingual vs. Md = 28.0, U = 18,927.00, p = .694, Mann-Whitney U). The findings suggest an equal knowledge intake in both groups. Monolingually and bilingually instructed students gained similar scores over the testing period.
Subsequently, net knowledge growth was assessed by calculating the actual learning success with respect to the maximum attainable score (44 correct answers): (T2-T1) x (T2/44). Calculation of the long-term effects followed the same procedure accordingly (T3-T2) x (T3/44) (see Figure 5.1.4). The results from Table 5.1.3 suggest a slightly higher actual and long-term learning success within the monolingual group. However, these results were not significant.

Table 5.1.3.: Calculated actual learning success for (T2-T1) x (T2/44) and long-term learning success (T3-T1) x (T3/44) for bilingually and monolingually instructed group.

Learning success	Bilingual	Monolingual
	$Mdn(25^{th}/75^{th}P)$	$Mdn(25^{th}/75^{th}P)$
Actual learning success	7.27 (3.18/13.09)	8.72 (2.91/14.18)
Long-term learning success	2.54 (-1.09/7.91)	3.63 (-1.45/9.91)

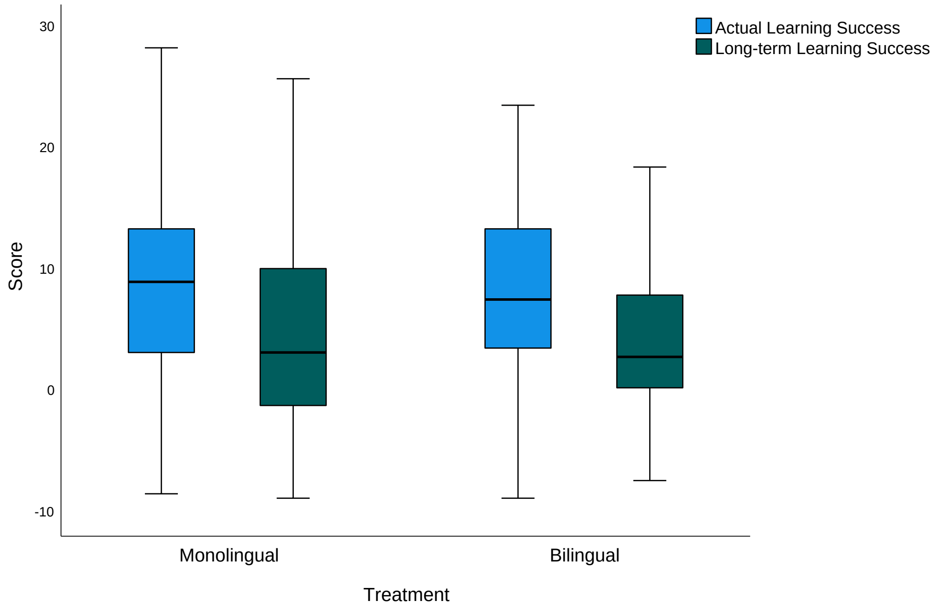


Figure 5.1.4.: Calculated actual learning success (T2-t1) x (T2/44) and long-term learning success (T3-T1) x (T3/44) of the bilingual and the monolingual group.

Further, correlation analysis was deployed to measure the influence of students' grades in chemistry and English on the posttest results. The findings displayed a weak negative correlation for students' grades in chemistry (r_s = -299, p < .001) as well as in English (r_s = -155, p < .001). Accordingly, learners with better grades scored higher in both groups immediately after the treatment while low scoring students indicated lower grades in both subjects.

5.1.3. Preparation and Post-Enhancement Impact

Controlling for preconditions

Research question F1.3 addressed the impact on knowledge acquisition and retention of integrating the laboratory module in school. To identify potential differences between the four treatment groups, the pre-pretest which was assessed a week ahead of the intervention was analyzed according to score differences. As shown by a Kruskal-Wallis test, there were no significant differences obtained and treatment group belonging did not affect the output ($H(3) = 6.75$, $p = .080$).

Content knowledge intra-group analysis for all treatment groups

A Friedman's test was applied for repeated measures for each treatment group to obtain intra-group comparisons. Figure 5.1.5 illustrates the findings from the monolingual group suggesting significant changes over the reference time. Calculations confirm significance values between test scores that were measured a week ahead of the intervention T0 ($Md =$ 16.0), right before the laboratory day T1 ($Md = 20.0$), T2 ($Md = 32.0$) and after eight to ten weeks T3 ($Md = 28.0$) $(X^2)_F(3) = 97.84$, $p < .001$. Subsequently, post-hoc tests using a Wilcoxon signed-rank test with a Bonferroni-adjusted alpha level were assessed as depicted in Table 5.1.4. Knowledge score increased over the reference time from T0 to T2 and decreased from T2 to T3 significantly. However, no significance values were measured between T0 and T1 which was expected due to the missing preparation.

Table 5.1.4.: Post-hoc test (Wilcoxon Signed Rank). Significance values on knowledge test between the reference times and effect size r in the monolingual group, $n = 79$.

Monolingual	T0	r	T1	r	T2	r	T3	r
T0	-	-	1.00		.000	.19	.000	.13
T1	1.00		-	-	.000	.017	.000	.10
T2	.000	.19	.000	.17	-	-	.037	.06
T3	.000	.13	.000	.1	.037	.06	-	-

Procedures were repeated for the bilingual group and Friedman's test again, indicated differences within the reference period (T0 ($Md = 20.0$), T1 ($Md = 20.0$), T2 ($Md = 36.0$), T3 ($Md = 28.0$)) $(X^2)_F(3) = 97.84$, $p < .001$ as illustrated in Figure 5.1.6. Similarly as in the monolingual group, no such differences were detectable between the T0 and T1 (Table 5.1.5).

Table 5.1.5.: Post-hoc test (Wilcoxon Signed Rank). Significance values on knowledge test between the reference times and effect size r in the bilingual group, $n = 77$.

Bilingual	T0	r	T1	r	T2	r	T3	r
T0	-	-	1.00		.000	0.187	.000	.103
T1	1.00		-	-	.000	.019	.000	.10
T2	.000	.187	.000	.019	-	-	.000	.086
T3	.000	.103	.000	.10	.000	.086	-	-

In the prepared monolingual group significant differences were already detectable between T0 (Md = 20.0) and T1 (Md = 24.0) indicating the impact of the preparation right before the intervention (Figure 5.1.7). Accordingly, significance values were also present between the other three reference times $(X^2)_F(3) = 95.45$, $p < .001$ (T2 (Md = 36.0), T3 (Md = 28.0)). These differences were further calculated by a post-hoc assignment using a Wilcoxon signed-rank test with a Bonferroni-adjusted alpha level. The outcomes are depicted in Table 5.1.6 showing knowledge score increase over the four reference times with significance values and effect sizes.

Table 5.1.6.: Post-hoc test (Wilcoxon Signed Rank). Significance values on knowledge test between the reference times and effect size r in the prepared monolingual group, $n = 93$.

Prepared monolingual	T0	r	T1	r	T2	r	T3	r
T0	-	-	.081		.000	.175	.000	.09
T1	.081		-	-	.000	.0131	.199	
T2	.000	.175	.081		-	-	.000	.085
T3	.000	.09	.199		.000	.085	-	-

Similar findings were obtained within the prepared bilingual group (see Figure 5.1.8) with an increase in knowledge between T0 and T1 thereby highlighting the effects of the preparation in school. Like the remaining treatment groups, a knowledge intake was measured from pretest to posttest (T0 (Md = 20.00), T1 (Md = 20.00), T2 (Md = 36.00), T3 (Md = 28.00)) $(X^2)_F(3) = 127.45$, $p < .001$. As in the prepared monolingual group, the significant decrease from posttest to follow-up highlights the low impact of the post-processing in school. A post-hoc test revealed significance values between the four reference times as depicted in Table 5.1.7. The overall small effect sizes that were obtained for all treatment groups point only to small interaction effects among the four knowledge tests.

Table 5.1.7.: Post-hoc test (Wilcoxon Signed Rank). Significance values on knowledge test between the reference times and effect size r in the prepared bilingual group, $n = 119$.

Prepared bilingual $n = 119$	T0	r	T1	r	T2	r	T3	r
T0	-	-	.063		.000	.157	.000	.088
T1	.063		-	-	.000	.012	.000	.005
T2	.000		.000	.118	-	-	.000	.069
T3	.000	.088	.000	.005	.000	.069	-	-

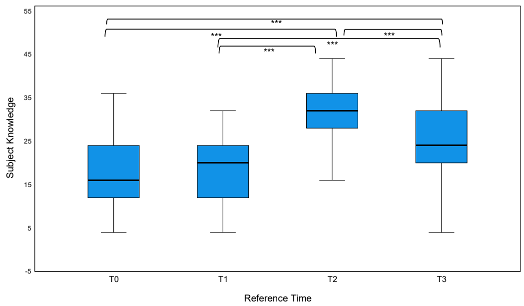


Figure 5.1.5.: Within group comparison of students' achievement on the knowledge test in the monolingual group at four reference times. Significance values are indicated with $^{***}p < .001$.

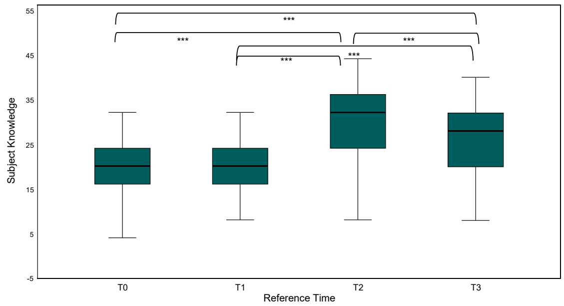


Figure 5.1.6.: Within group comparison of students' achievement on the knowledge test in the bilingual group at four reference times. Significance values are indicated with $^{***}p < .001$.

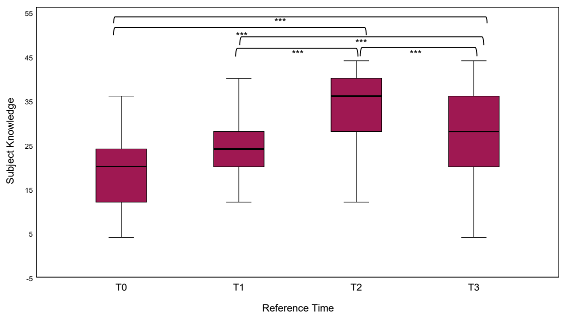


Figure 5.1.7.: Within group comparison of students' achievement on the knowledge test in the prepared monolingual at four reference times. Significance values are indicated with $^{***}p < .001$.

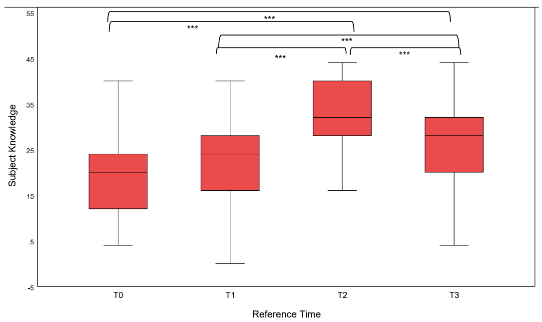


Figure 5.1.8.: Within group comparison of students' achievement on the knowledge test in the prepared bilingual group at four reference times. Significance values are indicated with $^{***}p < .001$.

In addition, the study examined learners' own evaluation of the preparation and post-processing of the laboratory in school (Figure 5.1.9). In the posttest significant differences were found between the monolingual (Md = 3.0) and bilingual participants (Md = 2.5). (U = 3,060,00 $p < .001$, Mann-Whitney U). Hence, learners of the monolingual group rated the preparation as more helpful than the bilingually instructed students. These results remained significant in the follow-up (U = 1,750.00, $p < .001$, Mann-Whitney U).

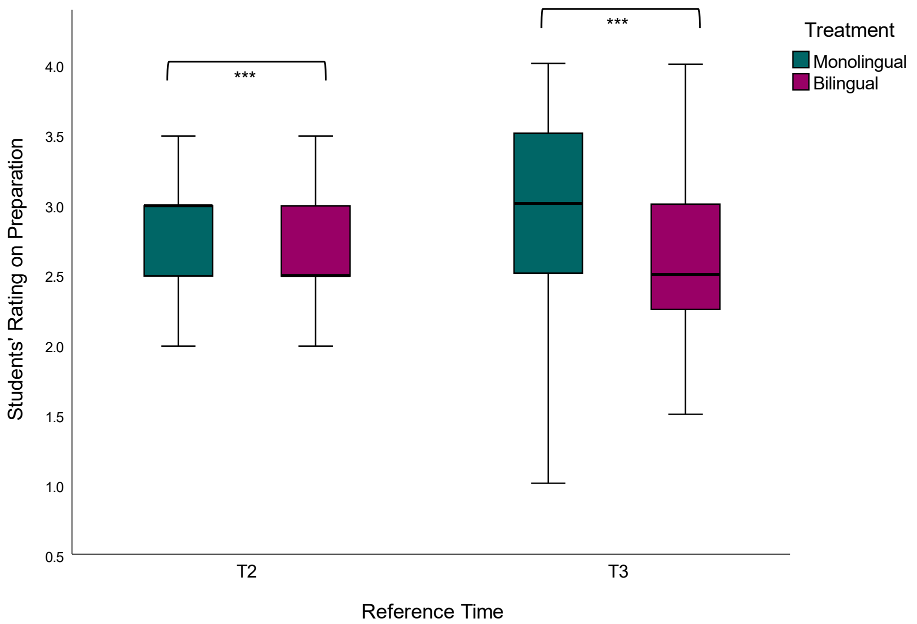


Figure 5.1.9.: Scale of students' perceived preparation evaluation for both prepared groups in the posttest and the follow-up. Significance values are indicated with $^{***}p < .001$.

Content knowledge inter-group comparison for all treatment groups

Inter-group comparisons were calculated with respect to students' total scores at the four reference times (Figure 5.1.10). After the preparation in school, students from both the bilingual (Md = 24.00) and monolingual (Md = 24.00) group significantly outperformed their unprepared peers in T1 (Md = 20.00 bilingual group, Md = 20.00 monolingual group) $H(3) = 17.77$, $p < .001$. In the posttest, these differences were no longer significant as Kruskal-Wallis test indicated $H(3) = 2.98$, $p = .396$. Similarly, there were no significant differences detectable between the four groups in the follow-up $H(3) = 17.77$, $p < .001$.

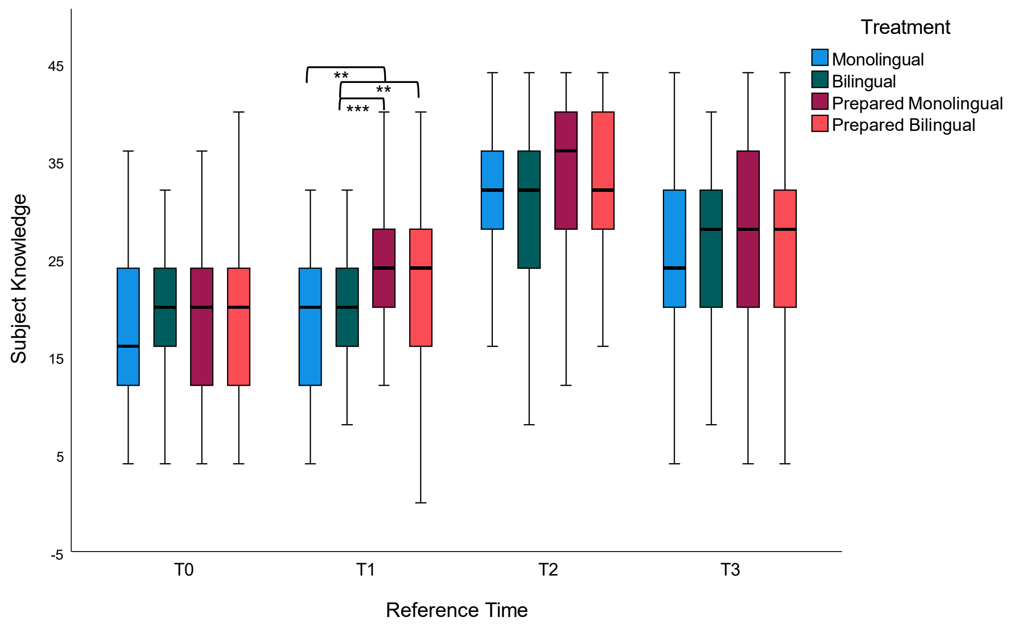


Figure 5.1.10.: Between group comparison of students' achievement on the knowledge test with respect to the factors language and treatment at four reference times. Significance values are indicated with $^{**}p < .01$ and $^{***}p < .001$.

Further, actual and long-term learning success were obtained to give account for students' net cognitive achievement. Pretest results were subtracted from posttest scores as well as posttest score from the follow-up (Figure 5.1.11. Comparing the actual learning success of all groups with each other, the Kruskal-Wallis test showed no significant effects based on treatment $H(3) = 6.27$, $p = .09$. Moreover, long-term learning effects were also not significant with regard to the treatment $H(3) = 4.33$, $p = .231$ (see Table 5.1.8). Hence, the integration of the module in school was less beneficial with regard to the posttest as independent of the treatment all experimental groups showed a similar cognitive output. The follow-up work a week after the intervention also did not lead to any significance effects based on the treatment. Accordingly, students who received a preparation outperformed their unprepared peers on a short-term level but the integration in school did not lead to long-term effects on their learning success.

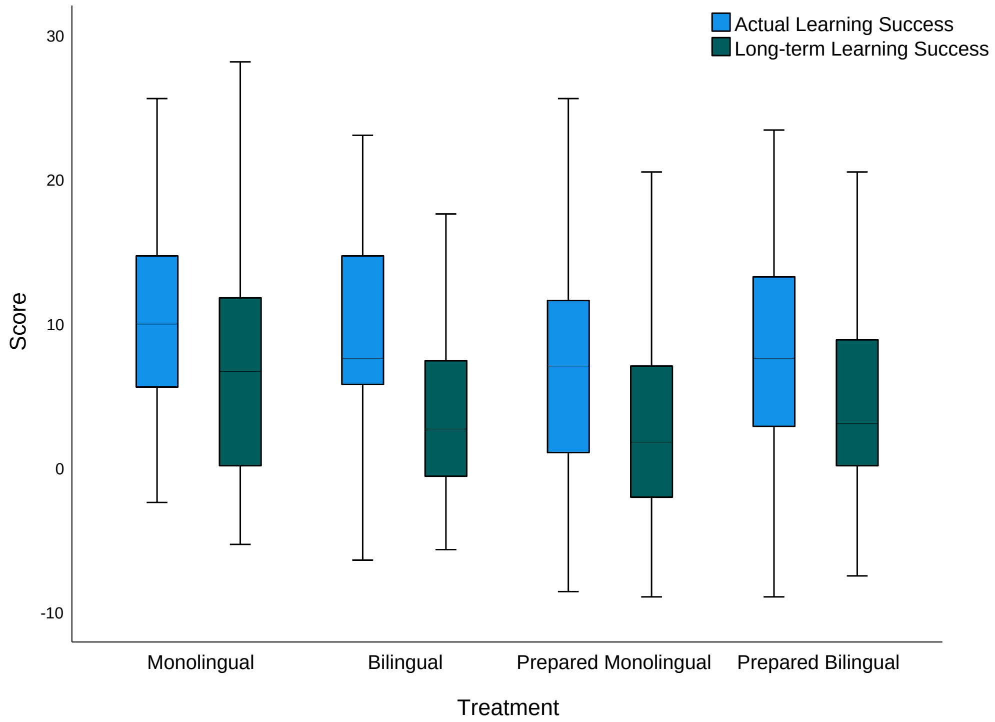


Figure 5.1.11.: Calculated actual learning success (T2-T1) x (T2/44) and long-term learning success (T3-T1) x (T3/44) for the four treatment groups.

Table 5.1.8.: Calculated actual learning success for (T2-T1) x (T2/44) and long-term learning success (T3-T1) x (T3/44) for the four treatment groups, $n = 393$.

Learning success	Monolingual	Bilingual	Prepared Monolingual	Prepared Bilingual
	Mdn ($25^{th}/75^{th}P$)	Mdn ($25^{th}/75^{th}P$)	Mdn ($25^{th}/75^{th}P$)	Mdn ($25^{th}/75^{th}P$)
Actual learning success	9.81 (5.27/14.54)	9.27 (5.45/14.54)	6.54 (.00/12.27)	6.54 (2.91/13.09)
Long-term learning success	4.36 (-1.00/9.81)	2.90 (.00/9.27)	2.54 (-2.90/9.27)	2.91 (-2.54/8.72)

Correlation with students' personal traits

Knowledge scores from the different treatments were further tested with regard to correlations between gender, advanced placement choice, grade in chemistry, grade in English, native language and experience with bilingual teaching using Spearman ρ correlations. Correlations were obtained for the monolingual group in the posttest between knowledge score and chemistry grade (r_s = -551, $p < .01$). However, no other variable seemed to impact cognitive intake in this group. This was also true for the prepared monolingual group (r_s = -357, $p < .01$). Similarly, in both bilingual groups, only grades in chemistry and English correlated significantly with the scores in the posttest (r_s = -353, $p < .01$) for English grade in the bilingual group, (r_s = -280, $p < .01$) for chemistry grade in the bilingual group and (r_s = -360, $p < .001$) in the prepared bilingual group). Thus, students' grades were the only parameter to have an influence on learners' scores in the knowledge test.

In conclusion, the findings indicated that the preparation and follow-up work in school as part of a program integration did not yield the assumed effect as actual learning success and long-term learning success were similar to the unprepared groups independent of language.

5.1.4. Cluster Analysis of Motivational Types

Cluster analysis was deployed to identify sub-groups based on students' preferences. These sub-groups were examined with respect to their influence on cognitive achievement. The hierarchical cluster analysis followed the procedure of former studies on science labs for school students [14, 25, 26]. A set of collected affective variables from the pre-pretest (self-concept English, self-concept chemistry, intrinsic motivation English, intrinsic motivation chemistry, pressure due to foreign language use) were taken into consideration for the categorization. With the agglomerative hierarchical cluster analysis, structures of homogeneous groups were determined. For the clustering, the *complete-linkage* method was used (most remote neighbor) with the distance measure of the squared Euclidian distance.

Cluster description

Accordingly, three types of learners were identified. Due to the missing data of one or more of the selected variables, 6 students were excluded from the analysis. Cluster 1 students had a high language-orientation but showed a low level of motivation in sciences. Cluster 2 contained all participants that perceived themselves equally interested and talented in both subjects (all-rounder). Cluster 3 summarized students with a strong pronunciation on sciences but at the same time showed a low affection on language-related components. These students were considered as rather science-oriented.

The largest group with 256 students was made up of learners that showed equally high means on both strands. Both, the language-oriented students (n = 66) and the science-oriented students (n = 56) were evenly distributed. Figure 5.1.12 and 5.1.13 depicts the means of the chemistry and English-related variables from the three clustered student types. The distribution of means within these three clusters clearly identified learners' preferences based on the subject-matter.

A Kruskal-Wallis test was performed on five variables that were used for the determination of the clusters. Significance values were measured for intrinsic motivation in English ($H(2) = 113.13$, $p < .001$) as well as intrinsic motivation in chemistry ($H(2) = 65.53$, $p < .001$). Calculations were further executed for self-concepts in chemistry and English. The findings point to highly statistically significant values for both, the self-concept in chemistry ($H(2) = 59.26$, $p < .001$) as well as for the English self-concept ($H(2) = 122.55$, $p < .001$). Furthermore, significant differences were measured for the variable pressure due to foreign language use ($H(2) = 118.09$, $p < .001$).

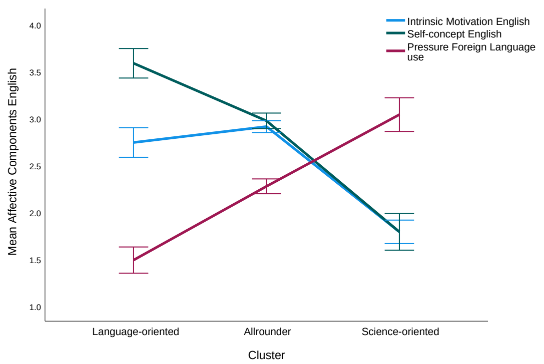


Figure 5.1.12.: Cluster analysis based on the components of motivation and self-concept in English with respect to the three formed clusters: cluster 1 (language-oriented), cluster 2 (all-rounder), cluster 3 (science-oriented).

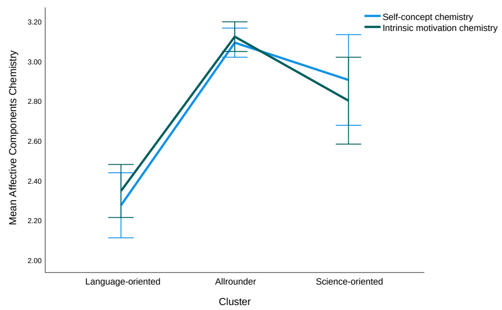


Figure 5.1.13.: Cluster analysis based on the components of motivation and self-concept in chemistry with respect to the three formed clusters: cluster 1 (language-oriented), cluster 2 (all-rounder), cluster 3 (science-oriented).

Post-hoc Mann-Whitney-U tests using a Bonferroni-adjusted alpha level (.017) were applied to compare the obtained group differences. With regard to the chemistry-related variables, the findings revealed statistically significant differences between the language-oriented and the all-rounder students for intrinsic motivation in chemistry (U = 3,255.5, $p < .001$, Mann-Whitney-U), between language-oriented and science-oriented (U = 1,116.5, $p < .001$, Mann-Whitney-U) as well as between science-oriented and all-rounder (U = 5,954.00, $p <$ .05, Mann-Whitney-U). Similarly, for students' self-concept in chemistry significance values were detected between the language-oriented and the all-rounder group (U = 3,337.00, $p <$ .001, Mann-Whitney-U) as well as between the language-oriented and science-oriented group (U = 982.5, $p <$ .001, Mann-Whitney- U).

Table 5.1.9 depicts the means and standard deviations for the three clusters with respect to the variables. With regard to the English-related variables, differences were further obtained for self-concept in English (U = 4,206.00, $p <$ .001 language-oriented vs. all-rounder, U = 181.00, $p <$ .001 language-oriented vs. science-oriented, U = 1,959.00, $p <$ .001 science-oriented vs. all-rounder Mann-Whitney-U), pressure due to foreign language use (U = 3,039.5, $p <$ .001 language-oriented vs. all-rounder, U = 187.5, $p <$ .001 language-oriented vs. science-oriented, U = 3,173, $p <$ .001 science-oriented vs. all-rounder Mann-Whitney-U) as well as on intrinsic motivation in English (U = 470.5, $p <$ .001 language-oriented vs. science-oriented, U = 748.5, $p <$ .001 science-oriented vs. all-rounder Mann-Whitney-U).

Table 5.1.9.: Kruskal Wallis test table based on students' dispositions. Cluster 1 (language-oriented), cluster 2 (all-rounder), cluster 3 (science-oriented). Mean rank and chi-square (χ^2) are indicated for each cluster. Significance values are indicated with $^{***}p < .001$.

Factor	**Cluster**	**Mean Rank**	χ^2	$\boldsymbol{n}$
Intrinsic motivation chemistry	Language-oriented	99.74	41.19***	66
	All-rounder	220.25		265
	Science-oriented	180.88		56
Intrinsic motivation English	Language-oriented	195.21	50.48***	66
	All-rounder	224.07		265
	Science-oriented	50.27		56
Self-concept chemistry	Language-oriented	98.95	35.01***	66
	All-rounder	216.4		265
	Science-oriented	200.03		56
Self-concept English	Language-oriented	288.03	70.86***	66
	All-rounder	197.48		265
	Science-oriented	66.71		56
Pressure foreign language use	Language-oriented	82.39	65.86***	66
	All-rounder	216.4		265
	Science-oriented	200.03		56

5.1.5. Cognitive Achievement with regard to Cluster Dependence

Controlling for preconditions in the bilingual group

A Kruskall Wallis test was conducted to identify possible differences between the clusters with regard to the knowledge acquisition right before treatment. Within the bilingual group, no cluster differences were detectable before the intervention ($H(2) = .390$, $p = .823$) as all groups performed similarly independent of their learner type ($Md = 16.0$ language-oriented group vs. $Md = 20.0$ all-rounder group vs. $Md = 20.0$ science-oriented group).

Subsequently, intra-group comparisons were calculated using a Friedman's test for repeated measures on each learner-type respectively. Figure 5.1.14 depicts the outcomes for three clusters at three reference points. For the language-oriented group, the test indicated significant changes from T1 ($Md = 24.0$) to T2 ($Md = 32.0$) to T3 ($Md = 24.0$) $(X^2)_F(2) = 14.71$, $p < .001$). With regard to the all-rounder group, highly statistically significant values were detected over the testing period $(X^2)_F(2) = 90.88$, $p < .001$ (T1 $Md = 20.0$, T2 $Md = 32.0$, T3 $Md = 28.0$). Accordingly, science-oriented learners scored similarly to their peers from pretest to posttest to follow-up ((T1 $Md = 20.00$) to T2 ($Md = 32.00$) to T3 ($Md = 28$)) with significant values in the Friedman's test $(X^2)_F(2) = 19.66$, $p < .001$. Z-scores and significance values for the three reference times are depicted in Table 5.1.10.

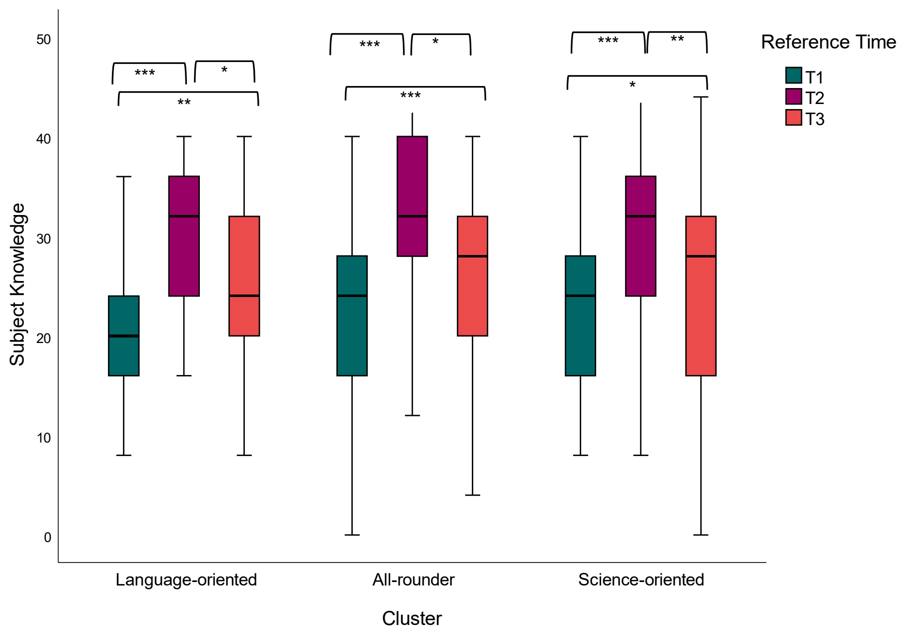


Figure 5.1.14.: Cognitive achievement with regard to the identified learner types in the bilingual group. Significance values are indicated with $^*p < .05$, $^{**}p < .01$ and $^{***}p < .001$.

Intra-group comparison for the three learner-types in the bilingual group

Table 5.1.10.: Cognitive achievement with regard to the identified learner types using the Wilcoxon signed-rank test at three reference times.

	T1/T2		*T1/T3*		*T2/T3*	
	Z	*p*	*Z*	*p*	*Z*	*p*
language-oriented, $n = 33$	-4.67	$p < .001$	-2.35	$p < .05$	-3.09	$p < .01$
all-rounder, $n = 131$	-8.92	$p < .001$	-4.11	$p < .001$	-7.25	$p < .001$
science-oriented, $n = 37$	-3.92	$p < .001$	-2.30	$p < .05$	-2.58	$p < .05$

Inter-group comparison of the three learner-types in the bilingual group

To test for group differences with regard to the three learner types in the bilingual group, a Kruskal-Wallis test was conducted at the three reference times. For T1, no differences were detectable between the three learner types $H = .911$, $p = .634$ ($Md = 20.0$). This was also the case for the posttest, as although the all-rounder group scored highest among the three ($Md = 32.0$), differences were overall not significant ($H = 5.82$, $p = .054$) and remained insignificant in the follow-up ($H = 2.76$, $p = .213$). The findings show that knowledge acquisition was independent from learner type in the bilingual treatment.

Controlling for preconditions in the monolingual group

Likewise, the Kruskal-Wallis test was conducted to test for possible group differences within the monolingual group before the intervention. There were no significance values detectable in T0 based on learner-type group dependency ($H(2) = 1.61$, $p = .447$) with similar scores in the pre-pretest ($Md = 16.0$ language-oriented vs. $Md = 20.0$ all-rounder vs.$Md = 20.0$ science-oriented group).

Intra-group comparison of the three learner-types in the monolingual group

As all learner types scored similarly high in the pre-pretest, a Friedman's test was assessed for repeated measures and conducted for each learner type individually (see Figure 5.1.11). In the language-oriented group, statistically significant changes were detected between the three reference times $(X^2)_F(2) = 13.51$, $p < .001$) from T1 ($Md = 20.25$) to T2 ($Md = 32.0$) to T3 (*Md* 24.0). Friedman's test was also significant for the all-rounder group (T1 $Md = 20.0$, T2 $Md = 36.0$, T3 $Md = 26.0$) from pretest to follow-up $(X^2)_F(2) = 78.04$, $p < .001$). The findings for the science-oriented group were similar as for the all-rounder group (T1 $Md = 22.0$, T2 $Md = 36.0$, T3 $Md = 26.0$) and cognitive achievement significantly increased from T1 to T2 but decreased between T2 and T3 $(X^2)_F(2) = 14.35$, $p < .001$). Post hoc analysis was conducted using a Wilcoxon-signed rank test with a Bonferroi correction for each group individually. Significant changes were obtained between the reference times as illustrated in Table 5.1.11.

Table 5.1.11.: Cognitive achievement with regard to the identified learner types in the monolingual group using the Wilcoxon signed-rank test at three reference times.

	T1/T2		*T1/T3*		*T2/T3*	
	Z	p	Z	p	Z	p
language-oriented $n = 31$	-3.91	$p < .001$	-3.38	$p < .001$	-2.75	$p < .01$
all-rounder $n = 128$	-7.83	$p < .001$	-5.24	$p < .001$	-6.23	$p < .001$
science-oriented $n = 19$	-3.55	$p < .01$	-2.97	$p < .001$	-3.26	$p < .01$

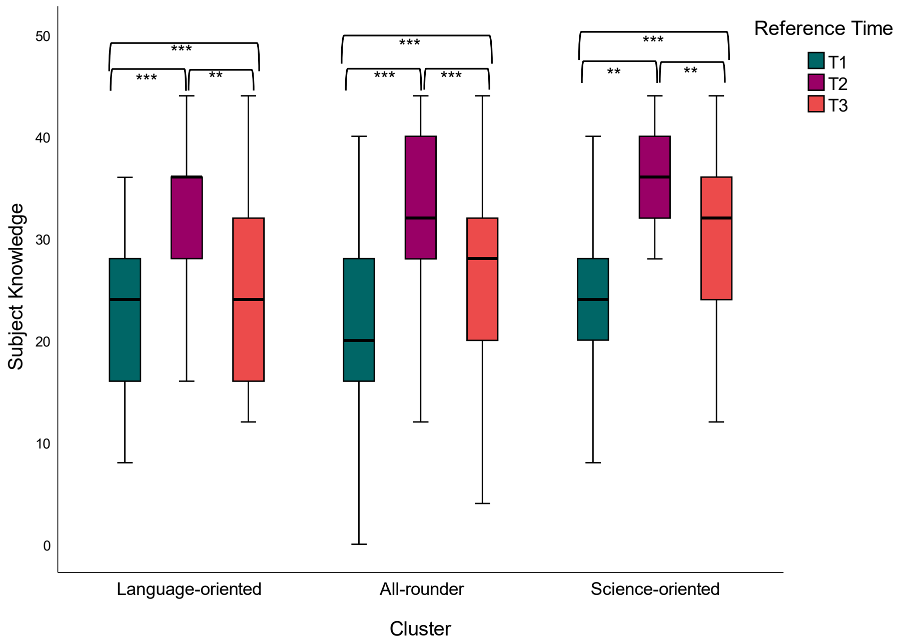


Figure 5.1.15.: Cognitive achievement with regard to the identified learner types in the monolingual group. Significance values are indicated with $^{**}p < .01$ and $^{***}p < .001$.

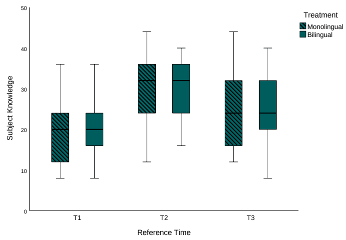
Inter-group comparison for the learner-types in the monolingual group

Group differences with regard to the learner types were assessed for each reference time using a Kruskal-Wallis test. All learner types scored similarly high in T1 as there were no significance values measurable $H = 1.11$, $p = .574$ ($Md = 22.0$ language-oriented vs. $Md = 20.0$ all-rounder vs. $Md = 22.0$ science-oriented). The same was true for T2 after the intervention $H = 1.27$, $p = .528$ ($Md = 32.0$ language-oriented vs. $Md = 36.0$ all-rounder vs. $Md = 36.0$ science-oriented) as well as for T3, the follow-up eight to ten weeks later H

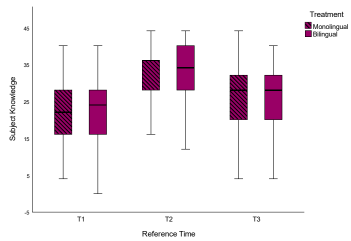
= .942, p = .625 (Md = 24.0 language-oriented vs. Md = 28.0 all-rounder vs. Md = 28.0 science-oriented).
The outcomes suggest that for the monolingual group, too, learner-type preferences were independent from knowledge acquisition. Thus, neither in the bilingual group nor in the monolingual group students were impaired from learning chemistry contents due to their personal dispositions.

Comparison of the three learner types based on the instruction language

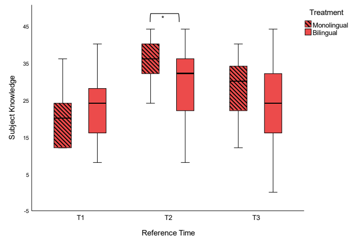
To investigate the impact of the language of instruction with regard to the learner types, Mann-Whitney-U tests were performed for the three reference times each. Descriptive statistics as well as Z- and p-scores are depicted in Table 5.1.12. The results suggest that for the language-oriented group the use of the foreign language (Figure 5.1.16a) did not seem to have an impact on the learners as both groups scored similarly high (T1 bilingual Md = 20.0, T2 bilingual Md = 32.0, T3 bilingual Md = 24.0 vs. T1 monolingual Md = 20.0, T2 monolingual Md = 32.0, T3 monolingual Md = 24.0) over the reference time. Comparable outcomes were obtained for the all-rounder groups as Figure 5.1.16b demonstrates. For the pretest T1, medians in the bilingual group Md = 24.0 and in the monolingual group Md = 22.0 differed slightly but became equal for the remaining testing times in the posttest (T2 bilingual Md = 34.0 vs. monolingual Md = 36.0) and the follow-up (T3 bilingual Md = 28.0 vs. monolingual Md = 28.0). Tendencies in the intervention point to an increased short-term knowledge in favor of the monolingual group. This was not detectable eight to ten weeks later. A different picture emerged within the science-oriented groups as can be seen in Figure 5.1.16c. Although pretest results obtained similar outcomes for both groups (T1 bilingual Md = 24.0, monolingual Md = 20.0), in the posttest (T2 bilingual Md = 32.0 vs. monolingual Md = 36.0) significance values were measured. Students who were monolingually instructed scored higher than their bilingually instructed peers. In the follow-up, these differences were not detectable (T3 bilingual Md = 24.0 vs. monolingual Md = 30.0) anymore even though the monolingual group still showed higher outcomes.



(a) Between group comparison of language-oriented groups based on language of instruction at three reference times.



(b) Between group comparison of all-rounder groups based on language of instruction at three reference times.



(c) Between group comparison of science-oriented groups based on language of instruction at three reference times. Significance values are indicated with $*p < .05$.

Table 5.1.12.: Mann-Whitney-U test table for learner types comparison based on language of instruction. Descriptive statistics, Mann-Whitney-U tests and significance values are indicated with $*p < .05$.

Learner type	**Bilingual**		**Monolingual**		***Z***	***p***	***n***
	Mean	***SD***	***Mean***	***SD***			
Language-oriented							
T1	19.87	7.18	19.6	7.37	-0.29	.774	63
T2	30.55	6.69	30.93	8.39	-0.41	.685	63
T3	24.12	9.51	25.43	9.81	-0.23	.821	61
All-rounder							
T1	21.69	8.27	22.38	8.55	-0.28	.783	269
T2	32.74	7.61	31.73	8.74	-0.75	.451	273
T3	25.81	9.95	27.07	9.33	-1.35	.178	271
Science-oriented							
T1	21.58	8.18	20.23	7.81	-0.68	.494	50
T2	29.00	9.58	34.75	6.96	-2.10	.035*	48
T3	24.62	11.13	28.25	8.32	-1.07	.284	48

5.2. Main Study Results on Intrinsic Motivation

5.2.1. Influence of the Laboratory Environment on Students' Intrinsic Motivation

Intra-group comparisons

An abbreviated version of Ryan's IMI [520] was applied to measure motivational impact of the hands-on activity within the setting. Using the IMI short form for the analysis of learners' intrinsic motivation links to already existing studies on out-of-school science settings [468, 25]. In order to investigate the influence of the instruction language as a factor present in this study, the scale on pressure due to foreign language use [26] was considered additionally to the instrument. Items of this scale were formulated in a conditional clause for the monolingual group by asking how students would have perceived the treatment if it had been in English.

Outcomes for each component of the IMI are depicted in Figure 5.2.1. The above-average means suggest a generally motivating bilingual module. Learners who participated in the one-day intervention indicated a high level of intrinsic motivation in the posttest. However, when comparing the mean scores of each group individually over the reference time, it becomes evident that activity-based intrinsic motivation decreased. Almost all sub-scales declined in their scores from posttest to follow-up. Table 5.2.4 depicts the performed Wilcoxon signed-rank tests for intra-group comparisons. With regard to the sub-scale *interest/enjoyment* students' means from the bilingual group decreased significantly from T2 (Md = 3.00) to T3 (Md = 2.67). Similar findings were obtained for the sub-scale perceived *choice* with a significant decline from posttest (Md = 2.00) to follow-up. Accordingly, the sub-scale *pressure* and the scale pressure due to foreign language use showed a significant increase over the reference time. Thus, the bilingually instructed students developed a higher pressure (T2 Md = 1.67, T3 Md = 1.67) with regard to the laboratory environment and the use of English (T2 Md = 2.00, T3 Md = 2.33) in this context. Hence, in retrospective learners experienced the learning environment as more demanding even though students' perceived competence remained similarly high over the two reference times (T2 Md = 3.00, T3 Md = 3.00).

Correspondingly, the initially high activity-based intrinsic motivation also decreased in the sub-scales of the monolingually instructed group from posttest to follow-up as illustrated in Figure 5.2.2. Again, scores in the sub-scale *interest/enjoyment* dropped significantly between T2 (Md = 3.00) to T3 (Md = 2.67). Thus, learners' initial excitement did not remain sustainable eight to ten weeks later. This was similarly true for the sub-scales perceived *choice* (T2 Md = 2.67, T3 Md = 2.33) and perceived *pressure/tension* (Md = 1.33 in the posttest, Md = 1.33 in the follow-up) where scores dropped after eight to ten weeks. Such a development was not observed for the sub-scale *competence* (Md = 3.00 in the posttest, Md = 3.00 in the follow-up) and the scale pressure due to foreign language use (Md = 2.33 in the posttest, Md = 2.17 in the follow-up) where scores remained comparable to the posttest.

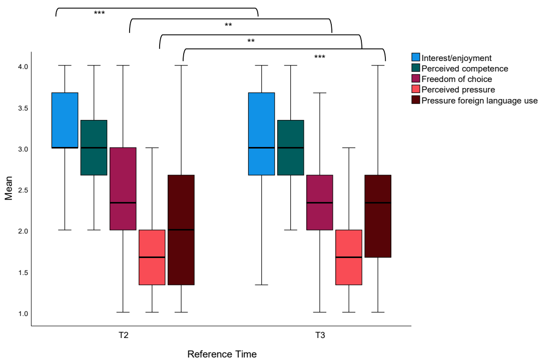


Figure 5.2.1.: Within group comparison of the sub-scales from the IMI short form [468] and the scale pressure due to foreign language use [26] for the bilingual group in the posttest and the follow-up. Significance values are indicated with $^{**}p < .01$ and $^{***}p < .001$.

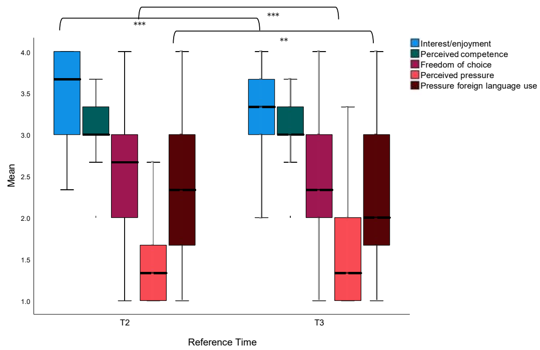


Figure 5.2.2.: Within group comparison of the sub-scales from the IMI short form [468] and the scale pressure due to foreign language use [26] for the monolingual group in the posttest and the follow-up. Significance values are indicated with $^{**}p < .01$ and $^{***}p < .001$.

Table 5.2.1.: Activity-based intrinsic motivation of bilingually and monolingually instructed group using the Wilcoxon signed-rank test at two reference times.

T2/T3	Bilingual $n = 206$		Monolingual $n = 187$	
	Z	p	Z	p
Interest/enjoyment	-5.59	$p < .001$	-3.99	$p < .001$
Perceived *competence*	-1.82	$p = .069$	-.28	$p = .778$
Perceived *choice*	-2.84	$p < .01$	-3.79	$p < .001$
Pressure/tension	-2.75	$p < .01$	-2.86	$p < .01$
Pressure due to foreign language use	-3.52	$p < .001$	-.56	$p = .576$

Spearman's ρ correlation calculations were further assessed between the sub-scales of the IMI and the scale on pressure due to foreign language use for the bilingual and monolingual group each in T2. Correlation results are depicted in Table 5.2.2 and Table 5.2.3.

With regard to the bilingual group, moderate correlations were found between the sub-scales *interest/enjoyment* and perceived *competence* (r_s= .36, $p < .01$) as well as between *interest/enjoyment* and perceived *choice* (r_s= .41, $p < .01$). As *pressure/tension* displays a negative predictor, the sub-scale negatively correlated with the remaining variables. Accordingly, negative weak correlations were found for *pressure/tension* and *interest/enjoyment* (r_s= .24, $p < .01$) and *competence* (r_s= .38, $p < .01$). Further, moderate correlations were detected between *pressure/tension* and the scale pressure due to foreign language use (r_s= -.42, $p < .01$). Thus, students who felt pressure due to foreign language simultaneously created tension towards the entire learning arrangement.

Similar correlations were obtained in the monolingual group. Again, sub-scales *interest/enjoyment* and perceived *competence* (r_s= .39, $p < .01$) as well as *interest/enjoyment* and perceived *choice* (r_s= .31, $p < .01$) correlated moderately with each other. Further, a negative correlation was obtained for perceived *interest/enjoyment* and perceived *pressure/tension* (r_s= .39, $p < .01$). Similar to the bilingual group, the sub-scales perceived *pressure/tension* and pressure due to foreign language use correlated with each other (r_s= .31, $p < .01$), indicating that students from the monolingual group, too, would have felt a higher pressure in the laboratory environment if English had been the instruction language.
In conclusion, the results in the posttest of both groups suggest relatively similar correlations between the sub-scales over time. The more the students enjoyed the activity the more competent and autonomous they felt. However, the use of English in the laboratory environment still had an impact on learners' feelings of pressure during the hands-on activity. The findings imply that activity-based intrinsic motivation was not independent from the treatment. This relation will be revised later in the discussion.

Table 5.2.2.: Spearman ρ correlation (r_s), two-sided significance for sub-scales of the IMI short form and scale pressure due to foreign language use for the bilingual group in the posttest. Moderate and high correlations are bold marked.

	Interest/ enjoyment	Perceived competence	Perceived choice	Perceived Pressure	Pressure foreign language use
Interest/enjoyment	$r_s = 1.000$	r_s **= .36**	r_s **= .41**	$r_s = .24$	$r_s = -.13$
	–	$p < .001$	$p < .001$	$p < .001$	$p= .067$
	$n = 206$	$n = 206$	$n = 206$	$n = 206$	$n = 206$
Perceived competence	r_s **= .36**	$r_s = 1.000$	$r_s = .17$	$r_s = -38$	$r_s = -.25$
	$p < .001$	–	$p < .05$	$p < .001$	$p < .001$
	$n = 206$	$n = 206$	$n = 206$	$n = 206$	$n = 206$
Perceived choice	r_s **= .41**	$r_s = .17$	$r_s = 1.000$	$r_s = -.09$	$r_s = .05$
	$p < .001$	$p < .05$	–	$p = .197$	$p = .517$
	$n = 206$	$n = 206$	$n = 206$	$n = 206$	$n = 206$
Perceived pressure	$r = .4$	r **= -.38**	$r_s = -.09$	$r_s = 1.000$	r **= -.42**
	$p < .001$	$p < .001$	$p = .197$	–	$p < .001$
	$n = 206$	$n = 206$	$n = 206$	$n = 206$	
Pressure foreign	$r_s = -.13$	$r = -.25$	$r_s = .05$	$r = -.24$	$r_s = 1.000$
language use	$p = .067$	$p < .001$	$p = .517$	$p < .001$	-
	$n = 206$	$n = 206$	$n = 206$	$n = 206$	$n = 206$

Table 5.2.3.: Spearman ρ correlation (r_s), two-sided significance for sub-scales of the IMI short scale and the scale pressure due to foreign language use for the monolingual group in the posttest. Moderate and high correlations are bold marked.

	Interest/ enjoyment	Perceived competence	Perceived choice	Perceived Pressure	Pressure foreign language use
Interest/enjoyment	$r_s = 1.000$	$r_s = \mathbf{.39}$	$r_s = \mathbf{.31}$	$r_s = .21$	$r_s = -.03$
	–	$p < .001$	$p < .001$	$p < .01$	$p = .067$
	$n = 187$	$n = 187$	$n = 187$	$n = 187$	$n = 187$
Perceived competence	$r_s = \mathbf{.39}$	$r_s = 1.000$	$r_s = .21$	$r_s = -34$	$r_s = -.12$
	$p < .001$	–	$p < .01$	$p < .001$	$p = .110$
	$n = 187$	$n = 187$	$n = 187$	$n = 187$	$n = 187$
Perceived choice	$r_s = \mathbf{.31}$	$r_s = .21$	$r_s = 1.000$	$r_s = .001$	$r_s = .03$
	$p < .001$	$p < .05$	–	$p = .984$	$p = .735$
	$n = 187$	$n = 187$	$n = 187$	$n = 187$	$n = 187$
Perceived pressure	$r = -.21$	$r = \mathbf{-.34}$	$r_s = -.001$	$r_s = 1.000$	$r = \mathbf{-.31}$
	$p < .01$	$p < .001$	$p = .984$	–	$p < .001$
	$n = 187$	$n = 187$	$n = 187$	$n = 187$	$n = 187$
Pressure foreign	$r_s = -.03$	$r = -.12$	$r_s = .03$	$r = \mathbf{-.31}$	$r_s = 1.000$
language use	$p = .730$	$p = .110$	$p = .735$	$p < .001$	-
	$n = 187$	$n = 187$	$n = 187$	$n = 187$	$n = 187$

Inter-group comparison activity-based intrinsic motivation in the posttest

Learners' motivational ratings with regard to the laboratory environment were selected in the posttest and the follow-up. The ratings of the posttest are indicated in Table 5.2.4. Significance values were detectable for the four scales of the IMI short form between the bilingual and monolingual group. The high means in the sub-scale on perceived *interest/enjoyment* confirmed an overall positive view of the day independent of the language of instruction as Figure 5.2.3 reveal. With regard to the treatment, students who were instructed in their school language, experienced the intervention as more joyful than their bilingually instructed peers (U = 15,174.00, $p < .001$, $r = 0.19$, Mann-Whitney-U). Similar results were obtained for the scales perceived *competence* (U = 16,305.5, $p < .01$, $r = 0.14$, Mann-Whitney-U) and perceived *choice* (U = 15,998.00, $p < .01$, $r = 0.16$, Mann-Whitney-U). *Pressure/tension* on the other hand was higher among the bilingual students (U = 15,882.00, $p < .01$, $r = 0.16$, Mann-Whitney-U). Surprisingly, learners from the monolingual group indicated to have had a higher feeling of pressure if the intervention had been in English. Yet, the findings were not significant (U = 16,278.00, $p = .100$, Mann-Whitney-U). As the means of both groups ranged in the lower field, it can be assumed that the use of the foreign language within the context of the laboratory module was adequate for the setting.

Table 5.2.4.: Means (M) and standard deviations (SD), range, median of the IMI short-form sub-scales and scale pressure due to foreign language use in the posttest, $n = 393$. Significance values are indicated with $^{*}p < .05$, $^{**}p < .01$ and $^{***}p < .001$.

			Mean	*SD*	Median	Range	*n*
IMI short form	interest/enjoyment***	bilingual	3.24	.578	3.00	3	206
		monolingual	3.46	.525	3.67	2.67	187
	perceived competence**	bilingual	2.94	.649	3.00	3	206
		monolingual	3.14	.498	3.00	2.33	187
	perceived freedom of choice**	bilingual	2.39	.680	2.33	3	206
		monolingual	2.63	.661	2.67	2	187
	pressure/tension**	bilingual	1.67	.655	1.67	3	206
		monolingual	1.47	.477	1.33	2.67	187
Additional instrument	pressure foreign language use	bilingual	2.09	.797	2.00	3	206
		monolingual	2.26	.877	2.33	3	175

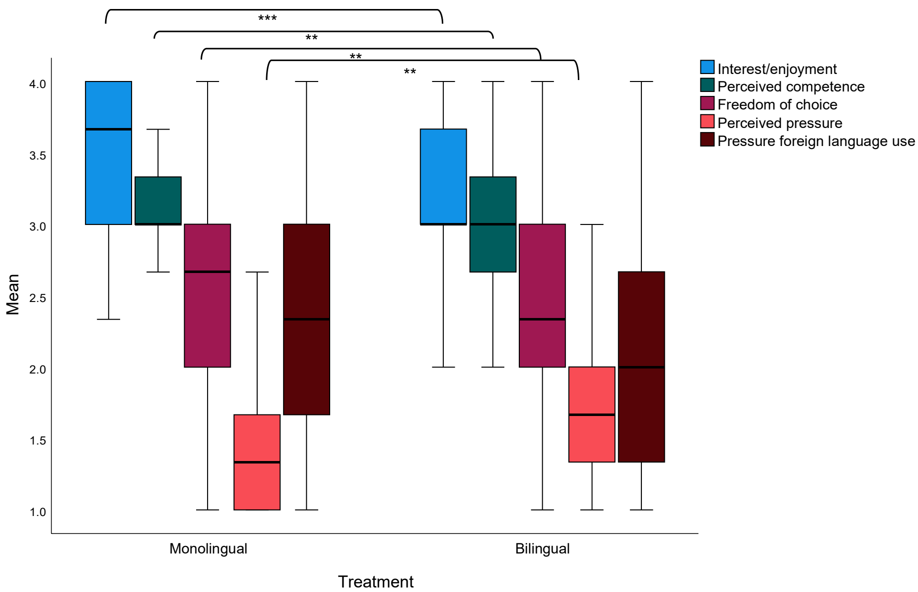


Figure 5.2.3.: IMI short-form sub-scales interest/enjoyment, perceived competence, perceived choice, perceived pressure and the scale pressure based on the language of instruction for the bilingual and monolingual groups in the posttest. Significance values are indicated with $^{**}p < .01$ and $^{***}p < .001$.

Inter-group comparison activity-based intrinsic motivation in the follow-up

The same procedure was repeated for the follow-up in order to understand what retention effects the intervention caused on learners' activity based intrinsic motivation with regard to the instruction language. The outcomes as presented in Table 5.2.5 suggest that means in the bilingual group dropped significantly higher compared to the monolingually instructed learners eight to ten weeks later (Figure 5.2.4). Hence, the bilingual groups' means decreased stronger for the sub-scale *interest/enjoyment* (U = 14,350.00, $p < .001$, r = 0.21 Mann-Whitney-U), perceived competence (U = 16,734.00, $p < .05$, r = 0.10 Mann-Whitney-U) as well as for the sub-scale perceived *choice* (U = 16,750.00, $p < .05$, r = 0.10 Mann-Whitney-U). For the sub-scale *pressure/tension*, learners who were monolingually instructed would have felt in retrospective even less tense due to the laboratory instruction if the module had been in English (U = 15,742.00, $p < .01$, r = 0.15 Mann-Whitney-U).

Table 5.2.5.: Means (M) and standard deviations (SD), range, median of the IMI short-form sub-scales and the scale pressure due to foreign language use in the follow-up, n = 393. Significance values are indicated with *$p < .05$, **$p < .01$ and ***$p < .001$.

			Mean	*SD*	Median	Range	*n*
IMI short form	interest/enjoyment***	bilingual	3.03	.668	3.00	3	206
		monolingual	3.3	.509	3.33	2.67	184
	perceived competence*	bilingual	3.01	.659	3.00	3	206
		monolingual	3.15	.545	3.00	3	184
	perceived freedom of choice*	bilingual	2.25	.638	2.33	3	206
		monolingual	2.40	.642	2.33	2	184
	pressure/tension**	bilingual	1.79	.672	1.67	3	206
		monolingual	1.59	.544	1.33	3	184
Additional instrument	pressure foreign language use	bilingual	2.24	.813	2.33	3	206
		monolingual	2.32	.924	2.17	3	182

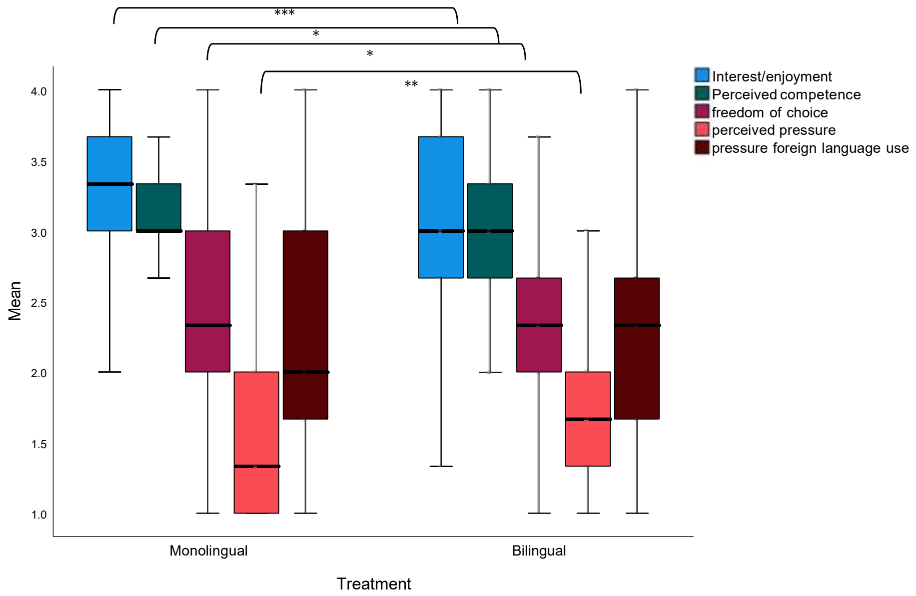


Figure 5.2.4.: IMI short-form sub-scales interest/enjoyment, perceived competence, perceived choice, perceived pressure and the scale pressure based on the language of instruction for the bilingual and monolingual groups in the posttest. Significance values are indicated with $*p < .05$, $**p < .01$ and $***p < .001$.

5.2.2. Predictors of Students' Activity-Based Intrinsic Motivation

To examine the relationship of students' activity based intrinsic motivation in chemistry with other independent variables, a multiple linear regression was performed for the posttest following the procedure of Röllke et al. [521]. Descriptive statistics (M and SD) as well as correlations (Pearson's r) were first calculated as depicted in Table 5.2.6. With regard to learners' perceived *competence*, statistically significant correlations were obtained between the remaining variables indicating that students' *interest/enjoyment*, perceived *choice*, the instruction in their school language and better grades in chemistry lead to a higher perception of *competence*. The same was true for the sub-scale perceived *choice* although students' chemistry grades did not correlate with the variable. With regard to the instruction language, negative correlations were obtained (monolingual = 0; bilingual = 1) with the variables of motivation. Thus, the monolingual treatment lead to a higher feeling of motivation. Overall, correlations were measurable between all variables and students' intrinsic motivation in chemistry.

Table 5.2.6.: Descriptive statistics and bivariate correlations between variables of motivation and independent variables for all students in the posttest. Significance values are indicated with $^{**}p < .01$ and $^{*}p < .05$.

	M	*SD*	1	2	3	4	5
1 Interest/enjoyment	3.58	.56	1.00				
2 Perceived competence	3.04	.59	.40**	1.00			
3 Perceived choice	2.61	.68	.38**	.23**	1.00		
4 Grade chemistry	2.39	1.07	-.16**	-.12*	.04	1.00	
5 Instruction language	–	–	-.19**	-.17*	-.18**	.08	1.00
6 Intrinsic motivation chemistry	2.84	.68	.41**	.28**	.21**	-.48**	-.11*

In a second step, a multiple linear regression was conducted to test the predictors for intrinsic motivation in chemistry. The model explained a statistically significant amount of variance in intrinsic motivation $F(5{,}349) = 38.67$, $p < .001$, $R^2 = .36$. Findings from the multiple linear regression are illustrated in Table 5.2.7. Students' perceived *competence*, *interest/enjoyment* and *freedom choice* were predictors of intrinsic motivation. Further, an increase in intrinsic motivation corresponded with better grades in chemistry ($B = -0.27$). Language of instruction did not predict learners' intrinsic motivation in chemistry.

Table 5.2.7.: Results of the linear regression model examining the predictors of intrinsic motivation. Significance values are indicated with $^{**}p < .01$ and $^{*}p < .05$.

Variable	β	*SE*	*t*	*p*
Interest/enjoyment	0.30	0.25	4.96	.001
Perceived competence	0.13	0.11	2.36	.019
Perceived choice	0.09	0.09	1.91	.047
Grade chemistry	-0.26	-0.42	-9.63	.001
Instruction language	-0.01	-0.01	-0.23	.819

The regression model explained 36% of the variablility of students' intrinsic motivation in the LMU*chemlab*. The variable was mainly determined by the positive predictors from the IMI short-form as well as students' prior grades in chemistry.

5.3. Main Study Results on Learners' Self-concept in Chemistry

5.3.1. Self-concept Dependence based on the Identified Cluster Types

Controlling for preconditions in the bilingual group

Impact on students' chemistry self-concept was examined by taking learners' dispositions into consideration. To indicate previous differences based on the identified learner types, a Kruskal-Wallis test was conducted from the results of the pre-pretest. There were no statistically significant differences detectable prior the intervention $H(2) = 5.61$, $p = .060$ ($Md = 2.0$ language-oriented vs. $Md = 3.0$ all-rounder vs. $Md = 3.0$ science-oriented).

Intra-group differences based on the identified learner-types in the bilingual group

Subsequently, intra-group differences were assessed based on the identified learner types. A Friedman's test for repeated measures was applied. Z-scores and significance values for each learner-type are illustrated in Table 5.3.1. At first glance, Figure 5.3.1 suggests no changes within each cluster in the chemistry self-concept. No significant differences were detected for the language-oriented group over the reference period $(X^2)_F(2) = 0.25$, $p = .880$. Hence, students from cluster 1 could not increase their self-concept in chemistry from pretest (T1 $Md = 2.0$, T2 $Md = 2.0$) to follow-up ($Md = 3.0$). The same was true for the all-rounder group $(X^2)_F(2) = 5.89$, $p = .053$. Learners' self-concept did not change from pretest to follow-up (T1 $Md = 3.0$, T2 $Md = 3.0$, T3 $Md = 3.0$). Likewise, no significant changes were detected for the science-oriented group, as scores remained similar over the testing period $(X^2)_F(2) = 0.43$, $p = .805$.

Table 5.3.1.: Chemistry self-concept with regard to the identified learner types using the Wilcoxon signed-rank test for the bilingual group at three reference times.

	T1/T2		*T1/T3*		*T2/T3*	
	Z	p	Z	p	Z	p
language-oriented $n = 33$	-1.04	$p = .298$	-.86	$p = .391$	-.58	$p = .558$
all-rounder $n = 131$	-.58	$p = .562$	-1.86	$p = .062$	-1.45	$p = .146$
science-oriented $n = 37$	-.27	$p = .783$	-.69	$p = .490$	-.72	$p = .470$

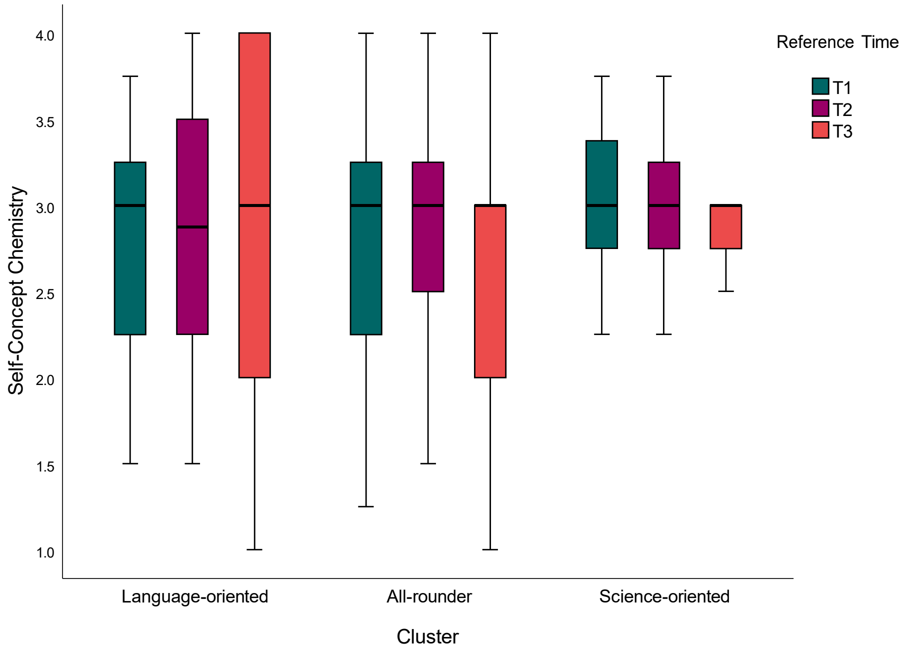


Figure 5.3.1.: Intra-group comparison of the three learner types in the bilingual group at three reference times.

Inter-group differences based on the identified learner-types in the bilingual group

To measure inter-group differences, a Kruskal-Wallis test series was performed on students' self-concept based on the learner-types (Figure 5.3.2). Again, the findings suggest no significant differences between the three learner types ($H(2) = 0.65$, $p = .723$) measurable in the pretest. Likewise, all learner-types scored similarly high immediately after the treatment ($H(2) = 0.21$, $p = .899$) and in the follow-up ($H(2) = 2.89$, $p = .236$). The results suggest that the bilingual intervention neither had any significant effects on different learner-types, in particular, nor did the bilingual intervention in general influence learners' self-concept in chemistry.

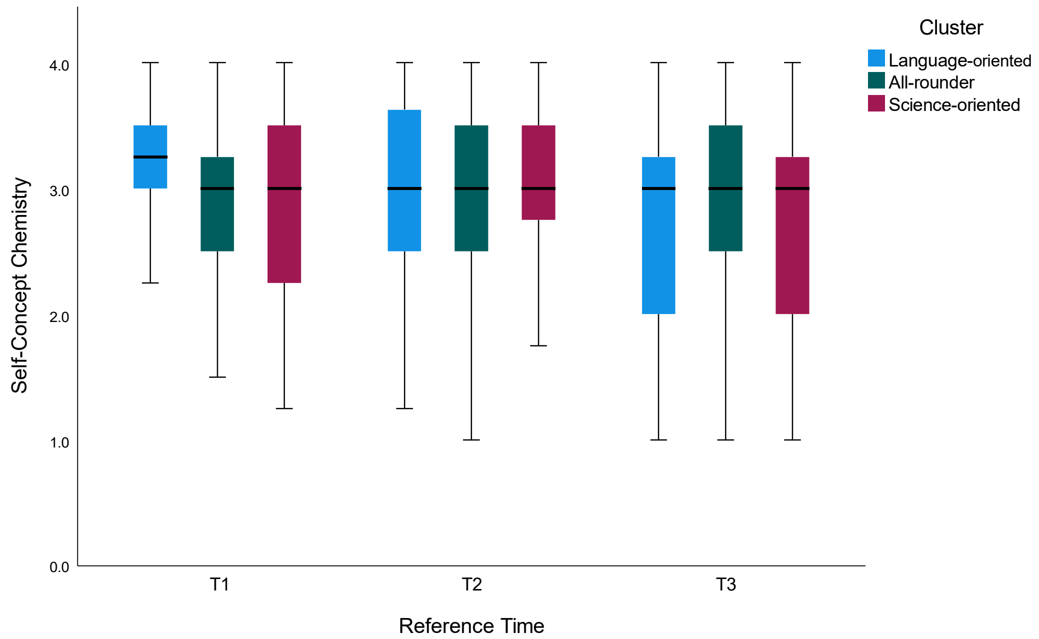


Figure 5.3.2.: Inter-group comparison of the three learner types in the bilingual group at three reference times.

Controlling for preconditions in the monolingual group

The same procedure was applied in the monolingual group. Preconditions were explored to exclude differences before the intervention in the pre-pretest. A Kruskal-Wallis test showed that students' self-concept in chemistry differed significantly between the three learner types where learners from the language-oriented group showed lowest scores in their chemistry self-concept ($H(2) = 9.31$, $p < .01$). The Bonferroni post-hoc test indicated significant differences between the language-oriented group and the all-rounder (U = 1,056500, $p <$ .001) as well as between the language-oriented group and the all-rounder (U = 125,000.00, p $<$ .001). These differences were considered for further calculations.

Intra-group differences based on the identified learner-types in the monolingual group

To calculate intra-group differences with regard to the identified learner-types in the monolingual group, a Friedman's test was conducted. Table 5.3.2 depicts the Z-scores and significance values between the reference times for the monolingual group. For the language-oriented group, the repeated measure did not reveal any statistically significant changes on learners' self-concept over the reference time (T1 $Md = 3.0$, T2 $Md = 3.0$, T3 $Md = 3.0$) $(X^2)_F(2) =$ 1.23, $p = .540$. For the all-rounder group T1 $Md = 3.0$, T2 $Md = 3.0$, T3 $Md = 3.0$), the output was similar as there was also no statistically significant changes in their self-concept $(X^2)_F(2) = 2.45$, $p = .291$. Situation was different for the science-oriented group. There, significance values were obtained within the three reference times $(X^2)_F(2) = 10.78$, $p < .001$. After a slight increase in T2, learners' self-concept in chemistry decreased significantly in T3 (T1 $Md = 2.86$, T2 $Md = 3.12$, T3 $Md = 2.71$) as illustrated in Figure 5.3.3. Students from the science-oriented group could increase their chemistry self-concept due to the treatment for a short period of time.

Table 5.3.2.: Chemistry self-concept with regard to the identified learner types using the Wilcoxon signed-rank test for the monolingual group at three reference times.

	T1/T2		*T1/T3*		*T2/T3*	
	Z	*p*	*Z*	*p*	*Z*	*p*
language-oriented $n = 33$	-.53	$p = .595$	-.96	$p = .319$	-1.52	$p = .128$
all-rounder $n = 131$	-1.41	$p = .160$	-.16	$p = .875$	-1.57	$p = .117$
science-oriented $n = 37$	-2.25	$p < .05$	-.96	$p = .339$	-2.15	$p < .05$

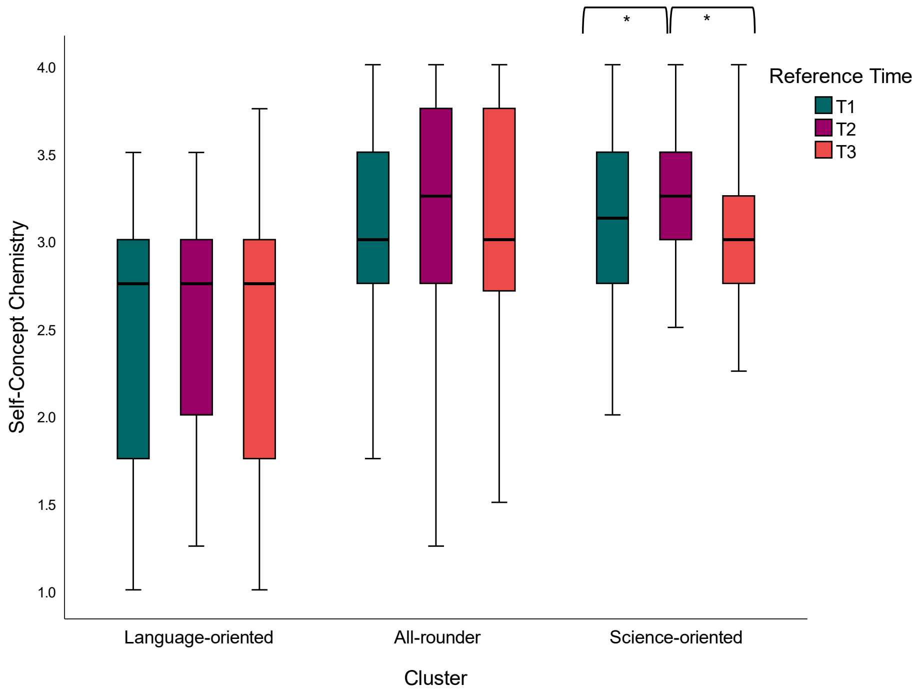


Figure 5.3.3.: Intra-group comparison of the three learner types in the monolingual group at three reference times. Significance values are indicated with $*p < .05$.

Inter-group differences based on the identified learner-types in the monolingual group

Inter-group differences with regard to the three learner types were assessed by using a Kruskal-Wallis test. The output in T1 was similar among all learner types ($H(2) = 1.11$, $p = .573$) and resembled the results from T2 ($H(2) = 4.39$, $p = .111$). Even though the science-oriented group showed an increased self-concept after the intervention, findings were not significant between the three clusters. Likewise, no significant values were detectable in the follow-up ($H(2) = .76$, $p = .682$). Thus, students with a science disposition scored highest among all learner-types but there were overall no significant effects detectable in this regard.

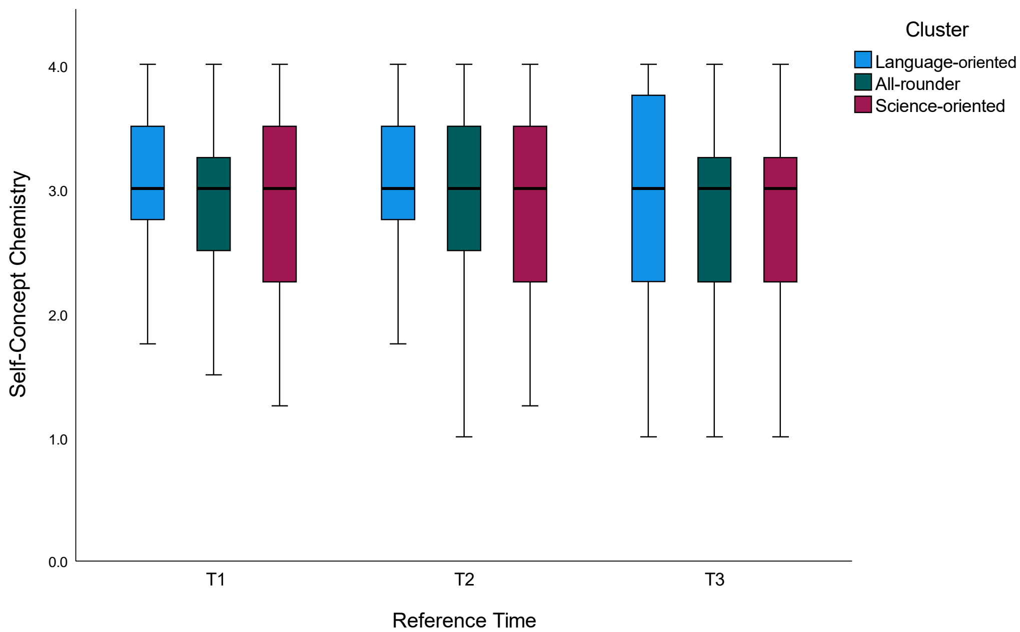


Figure 5.3.4.: Inter-group comparison of the three learner types in the monolingual group at three reference times.

5.3.2. School-Based Preparation and Post-Enhancement Impact in the Bilingual Setting

Controlling for preconditions

Research question F3.2 aimed at examining the impact of a school preparation and follow-up of the bilingual module on students' chemistry self-concept. To test for precondition differences, a Mann-Whitney-U test was performed. There were no significance values detectable before the intervention (Md = 3.00 in the bilingual group vs. Md = 3.00 in the prepared bilingual group, U = 3,362.5, p = .481, Mann-Whitney-U). Further, to exclude influences in these groups, differences with regard to the grade in English, elective module and self-concept in English were assessed. Again, no prior differences with regard to these variables were measurable which allowed continuing with the analysis.

Self-concept intra-group analysis for both treatment groups (bilingual vs. prepared bilingual group)

Comparing the findings on students' self-concept in chemistry, Friedman's test for repeated measures remained insignificant between the two bilingual treatment groups at four reference times: T0 (Md = 3.0), right before the intervention T1 (Md = 3.0), after the laboratory program T2 (Md = 3.0) and after an eight to ten weeks follow-up T3 (Md = 3.0) $(X^2)_F(3)$ = 2.59, p = .459. Thus, although learners showed an all-time high self-concept in chemistry, scores remained similar over the intervention. Subsequently, Wilcoxon signed-rank tests were deployed. The results are presented for both groups in Table 5.3.3 and Figure 5.3.5 and 5.3.6.

Outcomes of the prepared bilingual group were similar to the unprepared group. Again, Friedman's test for repeated measured did not show any significant changes with regard to students' self-concept in chemistry (T0 Md = 3.0, T1 Md = 3.0, T2 Md = 3.0, T3 Md = 3.0) over the four reference times $(X^2)_F(3)$ = 4.32, p = .229. Thus, a prolonged exposure to the bilingual intervention did not lead to any statistically significant changes with regard to students' chemistry self-concept.

Table 5.3.3.: hemistry self-concept of bilingual and prepared bilingual instructed group using the Wilcoxon signed-rank test at three reference times.

Instruction language	*T1/T2*		*T1/T3*		*T2/T3*	
	Z	p	Z	p	Z	p
bilingual n = 82	-.4252	p = .671	-.975	p = .330	-.902	p = .367
Prepared bilingual n = 124	-.809	p = .419	-1.79	p = .073	-1.89	p = .058

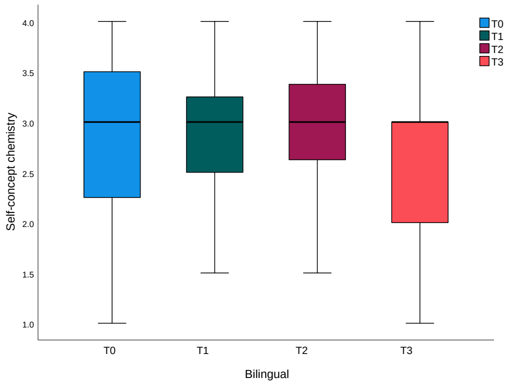


Figure 5.3.5.: Within group comparison of students' self-concept chemistry for the bilingual group at four reference times.

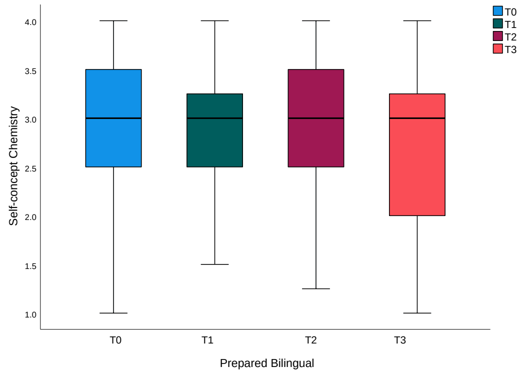


Figure 5.3.6.: Within group comparison of students' self-concept chemistry for the prepared bilingual group at four reference times.

Self-concept inter-group analysis for both treatment groups (bilingual vs. prepared bilingual group)

As a within group comparison already indicated similar outcomes (see Figure 5.3.3) on students' chemistry self-concept in both treatments, between group calculations were only restricted to a MWU test. Again, both groups showed similar scores for self-concept in chemistry over the four reference times (T0: U = 5,080.5, p = .887, T1: U = 4877.00, p = .618, T2: U = 5,073.00, p = .979, T3: U = 4,746.5, p = .698, Mann-Whitney-U). A prolonged exposure to a bilingual environment therefore did not lead to an increase of students' self-concept in chemistry as will be discussed later in this work.

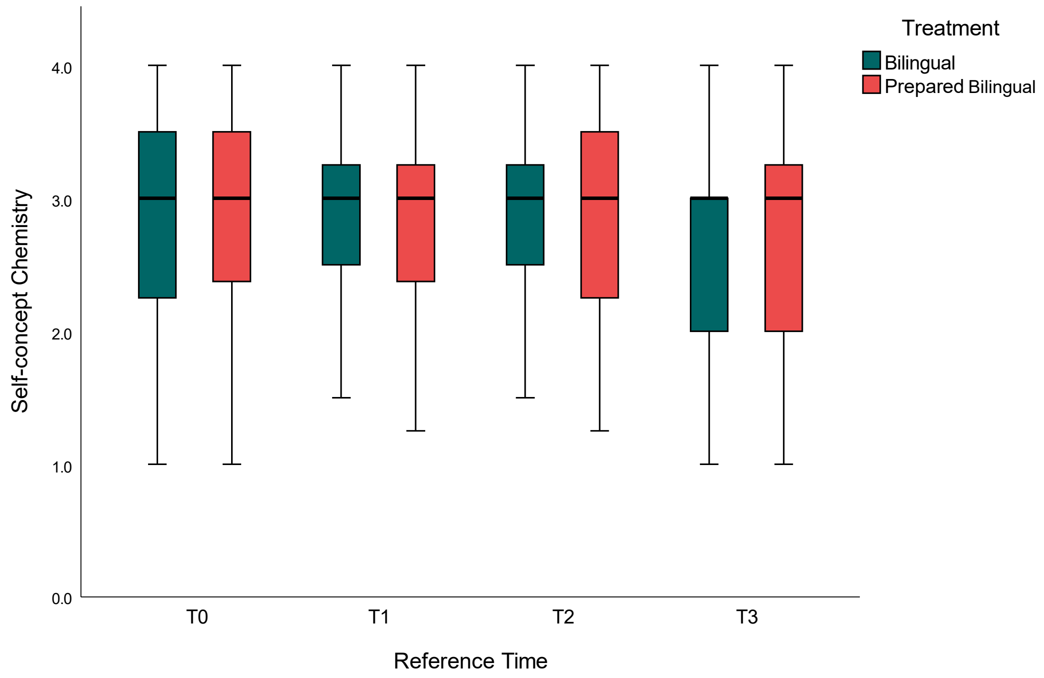


Figure 5.3.7.: Between group comparison of students' self-concept chemistry for prepared bilingual group and bilingual group at four reference times.

With regard to the collected experience on bilingual education, there were no correlations in both groups with the self-concept chemistry implying that students' self-concept was independent from prior bilingual teaching experience.

5.3.3. Predictors of Self-Concept Outcomes

The relationship between gender and instruction language with students' chemistry self-concept

Research question F3.3 examined the influence of different predictors on students' chemistry self-concept. A multiple linear regression was assessed to analyze the relationship of the construct with students' gender, grades in chemistry and English, instruction language and self-concept in English. Table 5.3.4 summarizes the descriptive statistics and correlations of the predicting variables on students' self-concept in chemistry. Learners' grades in chemistry and English both significantly negatively correlated with the gender and with each other. Thus, better grades in chemistry and English were rather found among girls and at the same time grades corresponded with each other with higher grades in English lead to higher grades in chemistry and vice versa. Accordingly, correlations of both self-concepts suggest an influence by the corresponding grades.

Table 5.3.4.: Descriptive statistics and bivariate correlations between variables of sel-concept and independent variables for all students in the posttest T2. Moderate correlations are indicated with $^{**}p < .01$.

	M	*SD*	1	2	3	4	5
1 Gender (0 = male, 1 = female)	-	-	-				
2 Grade chemistry	2.39	1.08	-.14**	1.00			
3 Grade English	2.49	.88	-.15**	-.21**	1.00		
4 Instruction language (0 = monolingual, 1 = bilingual)	-	-	.02	.08	-.04	1.00	
5 Self-concept English	2.95	.83	.07	.03	.-.64**	-.07	1.0
6 Self-concept chemistry	2.95	.71	-.05	-.51**	-.06	-.09	.01

Subsequently, a multiple linear regression was applied on the tested variables. A significant regression equation was found (F(5, 377) = 30.99, $p < .001$), with an R^2 of .29, for gender and grade in chemistry. Hence, these hypothesized predictors can be confirmed as predictors of students' self-concept in chemistry in this model (5.3.5). Language of instruction however, was not found to have an impact on learners' self-concept. Consequently, students' grades and self-concept in English also did not predict self-concept in chemistry.

Table 5.3.5.: Results of the linear regression model examining the predictors of self-concept in chemistry. Significance values are indicated with $^{***}p < .001$ and $^{**}p < .01$.

Variable	β	*SE*	*t*	*p*
Gender	-0.13	0.06	-2.87	.004**
Grade chemistry	-0.55	0.03	-11.96	.001***
Grade English	0.08	0.05	1.37	.172
Instruction language	-0.04	0.06	-0.85	.397
Self-concept English	0.07	0.05	1.21	.227

Overall, the model explains 30% of the relationship where only grades in chemistry and gender predicted the variability of students' chemistry self-concept.

5.4. Side Study Results

Descriptive statistics

The average age of all participating students was 16.6 years. In the Arabic-speaking monolingual group, 70% of the students were girls; in the Arabic-speaking CLIL group, only 26% of the participants were boys, indicating an uneven distribution in the Arabic-speaking CLIL group. A similar relation was present in both Hebrew-speaking groups. About 56% of the students in the Hebrew-speaking monolingual group were girls, whereas in the Hebrew-speaking CLIL group, 75% were girls. All participants were enrolled in an advanced chemistry course. Regarding the question of whether any of the students had had prior experience with bilingual education, 6.45% of the Arabic-speaking monolingual group stated that they had attended at least a one-year bilingual program. Likewise, 6.78% in the Arabic-speaking CLIL group had had experience with bilingual teaching. In the Hebrew-speaking groups, 6.06% of the CLIL group and 5% of the monolingual group stated that they had attended some form of bilingual education for at least one year. In the Hebrew-speaking monolingual group, 29.2% of all students indicated that they had spent at least six months abroad in an English-speaking country; in the Hebrew-speaking CLIL group, 12.5% indicated this. Only 6.7% of all Arabic-speaking students had been abroad for over six months; none of them were in the CLIL group.

5.4.1. Cognitive Achievement

Instruction language impact

Average cognitive achievement score with respect to the language of instruction was analyzed right before and after the treatment. Overall comparisons between the monolingual and the CLIL groups were examined with a one-factorial ANOVA and indicated no differences in the pretest based on the language of instruction ($F(1{,}195) = .808$; $p = .370$). Similar results were obtained in the posttest ($F(1{,}193) = 1.943$; $p = .165$). Dependent t-tests were assessed to investigate changes within the CLIL and monolingual groups in cognitive achievement between the two reference times. The findings from the t-test for the CLIL groups pointed to statistically significant differences between the two reference times ($t(90) = -5.78$; $p < .001$, $r = 0.52$). Although slightly higher, the outcomes revealed by the dependent t-test were similar to the outcomes in the monolingual groups ($t(103) = -7.34$; $p < .001$, $r = 0.59$).

Treatment Group Impact

Taking the treatment groups into consideration, a repeated measure ANOVA (pre, post) x 2 (Arabic, Hebrew) x (monolingual, CLIL) indicated statistically significant differences between pretest and posttest for both CLIL groups and both monolingual groups (Hebrew-speaking, Arabic-speaking), as interaction effects confirmed ($F(1{,}190) = 74.11$; $p < .001$, $\eta_p = .28$). Figure 5.4.1 presents the results of the pretest and posttest scores in cognitive achievement and the calculated knowledge gain. Further, to investigate differences between the groups, Scheffé post-hoc tests were conducted for both reference times. The measurement did not reveal any significant differences with respect to the treatment. Consequently, the findings point to a similar knowledge gain independent of the language of instruction. Knowledge

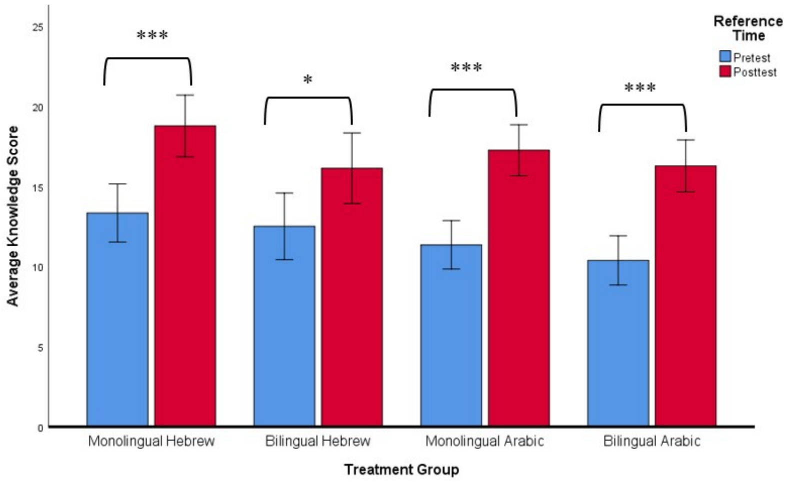


Figure 5.4.1.: Average knowledge score for all treatment groups from the side study. Significance values are indicated with *$p < .05$ and ***$p < .001$.

gain in the Hebrew-speaking CLIL group ($t(33) =$ -2.03, $p < .05$, $r = 0.34$), however, was lower in the posttest compared to the gain in the Hebrew-speaking monolingual group ($t(41)$ = -5.69; $p < .001$, $r = 0.66$). For the Arabic-speaking monolingual group ($t(61) =$ -5.16; $p <$ .001, $r = 0.55$) as well as for the Arabic-speaking CLIL group ($t(58) =$ -6.21; $p < .001$, $r =$ 0.64), statistically significant changes were measured between the pre- and posttest. The values of the effect sizes (Pearson's r) were large for the three remaining groups and medium for the Hebrew-speaking CLIL group.

5.4.2. Motivational outcomes

To assess motivational effects in the subject of chemistry based on the language of instruction, a repeated measure ANOVA was conducted. Although a decrease in the intrinsic motivation was measured for both CLIL groups after the posttest ($t(92) = 1.98$, $p = .051$), the changes were not significant. Likewise, the motivation of students who received the treatment in their school language slightly increased but the effects were not significant ($t(102) =$ -.381; $p = .704$). For the extrinsic motivation in chemistry, the CLIL groups' motivation decreased after the treatment ($t(92) = .443$, $p = .659$), while the monolingual groups showed a marginal increase ($t(102) =$ -.767; p =.445). The changes in motivation in chemistry were measured in the treatment groups for both reference times. Six students were excluded from these calculations. The repeated measure ANOVA on the extrinsic motivation in chemistry did not reveal any interaction effects between treatment group and reference time (F(1,190) = 0.154; $p = .695$). Nonetheless, a slight increase was detected after the treatment for both of the Hebrew-speaking groups and for the Arabic-speaking

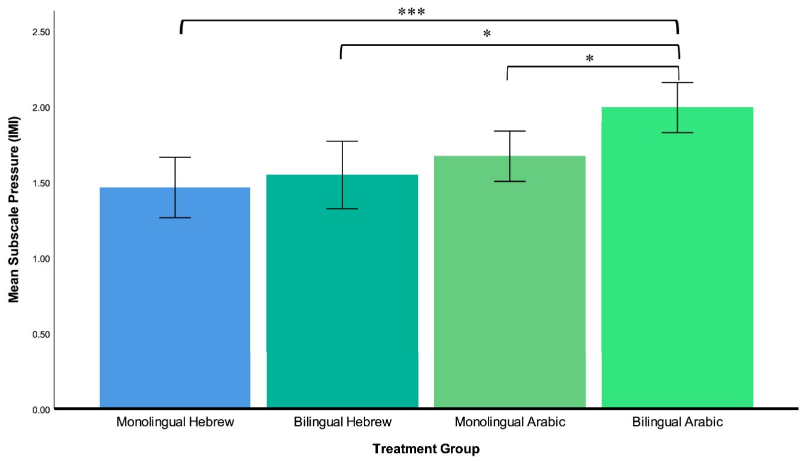


Figure 5.4.2.: Mean ratings on the sub-scale of perceived *pressure* (IMI) due to laboratory work. One-factorial ANOVA in the posttest indicating significance values with $*p < .05$ and $***p < .001$.

monolingual group. The extrinsic motivation of the Arabic-speaking CLIL students, however, decreased after the treatment. A similar picture can be observed for the intrinsic motivation in chemistry where, again, no statistically significant changes were found. Likewise, intrinsic motivation in chemistry decreased in the Arabic-speaking CLIL group ($t(60)$ = -2.49; $p < .05$).

Independent t-tests on the short scale of the IMI in the posttest indicated significance effects for the pressure sub-scale ($t(92)$ = -2.71; $p < .01$, $r = 0.19$) based on the language of instruction. However, the values for the sub-scales on competence, importance and enjoyment were similar in both groups, although marginally higher in the monolingual groups. Pressure based on foreign language use correlated with the pressure sub-scale from the IMI, pointing to a medium-to-strong relation between the two scales (r =.38, $p < .01$). Accordingly, with respect to the treatment, a one-factorial ANOVA was conducted to investigate group differences. The findings indicate between-group differences for the pressure sub-scale (F(3,191) = 6.405; $p < .001$) as depicted in Figure 5.4.2 and perceived choice sub-scale (F(3,191) = 4.54; $p < .01$). Levene's test of equality of variances produced non-significant results for pressure (F = 1.340; p = .263) and perceived choice (F = 2.618; p = .052).

6. Discussion and Limitations

This study investigated cognitive and affective effects of a bilingual module in a science lab for school students. Although prior research proved the potential of science outreach settings in general, little is known about their influence with regard to the authentic English language use in a scientific context. The present work therefore links to former studies that examined the impact of similar learning environments [14, 12, 15, 81, 272] and ties to those works with a focus on bilingual instruction [25, 26, 214] aiming at contributing to the yet small corpus in this particular field. The study was conducted at the LMU*chemlab* and examined the constructs cognitive achievement, activity-based intrinsic motivation and students' chemistry self-concept in a bilingual learning environment.

In the following, the discussion begins with a critical reflection of the research methodology and the measuring instruments applied in this study. Thereupon follows the discussion of the outcomes according to the stated research focuses and their underlying research questions. xplanations are based on the introduced theoretical framework earlier in this work. Furthermore, the findings will be compared to prior studies on science lab for school students in general as well as on bilingual science settings.

6.1. Discussion Research Methodology

6.1.1. Quality of the Measuring Instrument

In this section, the used testing instruments will be discussed according to their explanatory power. The here presented research work were executed as a quantitative study, and questionnaires had been the only method deployed. By restricting research to only quantitative methods, the validity might be questioned as it misses a verification that the supplementary application of a qualitative study might bring with [522]. Another disadvantage that the single use of questionnaires inherits might be due to the missing depth and the pre-determined answers that leave no room for a more concrete interpretation of the findings [523]. However, advantages of a quantitative study lie in their generalizability as the use of statistical methods allow to draw comparisons between groups [524]. Further, the analysis does not rely on subjective interpretations [525].

6.1.2. Setting and Experimental Design

The present study followed a quasi-experimental research design approach. The study refrained from a randomized assignment of the participants to specific treatment groups due to the heterogeneous nature of school classes. However, such groups develop with the premise of varying conditions that do not allow a controlled setting since a pure sample under laboratory conditions with school students is hardly to reach [526]. Even though classes were assigned to each treatment independent to the school's background that to some extent (with respect to the secondary school's electives on languages, sciences or humanities) determines the learners' preferences, school classes as such cannot hold to the standards of a true experimental design. This is followed by the difficulty to find a representative control group as was renounced in former studies on science labs for school students [25]. Other than in true experimental-designs, the evaluation of the study might suffer from a lowered internal validity or due to a confounding bias that might lead to unreliable results as not all factors could be controlled for. However, the study design as such is easy to repeat and allows a more generalizable view on the outcomes. All questionnaires had been formulated in the students' school language in order to avoid translation difficulties that could alter the objectivity of the test. The setting itself was structured equally in the monolingual and the bilingual treatment. Working sheets have been translated into English but only the bilingual treatment provided additional supporting sheets with the translation and meaning of relevant technical terms with the goal to facilitate communication during the hands-on activity.

In order to maintain similar conditions independent of the group, one part of the supervisors were employed student associates who were deployed for the instruction within the laboratory during the ongoing study. Such a consistency in instruction allowed for a stronger comparability between the experimental groups. However, the module was also embedded in a seminar for pre-service teaching students who were assigned to the supervision. All instructors first received a theoretical introduction to each experimental station which covered the scientific background of the module. This was followed by two units of practical exercises that ensured the correct handling of the equipment and the execution of the experiments. All teaching students were allocated to only two experimental stations assuring their expertise on the scientific background and handling of the equipment. Furthermore, contents and sequences within each of the experimental stations were regulated through preconceived scripts. These interview guidelines promoted an equal instruction process independent of the treatment as an identical wording was pursued. It also helped to lower confounding variables thereby raising the internal validity of the study. The use of similar constructs aimed at a higher comparability of the studies which ultimately contributes to a better understanding of such interventions.

This work followed the type of a multiple pretest/ posttest and follow-up design where the factor on the preparation work was controlled over the pre-pretest meaning that students that received a non-school embedded treatment also had to fill in this first questionnaire to attribute knowledge differences due to the video preparation. Since nanotechnology is not included into the Bavarian syllabus [230], the knowledge gain in the pre-test cannot be drawn back to chemistry classes during the testing period. As most variables were sampled over all four points of measurement, it could be expected that due to the rising fatigue level missing values would increase [527]. This has not been found to be the case and is in line with the outcomes of Steyn's study [527]. Neither was found that a decrease in students' performance was measured in the course of the testing period.

6.1.3. Quality of the Test Items

The construct validity is a measurement for the accuracy of the used instruments to test the stated hypotheses [528]. Almost all of the introduced and deployed scales on affective constructs were applied in former studies and have been either inherited precisely [14, 15, 25, 26, 468, 81, 124, 310] to the present study or have been modified accordingly [12, 480, 365, 485, 14, 469]. In both cases, reliability have been measured and adjusted to meet the requirement of a valid construct. Newly developed scales underwent a factor analysis and were afterwards also tested for reliability. In the case of the knowledge test, a Rasch analysis has been calculated. Items that didn't meet the requirement as their were recognized as either too easy or to difficult (lower than .2 and higher than .9) were excluded from the questionnaire. Furthermore, inter-item correlation coefficient that determines the reliability and variance of a test [529] as well as coefficient of discrimination were also adjusted accordingly. Overall, reliability of the majority of scales showed Cronbach's alpha values between sufficient .6 to very high .95 and could be considered as a measure for internal consistency of scales [530]. Even though Cronbach's alpha values are commonly used for determining the quality of the instrument [490], scales with values $\leq .6$ had been still considered into the analysis since a good instrument is not only restricted to its reliability [531] and can be seen as valid in particular cases [532].

6.2. Discussion Main Study Hypothesis Testing

The study pursued three research foci all examined in Chapter 5. Following the structure of this thesis, the discussion first begins with the research focus on cognitive achievement (1). Subsequently, the results from research focus (2) on students' activity-based intrinsic motivation and the outcomes from students' chemistry self-concept (3) will be discussed and interpreted. Figure 6.2.1 illustrates the main results of this study:

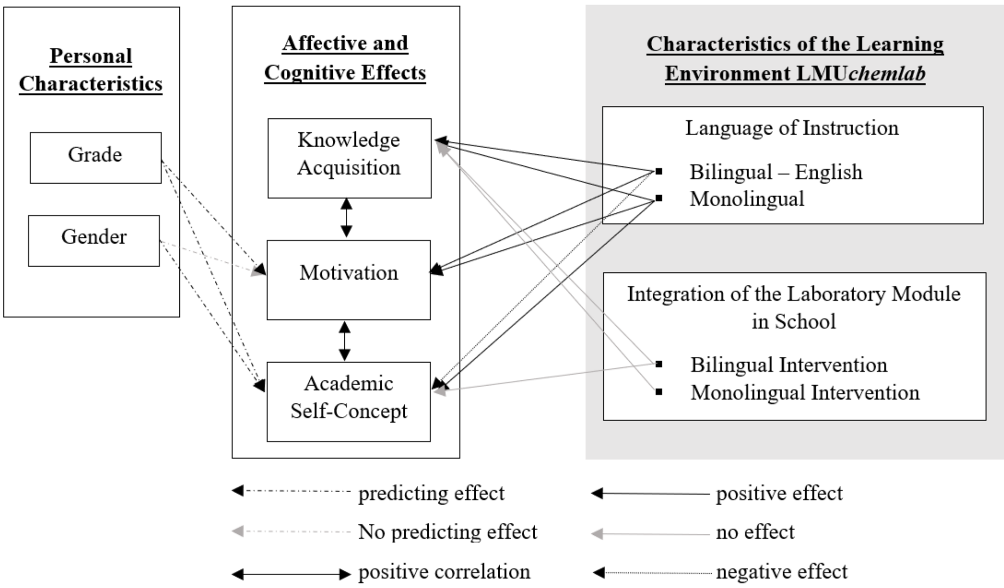


Figure 6.2.1.: Summary of the results from the main study.

6.2.1. Overall Knowledge Intake

As the bilingual laboratory module on *Modern Materials* was newly developed for this study, research question F1.1 examined whether contents which covered different aspects from the broad field of nanotechnology generally facilitated learning independent of instruction language. This was of particular interest, since the intervention was open to heterogeneous groups from different secondary schools varying in ages, migration backgrounds, and dispositions.

Overall, outcomes proved that students' cognitive achievement increased after the treatment. As expected, test scores were highest immediately after the intervention and decreased in the follow-up. Hence, learners could no longer fully recall their prior acquired learning eight to ten weeks later. Yet, despite a significant cognitive decline, the knowledge gained remained higher than before the intervention. These results verify the hypothesis that a science outreach activity allows students to acquire basic research concepts from a single day exposure thereby confirming prior studies on the effectiveness of science labs for school students [25, 272, 124, 26, 268, 517, 214, 13].

Outcomes of this study are to be regarded as promising considering that even though the presented topics were partially linked to contents from the chemistry curriculum, nanotechnology itself is not part of school science in Bavaria [230]. Such a connection to the syllabus is however assumed to enhance learning in general due to its relevance for students' lives [458]. The empirical research results still proved that the learning process was not inhibited with respect to the selected topic. A possible explanation for the obtained results may therefore be attributed to the learning environment itself. Science labs for students have the potential to foster more effective learning than in the classroom [533] because one is able to experience real-world situations through hands-on inquiry. Contents are delivered in real-world contexts [107] through the use of hands-on inquiry laboratory [534]. As such, the LMU*chemlab* enabled sustainable knowledge intake due to an authentic embedding of classroom chemistry. Each of the experiments provided a high application-orientation to which students can relate to and of which they acknowledge the relevance in their lives [239, 404]. For this purpose, common materials were analyzed on the basis of their properties in order to clarify their functional relevance. Pugh et al. [253] further emphasize the importance of such a contextualizing for a more elaborated learning. Thus, contents that reflect everyday problems are better embedded in previously acquired knowledge than those which are presented in a disconnected manner. The setting, too, gave students the opportunity to become more familiar with the new field as each experiment displayed different scientific phenomena that were linked to their day-to-day experience. In line with the theory of educational reconstruction [379], learners' conflicting ideas were taken into account and held against general scientific theories that meet the instructional design of a suitable learning environment [379]. According to Pawek, the iterating process ultimately results in the acquisition of subject-specific knowledge [15, p.22]. The LMU*chemlab* pursued this goal by presenting concrete implications of the interdisciplinary research area and highlighted connections to already known aspects from chemistry. The focus lied on new and recent research-related application fields of which students come across in everyday life. Offering learners opportunities to execute hands-on activities in a realistic setting thereby fostered an authentic picture of modern sciences [467].

Increase in knowledge depending on the intervention was further indicated through correlation calculations dependencies from repeated knowledge test measures. Hence, both low-achieving and high-achieving students were able to score higher within their scope over the reference time. Such a steady knowledge growth highlights the learning success of the intervention and confirms the importance of students' prior knowledge on the retention of subject content [124]. A similar relationship was obtained for students' grades in the school subject chemistry. Even though correlations were weak, results still point to a dependence on learners' academic achievement which lets assume that structure and conditions of the module in the laboratory met school requirements. Findings therefore support the ideas of the CLT [262]. According to Scharfenberg [124] the degree of the cognitive load determines students' knowledge output within a learning setting. A moderate cognitive load would thereby produce strongest learning outcomes [124]. Obtained scores for actual and long-term learning success proved that all contents taught in the unfamiliar environment were presented neither too easy nor too challenging. However, due to the weak correlations it is nevertheless reasonable to argue that, other than in school, there was a widespread facilitation of learning, as the output showed that learners who tended to perform poorly in the school subject were also able to increase their knowledge at least on a short-term level. This comparable learning success within heterogeneous groups is a characteristic feature many science labs for school students share [272, 124] and confirms the assumption that such a learning setting is more accessible to any type of student independent of their learning disposition.

Nevertheless, this study, too, faced the challenge of generating long-term effects. As the setting was also investigated with regard to its integration into the school curriculum a thorough discussion follows in the next section. At this point, it should only be noted that regardless of the treatment groups, a mere one-day visit was not sufficient to achieve significant long-term effects. These results appear consistent with literature [272, 214].
Even if the findings on knowledge intake are encouraging, the study left open to what extent the practical work actually impacted knowledge construction. It is assumed that a "hands-on and minds-on" [460] learning setting links theory to authentic practical work. This might have led to a stronger connection to already known concepts and the construction of newly acquired knowledge. Former research in this field proved that students in an informal out-of-school learning setting outperformed their school-taught peers [459]. Yet, Itzek-Greulich et al. [321] found that similar results could be obtained in school when students are provided with a learning environment that allows an autonomous work experience. However, as this work refrained to examine a control group in school, such an assumption is only left to speculation and needs to be further researched.

6.2.2. Instruction Language Impact

With regard to the critical voices that question the beneficial effects of a CLIL approach in sciences [535], it was of interest to investigate how the teaching style would impact chemistry knowledge output in a bilingual science lab for school students module. The results for research question F1.2 proved a fundamentally positive influence of the teaching approach on subject knowledge intake. It was thus demonstrated how cognitive input could be imparted irrespective of the language of instruction as no significant differences were found between the bilingual and the monolingual group right after the intervention. This was also true for the follow-up test where similar outcomes were observed for both groups. Such short-term to medium-term effects adapt to former comparable studies on bilingual settings in sciences which assessed the influence of the foreign language on knowledge acquisition [274, 212, 26, 83, 25, 218, 276, 214].

Yet, these results must be viewed from different angles considering that unlike Heine's

[256] study, the bilingual group did not outperform their monolingual peers. The slightly higher scores both in the posttest and the follow-up point to stronger retention effects in the monolingual group after the treatment. An explanation for the loss of information in the bilingual group provides the CLT [262]. Processing the learning content in the foreign language while performing hands-on work in the laboratory all at once could have caused a reduced effectiveness of the intervention [83, 26, 27] as learners' working memory capacity was impaired by the multiple tasks [141]. The demanding instructional procedures led to an intrinsic cognitive load [25, 214] due to increased mental capacities which resulted in poorer performances on knowledge retention [214, p. 62]. Hence, the mere foreign language use does not inevitably support learning the subject matter but an adequate representation of the contents is needed to facilitate knowledge intake. These include an age-appropriate level of the provided materials that meet students' foreign language proficiency [536, p. 16]. Such considerations were all the more important in this setting as learners were required to cope with challenging texts on nanotechnology in English. Their unfamiliarity with mandatory technical terms related to the topic could have increased the difficulty in understanding the chemical background in the foreign language so that learning the concepts behind each experimental station caused learners more effort than their monolingual peers.

To counteract possible linguistic short-comings which negatively effect conceptual understanding of the subject matter [182], *translanguaging* [152] and scaffolding techniques [29] were applied. These techniques contributed in students' information processing on a semantic level and helped to overcome linguistic barriers. At the same time, learners were supported in succeeding the task as these techniques are considered to reduce a cognitive load [152, 537]. Likewise, offering various additional mediums from diagrams to pictures at each experimental station helped further in reducing complexity of the contents. At the same time, learners were given more occasions to express their understanding of the topic [538] provided that the selected language and content level was appropriate to their competences [141]. Observations confirmed the conjecture that students in a CLIL setting are more willing to cope with language distraction in order to solve content problems ([292] as cited by [539]). The outcomes therefore let proceed on the assumption that the use of supporting materials played a contributing part in facilitating a low learning inhibition. Again, restrictions must be imposed on the interpretation of these results as the present study refrained from further investigating the actual impact of supporting materials. It is therefore recommended to take a systematic look on their importance in order to understand their influence especially on science-related bilingual learning arrangements more precisely.

Despite the promising results, CLIL studies generally underlie criticism which is mostly attributed to a lack of comparability due to pre-selection processes. These question the effectiveness of such bilingual interventions. Findings from former research confirm such an assumption where talented students who already attended a CLIL intervention scored higher than non-gifted students [540]. It has to be stated that even though participants in this work were not pre-selected with respect to their preferences or experiences in bilingual education, a selection was still carried out due to the setting of the laboratory module. Accordingly, only school classes from upper secondary schools (German Gymnasium) were asked to participate in the module. Such considerations support critics claims that CLIL interventions only benefit advanced students [157] and would leave behind learners with a weaker educational background. However, the focus did not lie on students with a strong faculty of speech but was open to all secondary level tracks. In fact, the majority of students who participated at the one-day intervention indicated a science-related focus in school. In addition, it was demonstrated that the mostly weak correlations with students' school grades in English, especially in the bilingual science lab for school students' module, contradict the hypothesis of only gifted students being qualified for bilingual learning. It is therefore more likely that an authentic insight was promoted due to the meaningful use of the language of science in an outreach laboratory affiliated to a scientific institution. The encountering of an authentic learning environment with original tasks and texts could have raised learners' awareness on the given topic which lead to comparable knowledge intake [24]. Leisen also emphasizes the necessity of authentic, yet linguistically appropriate language situations in order to activate learners in CLIL settings [541]. Nonetheless, further research is needed to investigate whether such a bilingual learning environment on nanotechnological experiments would equally benefit students from lower schools as the present work did not include such comparisons. The study is limited in this statement as it was arranged as a one-day intervention where most students never attended any type of bilingual education. Furthermore, the results are based on quantitative data. For an in-depth insight, a qualitative approach would be needed in order to analyze students' level of processing within such a learning arrangement.

Irrespective of the requirements in such settings, some studies cite the challenging conditions to measure a bilingual intervention as an additional confounding variable in performance measurement [542, 27]. As such, test translation difficulties that bilingual learners encountered may provide another explanation to the poorer results [25]. Although treatment instruction was in English, learners were asked to answer the test items in German. Accordingly, this first required a translation of the newly acquired knowledge from one language to the other in order to answer the questions in the test. However, such translation competences demand linguistic mastery of the working language which is different from bilingual competence, the skill to master both languages [543, p.19]. This assumption is confirmed by Duske's study [212, p. 157] where the bilingually instructed students scored higher in the test language English than those who were tested in German. It is conceivable that in this work, the process itself might have caused understanding problems as to most students many of these technical terms from the diverse field of nanotechnology were even new in their school language. It may be that due to the unavoidable focus on linguistic learning processes associated with the teaching approach, underlying difficulties of comprehending these technical terms became visible [544]. Hence, if learners are unable to transfer concepts in their native language, it is unlikely that they will be able to do so in a foreign language [83]. Even though the varying testing language only lead to an insignificant cognitive load, these small but existing performance losses need to be re-examined, as they could give further insight on what impact a language switch has on learners' performance.

Systematically examining knowledge impact in a bilingual learning arrangement followed the call of many practitioners in this field [276, 545, 157]. Findings contribute to the assumption that a realistic application of the CLIL teaching style allows a similar cognitive output of the subject-matter in English [212, 83, 25, 26, 214]. Consequently, using CLIL in sciences did neither good nor harm (cf. [212]). Even if the study only provided a punctual examination of a bilingual setting, it is still reasonable to draw conclusions with regard to the importance of language awareness in science teaching. Since Merzyn [546] it is known that studying the language of a subject-matter resembles foreign language learning as it requires students to not only memorize its technical terms but to understand the underlying concepts behind the language. As according to Leisen [443] science teaching should similarly foster a language-sensitive approach which focuses on exercising learners in the ability to act linguistically. Thus, developing language awareness promotes awareness of one's own learning [547]. As such, applying a foreign language could even positively support the acquisition of scientific language due to the focus on the subject's special register [233]. Hence, CLIL promotes the transition from conversational communication to academic classroom language to which Cummins refers to as BICS and CALP [163]. Chemistry teaching, in particular, benefits from such a language work as it increases students' attentiveness on the difference between subject-specific language and everyday language. In this way, terminology bound to everyday concepts is undermined, since the use of foreign languages leaves little room for ambiguity and supports conceptual change through adding a further level of representation [276, p. 235]. Even though the bilingual setting required additional time for participants to prepare for the intervention, its focus on language helped to identify and respond to students' content-related problems. Semantic errors in the school language became obvious [276, p. 227].

6.2.3. Preparation and Post-Enhancement Impact

In the past, critics have raised their concerns on the effectiveness of a one-day intervention in extracurricular learning settings [461] as most science labs for school students' modules only evoke short-term effects [235, 12, 272, 25]. Therefore, studies which controlled for preparation and post-enhancement impact plead for a planned laboratory activity in which students are prepared for the contents dealt in the learning arrangement through an embedding in

school [239, 13, 235, 453, 52, 86, 36] as otherwise they run the risk of producing only small effects on learning [548]. Classroom preparation, in particular, would significantly influence learners' experience of competence [12, p. 216] and reduce a cognitive load [549]. These were also the conclusions of the study from Klees and Tillmann [549]. The authors were able to produce long-term effects on students' knowledge acquisition through a pre-instruction of teachers how to integrate the laboratory module in their science class. However, there is little research on the impact of an integration in school without the involvement of teachers. As a consequence, the findings are of limited explanatory power [13]. Research question F1.3 therefore investigated the influence of a school-based preparation and follow-up on cognitive achievement. It was expected that prior knowledge positively affects practical experimentation, reflected in a thorougher understanding of the addressed contents in the laboratory. Moreover, integration of the module in school would especially benefit bilingual learners due to a prolonged exposure to the learning arrangement resulting in a deeper semantic processing [256] of the covered topics.
Module integration was carried out by student assistants who had been instructed beforehand. Test scores immediately prior the intervention confirmed an edge in knowledge acquisition among the prepared groups independent of instruction language. After the intervention, both treatment groups without preparation scored similarly high as those who were familiar with the contents. Comparable outcomes were also obtained after the post-processing in the follow-up. Even though the prepared groups still showed higher knowledge intake, the effect was infinitesimal to the unprepared students. Hence, preparing learners with videos that provided additional information on the contents of each experimental station was found to have no significant effect on knowledge intake right after the treatment. Neither did the bilingual learners outperform their monolingual peers. Findings confirm Rodenhauser's study [25] where she concluded that a bilingual learning arrangement with practical experimentation would lead to similar retention effects between the monolingual and the bilingual prepared group.

A rational behind these outcomes may be the selected area of research and its curricular relevance. In her study, Glowinski [12] found a correlation between the significance of the topics in school and the outcomes of the knowledge tests. As already stated, nanotechnology has not been an integral part of the Bavarian school curriculum [230]. Accordingly, students who participated in the laboratory possibly had difficulties in recognizing the general necessity of retaining these contents since it didn't impact their academic achievement as is the case for school science [458]. The current study was therefore confronted with the problem most classic science labs for school students face that try to convey an authentic picture of science; such learning arrangements can't afford a more curriculum-oriented program [550]. Even though attention was repeatedly paid to a linking of the topics with the school syllabus, participants had difficulties in fully drawing on their prior knowledge in chemistry. On the one hand, this may have been due to the various connections with the curriculum within the experimental station. Each of these stations presented different links to school contents covered from 10^{th} to 12^{th} grade. However, as most topics were not currently relevant in students' chemistry classes, learners had to rely on their basic knowledge, which was available to a greater or lesser extent. Future studies should therefore reconsider opportunities to engage students with the laboratory activities more effectively. The study thus comes to the conclusion that a purely operator-led embedding in the classroom cannot yield the desired success. It would therefore be advisable to follow the recommendations of Klees and Tillmann [549, p.106] who advocate for actively involving teachers into the embedding of such out-of-school interventions. In doing so, the authors recommend that involvement should not be limited to providing materials. Rather, the focus should be on highlighting the essentials of the contents thereby focusing on a clear structure. Problems set within this framework should be creative and reach a high level of complexity thereby allowing learners to assess their own abilities. However, it is important to consider that such a constructed intervention is limited in its effectiveness due to its nature of a single practical experience in the laboratory (cf. [235]). Rather, the primary goal should therefore be to strive for long-term embedding. In this way, the informal learning environment would also be perceived as a component of the curriculum. This would further counteract the "novelty space" effect [446] out-of-school settings provoke. From former studies it is known that an exposure to a new setting causes additional mental stress to learners [551]. This may lead to participants developing uncomfortable feelings as they are disturbed by new features in the setting which prevents them from concentrating purely on the contents. Consequently, providing prior knowledge about the learning environment helps increasing the effectiveness of the intervention [86]. As learners were more concerned with the framework conditions in the laboratory it is likely to assume that becoming familiar with the science lab for school students overshadowed content-related aspects. Ultimately, the learning arrangement caused an extraneous load [86] reflected in students' lower ability to recall the studied topics. This would also be a reasonable explanation why similar scores were obtained in the unprepared groups. While the prepared groups received an introduction to the experimental stations, the unprepared groups were introduced to geographical characteristics of the LMU *chemlab* illustrated through pictures. This enabled students to focus more on the contents during the laboratory day instead of becoming preoccupied from getting familiar with the learning setting. As a results, participants who were cognitively and psychologically prepared for the module were not able to outperform those who were solely geographically prepared. The results illustrate the validity of Orion's and Hofstein's considerations on "novelty space" which take all three components into account in order to reduce a cognitive load. Thus, merely preparing learners for the subject matter is not sufficient. In order to produce full benefits of the intervention, Guderian [86, p. 21] suggests, based on the work of Orion [552] and Orion and Hofstein [553], to follow a three-step approach for visiting science labs for school students. This first step begins with a geographical, cognitive and psychological introduction to the learning site (1). Information about the setting, pictures or videos and the presentation of concrete and relevant contents should serve this purpose. The second stage is described by the visit in the extracurricular environment itself (2) and finishes with the processing of the studied topics (3). For future studies it would therefore be advisable to align the embedding of the extracurricular setting according to the criteria which determine the novelty space of an environment.

With regard to instruction language, highest sustainable outcomes were to be found among the pre-instructed monolingual group. Hence, even though impact was insignificant, other than expected, a prolonged exposure to the bilingual setting through the embedding in school did not produce a deeper elaboration [256]. Reasons for the obtained results might be attributed to the cognitive demanding learning environment in the bilingual setting as described in F1.2. Additionally to the presented scaffolding techniques and videos, students were provided with vocabulary sheets for the respective experimental station prior to the intervention. Learners were required to study these technical terms before the event. With regard to the CLT [262] a bilingual learning arrangement causes an extraneous cognitive load, if students' experience their foreign language proficiency lower than required in order to solve the task [554]. Awareness of the linguistic demands as well as the scope of unfamiliar technical terms may have caused students to feel overwhelmed by the setting. As a result, the additional amount of workload might have demotivated learners [555]. Since a preparation considerably influences students' experience of competency [12, p. 216] which is crucial to knowledge intake [297], the intervention might have negatively affected learners' performance. A similar insight is reached by Dalton-Puffer [149, p. 189], who attributes better performance in bilingual groups to students' high motivation. In the CLIL setting, learners blamed their experienced mental stress on the incorporated pre-instruction as obtained results for the scale on perceived preparation suggest. Those participants felt significantly less prepared for the laboratory day. Despite multiple aids provided to the bilingual group prior and after their visit, the group indicated a lack of support when incorporating the module into their lessons. These findings highlight that despite similar performance in the subject knowledge test, the bilingual group desired a more in-depth preparation for the day. Similar to Riemenschneider's study [556, p. 131], it must be concluded that measures taken in the bilingual group did not provide sufficient support. In order to achieve a more targeted preparation, it would therefore be advisable to include students' prior knowledge more closely which allows them to develop more references from reality. Moreover, it might be helpful to focus more strongly on one grade level, especially in the field of nanotechnology. This would allow learners to

draw upon prior knowledge that was only recently learned and promote their willingness to engage with the contents. More importantly, on a motivational level it would be useful to emphasize the relevance of the bilingual teaching approach for students' own development. Many of the participants were not aware of the added value of a bilingual scientific literacy, especially in view of the fact that English is the new language of science. Drawing students' attention to the relevance of the English language to their own careers may also increase their motivation to engage more deeply with the learning environment.
Even if the study refutes the long-deferred expectation of a reduced content intake [557], it leaves open the question to what extent the CLIL approach causes a mental over-straining [201]. Future studies should therefore systematically address the use of the instructional approach on cognitive processing depth to allow conclusions on the application and implementation of CLIL in a science subject.

6.2.4. Cognitive Achievement with regard to Cluster Dependence

As literature on CLIL teaching suggest a dependence of students' dispositions on learning success [554], research question F1.4 assessed the effectiveness of a bilingual setting in this regard. Taking prior research into consideration, it was hypothesized that learners who had an aptitude for both languages and sciences would benefit most from the intervention [25, 26]. Likewise, it was assumed that students with a linguistic bias only, would profit from such a learning arrangement, in particular [372] as foreign language use in a CLIL setting increases affinity for the respective subject matter.
To investigate the impact of this bilingual intervention different learner types were analyzed separately. Examination thereby proceeded according to former studies [14, 124, 272, 25, 26]. Such an analysis enables a tailored promotion of learners with varying dispositions similar to the heterogeneity found in classrooms. For this purpose, motivational aspects in chemistry and English were considered to identify different learner types. To gain a better understanding of these outcomes with respect to the applied teaching style, a latent cluster analysis was conducted [25, 26, 272, 14]. As a result, three types of learners were indicated accumulated in the classification of students that were either language-oriented (cluster 1), learners with an equal interest in both subjects who were classified as all-rounders (cluster 2) and science-oriented students with a bias towards sciences (cluster 3).

Each cluster in the bilingual treatment was analyzed based on the findings in the knowledge test. Empirical research results suggested a homogeneous promotion independent of group assignment as short to mid-term increases in knowledge were obtained over the testing period. In general, these outcomes align to respective literature [83, 25, 26, 215] indicating that a bilingual module embedded in a realistic setting, too, has the ability to promote students with varying skills and preferences in school [14]. The partially weak correlations between test results and students' prior academic achievement in the subject matter further confirmed this broad support in knowledge retention science labs for school students pursue. It can therefore be established that learning motivation in a science lab for school students developed independently of the learning content [124]. As motivation and learning achievement are indispensably intertwined [558] such improved academic performances among students who otherwise tend to do poorly in chemistry foster a positive attitude towards the subject matter. This would meet the desired goal of promoting more students to engage into the natural sciences.

However, a more nuanced comparison of the outcomes between the three clusters revealed that highest scores were to be found among the group of all-rounders. As expected, bilingual instruction was most beneficial to those students who were equally interested in both subjects which made up the majority of participants. Students in this group were able to sustain their newly acquired knowledge both temporarily and permanently. This slight but insignificant advantage partly confirms the results of Rodenhauser's [83] study. Accordingly, dispositional motivation in the learning object was maintained due to the learning environment which resulted in a stronger performance in the knowledge test.

When comparing the outcomes between single language-oriented learners with those who were solely science-oriented, the empirical findings point to similar retention effects. Contrary to what would be expected in a monolingual intervention, scientifically gifted students who participated in a bilingual module did not score above average. A possible explanation for the performance drop found among cluster 3 students could be due to an extraneous load [25] which emerged from the requirements of the bilingual learning environment. Since these learners tend to see their competences as being more grounded in the natural sciences, the double burden of using the foreign language in this field may have negatively influenced knowledge acquisition [83]. Due to learners' negative fundamental position towards English the combination with the subject chemistry was rated as onerous. As a consequence, the scientifically gifted group were not able to fully realize their potential. These outcomes contradict Ohlberger's study [559], where a positive basic attitude towards the subject-matter was found to have an immediate positive effect on the bilingual learning arrangement. Rather, students' performances in the knowledge test indicated that the learning setting was perceived as obstructive. Such observations confirm critics' fears on bilingual learning arrangements, who predict a trade-off between language and subject-matter [27]. Still, since the few studies in this field have only little informative value, it is recommended to investigate whether performance drops among science-oriented students are generally related to the bilingual learning environment, or whether the comparatively weaker results are tied to specific topics in chemistry.

In contrast to this, the positive results among cluster 1 students confirm the hypothesis that due to the group's disposition linguistically gifted students profited most from the bilingual setting [26]. With regard to the need to experience competency [59], these students seemed to have felt more capable as they could draw on their strengths to perform in a reluctant subject-matter. Hence, a motivating attitude towards English is reflected in a higher self-efficacy in chemistry within a combined learning setting (cf. [559]). Better results among students with stronger foreign language skills could also be drawn to learners' different levels in BICS and CALP dimensions as described by Cummins [163], which explain the faculty of speech in terms of everyday language (BICS) and academic language aspects (CALP). Since bilingual learning promotes broadening one's linguistic practices from everyday language skills to subject-specific recognition, it is likely that these students developed a more pronounced CALP level. This was expressed through better comprehending and retaining the subject-matter content. Nevertheless, at this point it remains unclear how learners' language skills affect the acquisition of subject knowledge and what role literacy skills [545], which are frequently cited in this context, play. Such an analysis is all the more important considering that additional strategies (such as code-switching) were used in order to comprehend the chemical content. Moreover, it is important to recognize that participants came with different levels of foreign language proficiency which makes it difficult to determine precisely how much the linguistic component influenced the acquisition of knowledge. In order to provide a more accurate account and to allow for a more focused support, it would be advisable to seek further research that examines the relationship between language competence and subject knowledge acquisition. Nevertheless, results regarding this cluster are particularly encouraging, as reliance on foreign language skills can help learners with such preferences to feel more competent in the natural sciences.

A slightly different picture emerged regarding the monolingual group. Similar to the bilingual intervention, cluster membership was found to have no significant effect on knowledge acquisition. Thus, the laboratory module which was conducted in the school language, proved that the learning environment achieved its goal of a broad-based support [467] as was demonstrated in prior monolingual studies [124, 272, 14]. However, tendencies within the treatment suggest that scores of students with a single-language disposition were lower compared to their peers. It can therefore be concluded that the monolingual intervention aligned more the requirements of school chemistry. This proximity to the subject-matter caused students to perceive themselves as less self-efficient in the monolingual treatment, since their skills were not reflected in the learning setting. Nevertheless, the obtained homogeneous knowledge acquisition within the science lab for school students emphasize the advantage over regular school instruction which is usually adapted to the learners' preferences in the subject matter. To give these results more significance, future research should incorporate a control group at school. This would allow for better comparisons regarding the influence of the learning environment on different learner types.

Finally, between-group comparisons of the different learner types in the two interventions revealed no differences on subject knowledge acquisition irrespective of the language of instruction among language-oriented students and all-rounders. However, differences were detected for the science-oriented group. A significant decrease was measured in the follow-up among the bilingually instructed students. As already postulated in research question F1.2 these findings may be attributable to the deviating test language from the language used within the instruction [279]. In general, subject-specific language constructs are remembered more poorly if they are already unavailable in the learners' school language [283]. These effects might be particularly stronger for learners who do not see their preferences in foreign languages, anyway. For example, students that locate their strengths in the natural sciences, but to whom the subject area of nanotechnology is completely unknown, might not draw on existing technical terms, resulting in a detrimental effect on knowledge acquisition through the translation into the foreign language. Likewise, a bilingual setting that is perceived as less motivating can also have a negative effect on knowledge acquisition [558], as students felt overwhelmed by the additional demands in the learning environment. Similar to Rodenhauser's study [25] these findings let conclude that the bilingual module was considered less of a chemical event since the impact of the foreign language affected knowledge gain.

Overall, it can be summarized that independent of instruction language, the learning arrangements benefited a wider range of students and addressed learners with various dispositions. Thus, with regard to the research question, it was demonstrated that knowledge growth occurred regardless of the type of learner and instruction language. The linking of practical and theoretical elements seems to leverage dispositions thereby benefiting heterogeneous groups. Yet, since comparing these results with the subgroup from the monolingual intervention did not produce any significant differences it can be assumed that the language of instruction hardly effected learners' disposition.

6.2.5. Influence of the Laboratory Environment on Students' Intrinsic Motivation

Since learning motivation proves to be a necessary cornerstone for successful learning [560], research question F2.1 aimed at examining the potential of a bilingual learning setting in this regard. Findings were compared with the monolingual treatment. It was thus expected that applying CLIL in a science outreach laboratory would similarly support activity-based intrinsic motivation as found in prior studies on monolingual out-of-school science settings [561, 81, 468]. Impact of performed hands-on activities in the laboratory were measured by the German adaptation of the multidimensional measurement instrument IMI short-scale

[468]. High scores in all positive sub-scales of the IMI confirm the results from literature and indicate that a one-day laboratory visit has the power to positively influence students' intrinsic motivation at a short- to midterm level [81] even in a bilingual setting [25]. For the *competence* sub-scale, scores maintained a high value over the testing period which is consistent with similarly designed studies (cf. [218]). However, in comparison, significantly higher mean scores were found in the positive sub-scales of the monolingual group. Instructional language thus proved to be a barrier to intrinsic motivation.

In general, positive outcomes in these sub-scales can be attributed to the module's conceptualization which met all three dimensions of a person's basic needs' as postulated in the SDT framework [297]. According to the authors, an important precondition for intrinsically motivated action is the feeling of autonomy, relatedness and competence. These innate psychological needs are considered a driving force for motivated action. Consequently, fulfilling all three factors results in personal growth [288]. Independent of instruction language, students' basic need on social relatedness was satisfied through the joint work within the laboratory. Interaction with other learners and instructors led to a sense of belonging. As a consequence, the collaborative work in small groups contributed to the development of positive emotions with the learning object [302] which in turn allowed for a satisfaction of the respective dimension and the development of learners' intrinsic motivation.
With regard to the sub-scale on perceived *choice* mean scores were rather low compared to the monolingually instructed students. Thus, only to a limited extend the learning arrangement contributed to fulfilling the need for autonomy which echos the findings of Rodenhauser's [25] study. A possible explanation to these pronounced differences in the two treatment groups could be the loss of autonomy [59] due to the CLIL instruction. In Germany, bilingual settings are offered optionally in school. Thus, enrolling for bilingual classes is usually associated with increased self-efficacy [305]. Unlike school teaching, learning environments that are created in an out-of-school setting are rooted in the intense interest and desires of the learners [468]. Since registration for the English-German module was randomly assigned and most learners came with a biased attitude towards the setting, it can be assumed that the lack of choice in this regard was manifested in a low experience of autonomy. Likewise, using English in a chemical context demanded students to adhere more closely to the given instructions of the experimental stations enabling them to follow the contents within the module. Such a strong guidance could be at the expense of learners intrinsic motivation as indicated in correlations between the sub-scales perceived *choice* and *interest/enjoyment*. As the degree of freedom within an extracurricular setting strongly correlates with the feeling of autonomy [14], it is conceivable that learners enjoyed the intervention less that their monolingually instructed peers. There, learners also had to face time constraints which did not allow to work completely independently. However, the setting was still experienced more open since

students were less inhibited to speak and discourse with both supervisors and classmates was easier.

Competence develops from coping with challenging tasks an individual seeks to master. Tasks to be performed should therefore neither produce an over- nor an underpromotion, otherwise the opposite effect would be obtained [297]. In spite of the fact that the covered contents on nanotechnology as well as the teaching style were new to most participants from the bilingual group, above average means in the positive sub-scales let conclude that overall, hands-on activities were selected appropriately and to a larger extent met learners' proficiency level. Outcomes further align with the obtained test results on subject knowledge acquisition since cognitive achievement is, too, associated with experiencing competence and is maximized in a CLIL setting when tasks are just challenging enough to be accomplished with the help of scaffolding techniques [537].
Learners' intrinsic motivation in English might partly explain the obtained long-term effects in the sub-scale perceived *competence*. With regard to the identified learner types from research question F1.4 both students with a single language disposition and all-rounder indicated their engagement to deal with the foreign language in their leisure time. As a high feeling of competence in a particular domain increases intrinsic motivation in that very domain[562], students' positive view on foreign languages was expressed in fully engaging with the bilingual learning arrangement. Hence, learners felt competent to deal with chemical contents in English while executing hands-on activities. This particularly applies to purely linguistically gifted students. Their abilities in foreign languages helped to overcome the processing of difficult chemical tasks. As a results, these students experienced themselves as self-effective in the other domain, which in turn generated interest and enjoyment in the subject matter as confirmed by the correlations between the sub-scales *competence* and *interest/enjoyment*. Likewise, findings from the sub-scale on perceived *pressure/tension* which generally indicates a negative impact on learner's performance [563] and the additionally considered instrument *pressure due to the use of the foreign language* further align to this assumption. Low means in these scales suggest that CLIL did not impair learners in applying their science skills. In addition, linguistic preparation prior the intervention ensured that participants were familiarized with important terms in order to counteract linguistic overload. Since it was assumed that skills acquired in English classes would not be sufficient to cope with an extracurricular bilingual learning arrangement in the working language [545], all participants in the treatment were provided with vocabulary at test time T0 to prepare for communication in the laboratory. This allowed for an appropriate proficiency level despite students' heterogeneous language competencies. Thus, linguistic preparation kept pressure associated with the setting low. As bilingual arrangements in the natural sciences are generally skeptically viewed among learners [224], the success of the intervention may have led to a reassessment of students' perception towards

their competencies in both domains. This was indicated by the findings of the *pressure due to foreign language use* instrument. High mean scores prior the intervention indicated that the instructional language English was initially regarded as a potential obstacle to laboratory work. However, participants' low ratings of this negative predictor after the treatment suggest that learners reassessed their own skills in this regard. Nonetheless, although scores of the negative predictors were below average after visiting the laboratories, due to the comparison with the even lower means from the monolingual group it must be concluded that the selected instructional language significantly affected intrinsic motivation. Correlations between all positive sub-scales of the IMI with the variable on perceived *pressure due to foreign language use* highlight the moderation of students' activity based intrinsic motivation by the foreign language. Consequently, learners experienced the practical experimentation as less motivating. These outcomes were expected and are consistent with Rodenhauser's [25] study, who made comparable observations regarding the bilingual intervention. Hence, the laboratory day was classified as a purely chemical event despite the purposeful use of the English language [25]. To keep things in perspective, these findings would confirm the fears of CLIL critics who claim that bilingual teaching in sciences negatively affect students' motivation [270, 564]. It must be noted, though, that students' language proficiency was not in the focus of this research. Nor does this study claim to make definite statements regarding the impact of the foreign language, since students were only briefly exposed to the bilingual setting during a single day in the laboratory. Therefore, it remains speculative to what extent the teaching style actually affected learners' activity-based intrinsic motivation. Further analyses are required in order to gain conclusive evidence.

Lastly, the one-day event at the LMU*chemlab* succeeded in addressing all components of self-determined learning. Even though the module in students' school language was found to be more motivating, the outcomes are still promising considering that learners' activity-based intrinsic motivation was also raised in the bilingual module despite the additional requirements and students' limited experience in this regard.

6.2.6. Predictors of Students' Activity-Based Intrinsic Motivation

Research question F2.2 investigated predictors of activity-based intrinsic motivation. A multiple linear regression was assessed in order to examine what aspects predict learners' intrinsic motivation at a bilingual science lab for school students module. Such an analysis is all the more important since the affective construct starts decreasing at elementary school age [565]. Results illustrate interaction effects between learners' intrinsic motivation and interest, their experience of *competence*, perceived *choice* and their chemistry grades. Other than hypothesized, instructional language itself had no influence on motivational experience. These outcomes are largely consistent with those of the studies by Brandt [81], Rodenhauser

[25], and Röllke [268], who also investigated the influence of a science lab for school students on intrinsic motivation.

In concordance with Weidinger's [566] study, students' prior grades in the subject matter appeared to have an impact on the experience of activity-based intrinsic motivation. A reason for these findings may be rooted in learners' academic self-concept, which strongly correlates with the development of intrinsic motivation [567]. Thus, the construct seemed to be influenced by school-related performance feedback. These are formed by external and internal responses [331]. As according to the I/E reference frame model [331], comparisons with students' own prior grades in chemistry thus seem plausible as learners tend to compare their past performance with that of a learning setting related to the school subject. Hence, previously made experiences in classroom chemistry were transferred to the requirements of the new learning arrangement. Students who had performed poorly in the past were less motivated in the subject-matter and consequently also more likely to be less motivated in practical experimentation within a science outreach laboratory. The results partly contradict the notion that science labs for school students being capable of motivating learners regardless of their school performance [467]. Even though only minor correlations between test achievement and previous grades were found, it must be concluded that a short-term exposure to the extracurricular setting did not allow for a detached attitude towards the subject in this study. Due to the difficulty of comparing different science labs for school students, the study makes no claims to general validity. As a matter of fact, past research examining the influence of prior achievement grades on intrinsic motivation is contradictory and varies from no influence [268] to opposite tendencies [322] as those found in this study. It would therefore be worthwhile to pursue further research that identifies factors for the impact of prior achievement on the experience of intrinsic motivation.

Similar to Röllke's study [521], the development of intrinsic motivation was further moderated by students' perceived *choice*. The experience of autonomy describes one of the three pillars postulated in the SDT [290] which influences motivational experience. Lower scores obtained in F2.1 confirm the assumption that necessary restrictions within the learning arrangement influenced students' intrinsic motivation. Since this type of extracurricular setting describes a place of learning that is still unknown to the vast majority of participants, certain methodological parameters were imposed upon the conception of the module. These resulted in clear guidelines independent of instruction language and included the work with new devices [268, 25] which was largely unfamiliar to students and required that most experiments needed to be carried out under the guidance of a supervisor. Such a proceeding ensured secure handling, but resulted in a loss of autonomy. Time also limited students' ability to cope independently with hands-on activities. The module was subject to a tight schedule so that participants only

had a certain amount of time per station during which they worked on each topic assisted by the supervisors in the laboratory. Hence, the semi-open form of experimentation kept students on schedule and ensured the completion of all experimental stations within the allotted time frame. Moreover, especially in the bilingual group, supporting techniques were required. These entailed additional verbalization of the contents but further resulted in a restriction to the handed materials due to the learner's language proficiency. Even though actively guided instruction is more likely to improve attitudes toward the subject matter [568], such restrictions prevent learners from the a perception of autonomy as these time-bound interventions are subject to a strong organization.
All in all, more studies are needed to investigate and compare students' perception of autonomy with regard to the conditions of different science outreach settings. The learning arrangement studied in this research describes a classic laboratory that seeks broad-based support. Different results regarding the influence of autonomy on intrinsic motivation would be expected to have an impact, especially in science research centers where focus is on the promotion of single individuals.

As assumed, students' perceived competence also influenced the independent variable which confirms the findings of previous research [25, 268] in this field. As according to the SDT [289], the experience of competence is regarded as one of the cornerstones for the development of motivation. In a science lab for school students, strong independent practical experimentation is promoted which is considered as a specific feature to the learning site [467]. Students are granted time to practice hands-on activities in a protected space without receiving any negative responses to their performance. Such a setting allows learners to develop practical competences more readily which in turn leads to an increased feeling of intrinsic motivation [569]. Likewise, the level of the assigned tasks also plays a decisive role [307]. The closer it was aligned to learners' abilities and the less students experience a sense of being overwhelmed, the more competent they felt. Accordingly, applying previously acquired knowledge to realistic problems also contributes to the successful development of competence [570]. The experimental stations designed for the science outreach laboratory addressed scientific phenomena that have an increased application relevance and allow the acquisition of subject-specific working techniques in the process. Hence, due to the subject matter's relevance to everyday life, inert knowledge is avoided, which contributes to the development of intrinsic motivation [571].

Lastly, other than expected the predictor instructional language did not show a significant impact on the affective construct. Even though the findings from F2.1 point to lower levels of intrinsic motivation in the bilingual setting, it appeared that the teaching style did not directly influence the variable. These findings do not imply that there is no relationship between instructional language and intrinsic motivation. It may be that this relationship is masked by other influences so that mediation effects dominated the influence. Still, correlation calculations indicated a negative relationship (monolingual = 0, bilingual = 1) between the two variables. This negative relation of the use of English on students' intrinsic motivation is also in line with prior studies that examined bilingual settings [559, 572]. Again, one reason for this may be the bias against the teaching approach. In Germany, such courses are usually attended by high-achieving students who underwent selection processes [573]. In this study, groups were randomly assigned to the intervention. Preconceptions about participating in a bilingual module could possibly have led to a loss of intrinsic motivation. The findings are in line with Meyerhöffer's [218] study where students who already participated in bilingual classes in particular benefited more from the CLIL intervention than those without experience. Consequently, it can be conceded that, as in Rodenhauser's [25] study, activity-based intrinsic motivation was determined by the experimental and chemical portions of the course and less by the use of the foreign language. Still, as the multiple regression model only explained 36% of the variability, future research should consider further determinants in order to understand what predictors effect learners' intrinsic motivation. Taking the aforementioned selection processes into account, more research is needed to allow for more meaningful statements.

6.2.7. Self-concept Dependence based on the Identified Cluster Types

Since prior studies confirmed a beneficial impact on students' academic self-concept caused by a science lab for school students' visit [81, 15, 12, 81, 15, 13, 238], this present work also pursued the investigation of a one-day intervention on learners' academic self-concept in chemistry. With regard to bilingual out-of-school settings on biology, it was further proved that students with a language disposition would benefit most from the setting as these learners felt more competent in solving task-based problems in English [83, 25, 215]. Consequently, using CLIL in an extracurricular setting can lead to targeted support for learners who see themselves as less gifted in sciences [214]. It was therefore hypothesized that the offered hands-on activities in the LMU*chemlab* would similarly improve the chemistry self-concept of students with a language disposition. Yet, findings contradict the assumption in the bilingual setting as the construct remained stable over the reference time. Students' own capability assessment was not affected by a singular visit in the laboratory. The learning arrangement therefore failed to positively impact participants' chemistry self-concept independent of learner type.

As the academic self-concept underlies among others social comparisons [574, p. 139], it was expected that foreign-language-motivated students would be advantageous since they are considered to be more comfortable with the language use and are thus able to compensate deficits from a scientific point of view. Yet, as change of linguistically gifted students' chemistry self-concept was infinitesimal, the outcomes could be drawn to point to internal referencing strategies [575, 331]. According to Marsh [331], the effect refers to comparisons with other domains of classroom instruction. Learners operate more self-consciously in their preferred domain. Even though the learning arrangement gave language-oriented learners, in particular the opportunity to perceive themselves as capable speakers in a scientific domain, the desired competence experience was not facilitated. This is due to a person's own beliefs of his or her achievement which also play a crucial role in the development of a self-concept [346]. Hence, what is considered as good or bad performance is at the learners' discretion. From the findings it can be assumed that these students still assessed their skills in chemistry lower even though actual scores in the knowledge test indicated a benefit due to their language disposition in the CLIL setting. The single-day intervention therefore failed to change the relatively stable construct and the group's prior self-concept in chemistry remained. Rodenhauser [25, p. 265] further concluded that the outcomes are attributable to the learning arrangement itself which must have been too similar to learners' school self-concept causing them to not perceive the intervention as an opportunity to use their competencies. These results do not seem contradictory considering that dispositional interest characterizes a slow-changing motivation whose alignment is to some extent rooted in a person's self-concept [310]. Therefore, simply using a foreign language does not necessarily lead to learners engaging fully with an unrelated subject. Rather as found in other CLIL settings, bilingually instructed students' self-concept appeared lower compared to their monolingually taught peers [576].

Similarly, results obtained in the science-oriented group (cluster 3) were also subject to internal referencing effects as described by Marsh [331]. Due to the special requirements in the bilingual setting, scientifically gifted students were forced to compare their self-concepts in both the language and numerical domain. This direct comparison caused by the exposure to the foreign language English might have led to a lower evaluation of the chemistry self-concept [332] as scientifically interested students experienced a limited sense of action due to the learning arrangement. As a result, they might have failed to perform as they are used to. Outcomes from the monolingual group further confirm the hypothesis that the lower self-concept was due to treatment conditions. There, specifically the scientifically gifted students benefited from the intervention as illustrated in a short-term increase in self-concept. Since the intervention aimed at solving topics relevant to everyday life, raise of these learners' self-concept may be due to a domain-specific self-efficacy [577]. Science-oriented learners were confronted with their strengths in a school laboratory that is affiliated to a research institute. They evaluated their performance based on grades in the school subject as well as with their environment. An already developed chemical self-concept causes learners to feel capable in performing subject-specific tasks in a previously unfamiliar environment. Such achievements reflect prior learning success in the subject and stress the reciprocal relationship with one' s self-concept [578]. Students clearly succeeded in referring to and applying existing knowledge to the solution-finding process. In turn, being successful at this led to an increased acquisition of subject knowledge in the short term. At the same time, external referencing [331] also influenced the development of the self-concept. Comparing learners' performance to their peers can also impact students' self-concept. As the intervention allowed for an increased group work phase, students with strong scientific abilities in particular were able to contribute to the problem-solving process.

Even if the goal of increasing students' self-concept was partly achieved, it becomes apparent that similar to school, mainly students with a science orientation were addressed in the learning arrangement. This contradicts the original goal of science labs for school students' operators, who aim to promote broad-based learning [82]. Although, in general, the intervention did not have a negative impact on participating students' self-concept, it still remains to be clarified how a decoupling of the extracurricular setting from the school subject chemistry can be achieved, in order to reach even those students who tend to be less confident in the domain. Furthermore, it has to be clarified how to apply CLIL in a more beneficial way to reach linguistically oriented learners. In light of the fact that these findings contribute to the contradictory literature which at this point do not allow to draw clear conclusions on the impact of the instructional approach within a science learning context, it would be reasonable to conduct further studies to examine students' academic self-concept.

6.2.8. School-Based Preparation and Post-Enhancement Impact in the Bilingual Setting

To address the need for robust research on longitudinal effects of bilingual learning arrangements in sciences [554], research question F3.2 investigated the impact of integrating the laboratory module into the classroom with regard to students' chemistry self-concept. Previous studies revealed that a prolonged exposure to the teaching approach yields the desired permanent raise of the construct in foreign languages [576, 540, 579]. Yet, to date, these outcomes could not be confirmed within the subject-matter [554]. Moreover, with regard to classic science outreach laboratories findings are also still contradictory. While most studies report on short-term effects of students' academic self-concept after a single day event [81, 15, 25, 26, 324, 272, 580, 215] others found that preparing learners had a long lasting positive impact on their self-concept [237, 13, 581]. As literature proposes a reciprocal relationship between learning achievement and students' academic self-concept [345], it was anticipated that preparing and reviewing relevant content in a bilingual science lab for school students would also lead to a deeper elaboration of the contents. This should go beyond mere memorization and would result in a positive influence of learners' domain-specific self-concept. Despite better performances even among students who tended to have a lower chemical self-concept before the intervention, no significant long-term effects could be identified. As Jansen et al. already stated [582], a high experience of competence does not necessarily go hand in hand with a high self-concept. Various confounding variables can be identified for this trend.

As discussed in research question F1.3, a potential reason for the missing impact in the prepared group may be due to a cognitive overload evoked from the learning arrangement. Even if science labs for schools students generally offer enough incentives to stimulate learners affectively, it is necessary to identify those factors that facilitate such a stimulation. After all, the success of such learning arrangements primarily depends on the fact that learners do not feel overwhelmed by the setting [583]. While a slight increase could be observed in the prepared group, major improvements were not found, precisely as the self-concept was not stimulated strongly enough. These outcomes align with the results found in the studies of Hubricht and Ralle [452] as well as in one of the bilingual laboratory modules offered by Rodenhauser [83] in which no changes regarding the learners' science self-concept could be detected after the posttest. Students unfamiliarity with the setting, the teaching approach and the additional requirements within the out-of-school learning arrangement might have resulted in a lack of impact on their chemical self-concept as was also mentioned in literature [581, 584, 554] study. With regard to CLIL, Piesche et al. [554] further conclude, challenges are related to students' insufficient foreign language knowledge and their missing experience with the teaching approach. It is therefore even more unlikely to expect high outcomes in a bilingual setting considering that due to the study design no pre-selection process with regard to learners' experience had been performed. Moreover, it needs to be questioned whether a bilingual learning arrangement on inexperienced learners generally can achieve a positive expression in the respective subject-matter as most research report on lasting effects from students who participated in CLIL settings for at least a year. Hence, a more nuanced approach is suggested which further investigates the learning environment with regard to pre-selection processes. The study of Meyerhöffer [218] emphasizes these differences in her study, as pre-selected students' showed higher affective outcomes than learners who were inexperienced with the CLIL teaching style.
Moreover, it is already known that determinants of motivation also influence learners' academic self-concept [558]. As discussed in section 6.2.5, there were neither short-term nor long-term effects measurable regarding learners' experienced *choice* in the bilingual intervention. It can therefore be assumed that students' low feeling of autonomy [59] inhibited increasing learners' chemistry self-concept. Similar to other laboratory arrangements, this study was confronted with the problem that no real degrees of freedom were possible regarding the design of the intervention [72]. This largely limited working in the laboratory independently, resulting in learners not being activated strongly enough. However, such a feeling of autonomy is necessary for both short-term and long-term changes of learners' academic self-concept. Derda

[368, p. 65] confirms this assumption. In her study, she found autonomy to significantly impact learners' academic self-concept. Since this relationship remained largely unexplored in accompanying research on science labs for school students, it would be desirable to clarify in further studies what influence the openness of the learning environment has on the relation to affective variables such as the learners' academic self-concept. Overall, the study could not confirm a significant effect on learners' chemistry self-concept due to the embedding of the learning site into school. As already stated, there is still conflicting evidence with regard to science labs for school students in general, and bilingual science outreach labortories, in particular. At this point it would be important to explore which aspects of such a learning atmosphere actually lead to the desired motivational increase. Therefore, further studies are required to investigate what role self-concept generally plays in extracurricular learning settings.

6.2.9. Predictors of Self-Concept Outcomes

Although the domain-specific self-concept constitutes a stable construct even in adolescence [585], science labs for school students are considered a beacon of hope with the potential to raise students' dispositional self-concept within a one-day laboratory event [235, p. 4]. Research question F3.3 therefore investigated what predictors exactly affected participants' chemistry self-concept due to a short-term exposure in a bilingual learning setting. However, since little is known about these influencing variables, the study was limited to common factors such as prior grades in the subject-matter, gender, and language of instruction. Based on the review, it was hypothesized that grades [124] and language of instruction [25] would impact students' chemistry self-concept. Gender, however, would not effect the construct as was demonstrated in prior studies [81, 238, 272, 15] in the field.

Findings illustrate that previous grades in chemistry are the largest predictor in this study. Such a strong relationship between learners' prior performance and science self-concept was also demonstrated in Rodenhauser's [25] study. Thus, the present learning arrangement was found to influence the self-concept of those participants who were already high performers in chemistry. Contrary, little impact was found on low-achieving students in this regard. Such a correlation is consistent with the reciprocal I/E model to verbal and numerical domains [586]. Accordingly, past experience and academic achievement determine learners' self-concept in a specific field [587] resulting in both internal and social comparisons. Thus, self-concept is shaped by experiences that are transferred to similar situations [588]. Although science labs for school students are free from classic performance feedback as found in school [15, p. 49], learners still assessed their effort in the laboratory based on their prior and current performance in school chemistry. At the same time, peer comparative processes and direct feedback from the supervisors determined learners' self-perception. As a consequence, students were encouraged to readjust their current self-concept. Even if these results conflict with the intended goals of classic science labs for school students in promoting academic self-concept of all types of learners [467], a decrease of the construct is unlikely due to the lack of a comparable test setting given by the framework of the learning environment [15]. Still, as grade impact has been demonstrated throughout literature [124, 25], it would be useful for the design of future modules to explore how to disconnect science lab for school students from classic formal learning environments in order to increase the self-concept of students with a low numerical self-concept.

Second, the calculated multiple linear regression also demonstrated that gender had a predicting influence on the development of students' chemical self-concept. Other than expected girls' self-concept was less influenced from the intervention. These results support classical gender theories in science subjects [353, 589, 356, 355] as despite lower grades, participating boys formed a higher chemistry self-concept. Similar to Streller's [13, p. 129] study, girls thus rated their skills in sciences lower than boys even though test scores do not support a relationship between gender and knowledge acquisition. External comparisons [361] deliver a prevailing explanation to the observed outcomes. These evaluation processes are based on social comparisons students make with their classmates. A frequently mentioned phenomenon in this regard is the BFLPE, which explains the influence of a reference group on students' academic self-concept [590]. Thus, comparing boys with girls in a science subject such as chemistry results in girls' forming a lower self-concept than their peers despite stronger performances in the respective subject. This was also found to be similarly true in Simon's [11] study, in which boys showed an elevated academic self-concept in contrast to girls. In her study, Roth [214], too, found that girls' rated their self-concept lower based on social comparisons. The results of this investigation therefore contradict the notion that a single visit helps overcome the relationship between gender and self-concept [15]. Yet, with regard to the primary goal of science labs for school students closing the gender gap, further studies on science outreach learning settings are needed addressing the influence of the social gender on students' self-concept.

Other than expected, the predictor instructional language was not found to influence students' academic self-concept. Even though there were tendencies regarding an increase in chemistry self-concept among the monolingually instructed group, these findings were not significant. Thus, the use of English did not play a major role in this regard. These outcomes seem accurate since the verbal and chemistry self-concept are based on different dimensions of the general self-concept [331]. Taking prior studies into consideration [83, 25, 26], it was reasonable to assume that learners who had stronger foreign language dispositions and possessed a higher verbal self-concept in particular would benefit from their competences in a bilingual learning arrangement, which would then be reflected in the chemistry self-concept. Although the results indicated tendencies similar to Rodenhauser's [25] findings regarding linguistically gifted students, did not influence the learners' chemical self-concept. Consequently, a correlation with the English self-concept could not be demonstrated with respect to bilingual science lab for school students' settings, either.

6.3. Discussion Side Study Hypothesis Testing

The study examined the effects of CLIL on Arabic-speaking and Hebrew-speaking students by assessing practical experiments at a science outreach laboratory that used English as the medium of instruction. Results were compared with findings from the respective monolingual groups.

6.3.1. Cognitive Achievement

Instruction language impact

The analyses revealed that, independent of students' linguistic background, cognitive achievement was not impaired by the application of English. Thus, increased subject-related competences were detectable for all groups after the treatment. Students who received the instruction in their school language only slightly outperformed the CLIL groups. Yet, these differences were not significant. Controlling for other variables such as person-related data or motivation also did not indicate reasons for these findings. The results are in line with the outcomes of previous studies on science-related CLIL interventions in outreach settings [215, 83, 591]. One explanation for these findings could be provided by the Levels of Processing Framework [245]. In CLIL settings, instructors and students alike make use of scaffolding techniques [29] to transfer knowledge. In our study, students in the CLIL groups were supported with language aids such as vocabulary sheets to assist them in constructing speech. It could be assumed that students had to put more effort into processing nanochemical content on a semantic level [141], which might have resulted in outcomes similar to those achieved by their monolingual peers. Moreover, it is equally conceivable that translanguaging, a strategy used to support understanding helped the students in the CLIL setting to overcome language obstacles and better understand the contents.

Treatment group effects

The second research question addressed possible differences in the effects that a CLIL science setting has on Hebrew-speaking and Arabic-speaking students. Even though the outcomes did not differ significantly between the CLIL groups in the posttest, the actual knowledge gain in the Hebrew-speaking CLIL group was lower than that in the Arabic-speaking CLIL group. As cognitive achievement is regarded as an indicator of the indirect measurement of cognitive load [265], a possible explanation for the lower gain in the Hebrew-speaking CLIL group could be found in the CLT [464]. Besides experimental work, the unaccustomed learning environment, and the nanochemical topics, students had to deal with the English language in order to communicate and discuss their thoughts. The presented learning setting might have inhibited the learning process, resulting in a lowering of the students' cognitive achievement due to intrinsic, extraneous, and germane cognitive load [464]. A simultaneous learning of content and a foreign language is only possible to a certain extent before it becomes challenging for the working memory. This could explain why the Hebrew-speaking CLIL group did not score higher in the posttest even though the group had performed higher than the Arabic-speaking CLIL group before the treatment.

Furthermore, the findings open up the question of why the actual knowledge gain in the Arabic-speaking CLIL group was higher despite the fact that English is taught as the second foreign language to Arabic-speaking students. It may be reasonable to explain the outcomes based on the situation within the country, where bilingualism is fostered in the Arab sector in particular. Thus, Arabic-speaking citizens need to master Hebrew, the major language of the country, in order to fully participate in society [471]. These students are therefore constantly exposed to a second language in various life situations [471] that require a certain degree of language proficiency. Research on bilingualism has shown that trained bilingual brains have the ability to draw from two linguistic systems, which leads to a higher form of abstraction in language acquisition [165]. The existing language repertoire might further help such students to overcome obstacles when encountering a third language [592]. This thesis aligns with the results of the study from Bekerman et al. [593] study, where the authors found that Arabic-speaking school students outperformed their Hebrew-speaking peers in an English-language comprehension test. It can therefore be assumed that although the English-language level of Arabic-speaking students is predictably lower than that of their Hebrew-speaking peers, the bilingual environment in the Arabic-speaking students' everyday life supports their ability to understand the contents offered in the CLIL treatment.

6.3.2. Motivational outcomes

In general, and in line with the results of former studies on motivation related to experimenting in an outreach setting, we found a positive association between motivation and the CLIL outreach setting [81, 25, 468]. Results from the posttest confirm a short-term rise in intrinsic motivation in all groups. However, in the posttest, the Arabic-speaking CLIL group indicated an increase on the sub-scale of perceived pressure compared to the other groups. As this negative predictor correlated with the pressure felt due to the use of English, it can be assumed that the Arabic-speaking CLIL group also experienced the practical work as more challenging. According to Deci and Ryan's SDT [288], the motivation of a person is determined by a desire to experience competence and to comply with the requirements. In our study, this dual focus might have caused feelings of not being able to act as required in the laboratory environment, which may have further resulted in lower intrinsic motivation within the laboratory environment. It is equally possible to attribute the perceived pressure to the students' own reassessment of their practical skills in the laboratory environment. Students might have overrated their competencies in the application of scientific methods before the hands-on activity. With respect to their motivation when experimenting in a bilingual setting, the results found on the perceived pressure in the Arabic-speaking CLIL group support the assumption that the students rate their English-language proficiency as being lower than that of their fellow Hebrew-speaking students [474]. A low level of motivation could be further explained by the fact that the majority of learners of the English language do not plan to leave their country [594] and therefore cannot relate to the relevance of learning the English language.

Taking the treatment into consideration, extrinsic and intrinsic motivation in chemistry decreased within the Arabic-speaking CLIL group. As motivation is regulated through the object of interest [288], the analysis of the presented outcomes revealed that the use of English in the outreach activity might have contributed to a lower motivational level in chemistry. Students had to process information not just on a content level but also on a language level. In the present case, there is reason to assume that although students' motivation in chemistry decreased, learning output was not impaired. This is also confirmed by the theory of Coyle et al. [157] which states that, at the start of students' participation in a CLIL setting, they can experience a lowering in motivation due to the CLIL setting. Nonetheless, in our study, the remaining groups showed a slight increase in intrinsic and extrinsic motivation in chemistry and this finding therefore confirms the results of previous studies on the increase in motivation in CLIL classes, which students experience as being more motivating than regular foreign language classes [159].

6.4. Study Limitations

Despite the effort to attain a scientific standard, certain limitations need to be addressed when interpreting the outcomes. Recalling experiences retrospectively, methodological shortcomings concern the applied research instrument and design of the study. Due to the four reference times, it is not surprising that a great deal of data sets had to be dismissed of students who missed at least one reference time over the testing period. Moreover, this battery of questionnaires could have lead to a sinking accuracy and consistency as the test lengths presumably influenced the learners' performance [595]. Indeed, some cases had to be rejected based on the answering pattern where data did not indicate an influence of the intervention but rather some students' unwillingness to engage with the questions. This is accompanied by a reduced sample size, which neither allows to draw any definite conclusions nor to generalize the findings on similar studies. Further, in some classes, the follow-up test was administered two to three weeks behind the usual time frame due to school breaks or overlaps with other class events (e.g. exams or school projects). This delay could have distorted the results and let to a recording of weaker longitudinal effects. Even though the inquiry period had been set prior the treatment, it is difficult to prevent such defaults.

Second, as for organizational reasons the study renounced to consider a control group design. This lack of comparison primarily resulted in an inability to assess what impact the out-of-school learning setting actually had on knowledge acquisition, in particular. It is therefore difficult to explain why presenting the topic with original laboratory equipment in a realistic environment would cause a stronger learning effect than when taught in the classroom. Thus, including a control group in school would have let to a more differentiated view of the here obtained effects as it would have allowed for a greater value of the findings [368] as it significantly contributes to an increased internal validity [596].

Third, limitations also concerned the language used in the testing instrument. As discussed in Section 6.2.4, comparability between the experimental groups was ensured by choosing German as the test language in the questionnaires. This procedure aligned to preceding studies [276, 25, 26] but affected the validity of the test, since it cannot be ruled out that the instrument also examined learners' language proficiency [542]. These test-language effects apply to the knowledge test, in particular, as bilingually instructed learners had to translate the information from the intervention first from English to German in order to be able to answer the items. Accordingly, in their study, Canz et al. [542] detected such test-language effects that favored students' school language. It can therefore equally be assumed that the deviating language use might have impaired accuracy and speed while answering the items [141, p. 89].

Fourth, other limitations addressed the learning setting itself. Taking the heterogeneity of science labs for school students into consideration, different operations, conditions, sample size, target groups and research fields make it hard to draw comparisons on their effectiveness [322]. One example that displays such a reduced comparability is determined by currently existing heterogeneous educational curricula [235, p. 96]. As already pointed out, the nanotechnological contents presented in this study were not considered in the Bavarian curriculum [230]. However, in other German states the research field is firmly anchored in the syllabus [597]. As a consequence, no direct conclusions can be drawn on the effectiveness of a school embedding, since prior knowledge and school reference diverge strongly. This circumstance made it further difficult to establish a direct reference to the current school subject-matter which as a consequence, lets visiting the extracurricular setting look like a one-day excursion for participating students which makes an integration in school hard to justify.
Embedding of school-based preparation and follow-up must also be questioned in this regard. In contrast to previous studies [235], the present work did not involve teachers of the respective school, but preparation and follow-up was taken over by student assistants. This different approach in the integration of the laboratory day makes it difficult to identify which factors actually are responsible for the success of the pre- and post-testing.
From a CLIL teaching perspective Rumlich [598] already pointed to difficulties in drawing conclusions from current research due to the diverse executions of simultaneous existing modules, requirements and intensity of bilingual interventions. Considering that the present work which focused on a chemistry-related science lab for school students is unique of its kind, the assumption that this study had an entirely different focus [141, p. 77] similarly applies to this examination. Thus, it is difficult to generalize the findings and transfer them to other studies as the majority of existing research investigated CLIL in a school context.

Fifth, as criticism on bilingual studies refer to the investigation of gifted students [270], the setting and choice of methods in this present work limit comparability with many other investigations. Most studies in this field were either conducted on students who had previously qualified for the teaching style in some form or who already had experience in this area [218]. These learners come with an increased motivation and self-efficacy which make their results only marginally transferable to similar interdisciplinary settings. This was not the case in this study, as school classes were at least partially randomly assigned to the different interventions similar to Piesche's study [141]. Thus, it could be ruled out that students' linguistic proficiency had an influence on the bilingual treatment. In addition, the majority of participants were not experienced with the teaching approach.

Sixth, so far, there are still no clear guidelines to which parts school language may be applied in bilingual learning arrangements. While English was set as the language of instruction within the laboratory, it was inevitable that learners would communicate with each other in their school language. This enabled major comprehension difficulties to be levelled out, which might have affected results in the subject knowledge test. Thus, it is hard to estimate how successful the use of the foreign language in a science context had been. Even though in the past, many authors made efforts to contribute to the development of a bilingual didactic, the path is still not paved. Moreover, there is still no theoretical model that would allow a more precise measurement [599].

Seventh, another factor that applied to the current work refers to the insufficient vocational training of student teachers in bilingual teaching programs. German teacher education requires student teachers to major in two subjects, a combination that is dictated by the ministries of each German state [600]. Even though some universities started degree programs that foster pre-service teachers skills in bilingual teaching, there is still a lack of qualified staff that is competent in both, chemistry and a foreign language [601]. Albeit the preparation of the instructors in this study encompassed an interview guideline for each experimental station that would allow the conversation with students, it is possible to assume that some instructors' missing competence in English impaired students' learning. Hence, due to the placement of the module within a seminar program in which chemistry student teachers were enrolled in order to get credits for their studies, instruction quality might have suffered from pre-service teachers' English abilities since non of the students were enrolled in English studies.

7. Conclusion and Outlook

This present work outlined the conception and evaluation of a bilingual science lab for school students' module which covered five experimental stations from the field of nanotechnology summarized under the term 'Modern Materials'. Aim of the comparative study was to investigate the impact of the factors instruction language and school-based preparation and follow-up work on students' knowledge acquisition, activity-based intrinsic motivation and chemistry self-concept. The mainly positive results in the bilingual treatment groups support an embedding of the teaching approach in a scientific context and help to dispel existing fears of teachers, parents and students on CLIL in science education. Based on the results of this study, some implications for further accompanying research on bilingual science education can be drawn. It should be noted, however, that conclusions primarily refer to extracurricular learning environments even though it is nevertheless possible to extend the following remarks to school-based bilingual instruction.

Considering the outcomes on the effectiveness of a bilingual science labs for school students' visit, it can initially be stated that the purposeful use of English as the language of science allows a successful studying of subject-specific scientific content in chemistry. The in the study observed effects are significant insofar by illustrating that the application of English in an authentic learning setting is suitable for realistically conveying research activities. Purposefully using the foreign language thereby fosters meaningful learning. A focus on language further promotes a reflective discourse and allows for a thorougher observation of learners in their scientific understanding. At the same time, it opens up the opportunity to better address learners' needs. This assumption is based on the fact that foreign language use also always indicates cognitive influences. In this regard, further investigations would be helpful to examine the impact of English in science education, especially in relation to linguistic challenges in the subject matter.
Moreover, it has become evident that the learning arrangement also provided sufficient opportunities for speech and, in addition to the acquisition of evaluation competence, promoted a realistic reflection on socially relevant topics. The study was able to show that a bilingual science lab for school students has the potential to foster commitment on globally relevant issues, while at the same time it teaches learners to become responsible citizens of the 21^{st} century by developing an interdisciplinary scientific literacy. In order to address this issue, long-term programs would be desirable that examine bilingual interventions more closely,

focusing, for example, on sustainability education.

With regard to the here examined affective constructs further implications can be deduced for science classes, in general. By examining motivational predictors, for example, it was possible to determine which factors from the learning environment were favorable for students' motivation. The successful implementation of the teaching approach in the LMU *chemlab* indicated a high impact of the learning setting itself, along with students' prior knowledge, cooperative work in the laboratory and independent experimentation. These aspects should therefore be given greater consideration in order to achieve the competencies addressed in the curriculum and to make science teaching more attractive overall. The homogeneous success in knowledge intake as well as the obtained motivational effects highlight the importance of these aspects and how school lessons should be designed in this respect. Such considerations also address topics and materials used, which should emphasize not only the presentation of current research content, but also offer realistic applications to which learners can relate to supported through authentic data, texts and graphics.
Even if this study did not succeed in significantly influencing students' chemistry self-concept in the bilingual intervention, it was still possible to identify some of the factors that alter the construct. These included gender effects as well as students' prior grades in chemistry. Hence, in order to pursue equality in science domains, it would be equally beneficial to conduct studies on bilingual interventions that investigate the influence of the use of a foreign language on students' academic self-concept.

Likewise, although the present investigation could not prove a direct impact of the pre- and post-processing on learners' cognitive achievement, it is nevertheless important to create a stronger integration of the science outreach laboratory in the classroom. In this way, out-of-school settings lose their excursion character and subject content acquired in the laboratory may become more strongly connected to school science. This would require to involve teachers by pursuing a closer cooperation with the operators. Thematically coordinated modules would also help both teachers and students to achieve the greatest possible benefits from such interventions. Conversely, it allows operators of science labs for school students to tailor the range of activities to learners' needs in the classroom and thus increase its significance for science education.

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Abbreviations

AFM	Atomic force microscopy
ANOVA	Analysis of Variance
AP	Advanced Placement
AuNPs	Gold nanoparticles
BFLP	Big-fish-little pond
BICS	Basic Interpersonal Communication Skills
CA	Contact angle
CALP	Cognitive Academic Language Proficiency
CAPB	Cocamidopropyl betaine
CLIL	Content and language integrated learning
CLT	Cognitive Load Theory
DAAD	German academic exchange program
I/E-model	Internal and external frame of reference model
IMI	Intrinsic motivation inventory
LOP	Levels-of-Processing theory
LTM	Long-term memory
MNSQ	Mean square
PISA	Programme for International Student Assessment
SD	Standard deviation
SDT	Self-determination Theory
STEM	Science, Technology, Engineering and Mathematics
STM	Short-term memory
TIMSS	Third International Mathematics and Science Study
UV	Ultra violet

Vis	Visible
ZSTD	Z-standardized

Appendix

A. Scale Documentation Instruments

This section covers the scale documentation of all instruments that were included to the questionnaires. These instruments were not considered in this study (see Section 4.2 for the in the study investigated scales). All scales are depicted in the original language. The tables give an overview about the obtained Cronbach's *alpha* values, internal consistency $\mathbf{r}_{it}$ and discrimination coefficient a resulting from the omission of items. Originals and adoptions of single items are reported accordingly.

Skalen Dokumentation

Table A.0.1.: Items und Cronbach's α Werte zur Skala Freizeitinteresse Chemie. In Anlehnung an Hoffmann et al. [365].

Item **Gib bitte an, wir oft du die folgenden Dinge, die mit Chemie zu tun haben in deiner Freizeit tust**	**T0** $\alpha = .72$	**T1** $\alpha = .77$	**T2** $\alpha = .77$	**T3** $\alpha = .79$
Naturwissenschaftliche Fernsehsendungen ansehen, die mit Chemie zu tun haben	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .56$ $\mathbf{a} = .72$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .70$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .73$
Bücher lesen, die Themen aus dem Bereich der Chemie behandeln	$\mathbf{r}_{it} = .50$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .66$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .71$
In Zeitungen oder Zeitschriften Berichte über chemische Themen lesen	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .70$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .72$
Mich im Internet mit chemischen Themen zu beschäftigen	$\mathbf{r}_{it} = .50$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .43$ $\mathbf{a} = .79$	$\mathbf{r}_{it} = .49$ $\mathbf{a} =.79$

Table A.0.2.: Items und Cronbach's α Werte zur Skala Selbstkonzept Englisch. Übernommen von Kunter et al. [480].

Item	**T0** $\alpha = .93$	**T1** $\alpha = .92$	**T2** $\alpha = .92$	**T3** $\alpha = .93$
Ich bin in Englisch gut	$\mathbf{r}_{it} = .86$ $\mathbf{a} = .88$	$\mathbf{r}_{it} = .86$ $\mathbf{a} = .86$	$\mathbf{r}_{it} = .86$ $\mathbf{a} = .87$	$\mathbf{r}_{it} = .88$ $\mathbf{a} = .88$
In Englisch schneide ich in den meisten Schularbeiten gut ab	$\mathbf{r}_{it} = .86$ $\mathbf{a} = .88$	$\mathbf{r}_{it} = .84$ $\mathbf{a} = .87$	$\mathbf{r}_{it} = .85$ $\mathbf{a} = .88$	$\mathbf{r}_{it} = .86$ $\mathbf{a} = .89$
In Englisch lerne ich schnell	$\mathbf{r}_{it} = .81$ $\mathbf{a} = .92$	$\mathbf{r}_{it} = .79$ $\mathbf{a} = .91$	$\mathbf{r}_{it} = .81$ $\mathbf{a} = .91$	$\mathbf{r}_{it} = .83$ $\mathbf{a} = .92$

Table A.0.3.: Items und Cronbach's α Werte zur Skala Sachinteresse Chemie. Neu entwickelt.

Item **Wie groß oder weniger groß ist dein Interesse für die folgenden Themen aus der Chemie?**	**T0** $\alpha = .72$	**T1** $\alpha = .77$	**T2** $\alpha = .77$	**T3** $\alpha = .79$
Ich will mehr über analytische Messmethoden erfahren, z.B. für die Funktionsweise eines UV/Vis Spektrometers	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .56$ $\mathbf{a} = .72$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .70$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .73$
Ich will mehr über den Themenbereich Nanotechnologie lernen	$\mathbf{r}_{it} = .50$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .66$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .71$
Mich interessieren Themen aus der anorganischen Chemie	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .70$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .72$
Ich will mehr zur organischen Chemie erfahren	$\mathbf{r}_{it} = .50$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .43$ $\mathbf{a} = .79$	$\mathbf{r}_{it} = .49$ $\mathbf{a} =.79$

Table A.0.4.: Items und Cronbach's α Werte zur Skala intrinsischen Motivation bilinguale Chemie. Neu entwickelt.

Item	T0 α = .53	T1 α = .69	T2 α =.59	T3 α = .74
Mich interessieren in der Chemie fachwissenschaftliche Artikel aus aller Welt	$\mathbf{r}_{it}$ = .32 **a** = .47	$\mathbf{r}_{it}$ = .37 **a** = .68	$\mathbf{r}_{it}$ = .17 **a** = .64	$\mathbf{r}_{it}$ = .31 **a** = .78
Ich sehe es als eine machbare Herausforderung, Chemie auf Englisch zu lernen	$\mathbf{r}_{it}$ = .36 **a** = .44	$\mathbf{r}_{it}$ = .59 **a** = .54	$\mathbf{r}_{it}$ = .54 **a** = .37	$\mathbf{r}_{it}$ = .59 **a** = .63
Mir würde Chemie auf Englisch mehr Spaß machen	$\mathbf{r}_{it}$ = .28 **a** = .49	$\mathbf{r}_{it}$ = .48 **a** = .63	$\mathbf{r}_{it}$ = .32 **a** = .56	$\mathbf{r}_{it}$ = .61 **a** = .63
Wäre das Schülerlabor auf Englisch, würde ich die Sprache sinnvoll nutzen	$\mathbf{r}_{it}$ = .36 **a** = .43	$\mathbf{r}_{it}$ = .47 **a** = .63	$\mathbf{r}_{it}$ = .47 **a** = .44	$\mathbf{r}_{it}$ = .61 **a** = .62

Table A.0.5.: Items und Cronbach's α Werte on zur Skala intrinsischen Motivation Englisch. Übersetzt und angelehnt an Noels et al. [485].

	T0	T1	T2	T3
Item	α = .71	α = .72	α = .70	α = .74
Ich will Englisch lernen, weil ich denke, dass es gut für meine persönliche Entwicklung ist	$\mathbf{r}_{it}$ = .45 **a** = .63	$\mathbf{r}_{it}$ = .46 **a** = .70	$\mathbf{r}_{it}$ = .49 **a** = .72	$\mathbf{r}_{it}$ = .49 **a** = .72
Ich lerne gern Englisch, weil ich es gut finde mich mit der Kultur und der Geschichte des Landes der Fremdsprache auszukennen	$\mathbf{r}_{it}$ = .54 **a** = .51	$\mathbf{r}_{it}$ = .46 **a** = .54	$\mathbf{r}_{it}$ = .60 **a** = .59	$\mathbf{r}_{it}$ = .60 **a** = .59
Ich lerne gerne die englische Sprache, weil ich es mag, eine schwierige Aufgabe in der Fremdsprache zu lösen.	$\mathbf{r}_{it}$ = .48 **a** = .60	$\mathbf{r}_{it}$ = .54 **a** = .61	$\mathbf{r}_{it}$ = .58 **a** = .62	$\mathbf{r}_{it}$ = .58 **a** = .62
Ich höre mich gerne selbst Englisch sprechen, weil es sich gut anfühlt die Sprache zu verwenden	$\mathbf{r}_{it}$ = .48 **a** = .60	$\mathbf{r}_{it}$ = .54 **a** = .61	$\mathbf{r}_{it}$ = .58 **a** = .62	$\mathbf{r}_{it}$ = .58 **a** = .62

Table A.0.6.: Items und Cronbach's α Werte zur Skala extrinsischen Motivation in Chemie. Übernommen von Brandt [81].

Wenn Du Dich am Chemieunterricht beteiligst, aus welchen Gründen tust du es? Weil ...	**T0**	**T1**	**T2**	**T3**
Item	$\alpha = .67$	$\alpha = .71$	$\alpha = .73$	$\alpha = .71$
ich keine schlechte Note bekommen möchte	$\mathbf{r}_{it} = .45$ $\mathbf{a} = .63$	$\mathbf{r}_{it} = .46$ $\mathbf{a} = .70$	$\mathbf{r}_{it} = .49$ $\mathbf{a} = .72$	$\mathbf{r}_{it} = .49$ $\mathbf{a} = .72$
von mir erwartet wird, dass ich gut aufpasse	$\mathbf{r}_{it} = .54$ $\mathbf{a} = .51$	$\mathbf{r}_{it} = .46$ $\mathbf{a} = .54$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .59$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .59$
ich möchte, dass man mich für einen guten Schüler/ eine gute Schülerin hält	$\mathbf{r}_{it} = .48$ $\mathbf{a} = .60$	$\mathbf{r}_{it} = .54$ $\mathbf{a} = .61$	$\mathbf{r}_{it} = .58$ $\mathbf{a} = .62$	$\mathbf{r}_{it} = .58$ $\mathbf{a} = .62$

Table A.0.7.: Items und Cronbach's α Werte zur Skala intrinsischen Motivation in Chemie. Übernommen von Brandt [81].

Wenn Du Dich am Chemieunterricht beteiligst, aus welchen Gründen tust du es? Weil ich...	**T0**	**T1**	**T2**	**T3**
Item	$\alpha = .74$	$\alpha = .74$	$\alpha = .75$	$\alpha = .77$
die Dinge verstehen möchte	$\mathbf{r}_{it} = .57$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .56$ $\mathbf{a} = .68$	$\mathbf{r}_{it} = .55$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .61$ $\mathbf{a} = .70$
ich mich gerne am Chemieunterricht beteilige	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .57$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .57$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .59$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .65$
ich gerne knifflige Aufgaben löse	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .73$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .72$	$\mathbf{r}_{it} = .56$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .58$ $\mathbf{a} = .73$

Table A.0.8.: Items und Cronbach's α Wert zur Skala extrinsischen Motivation bilinguale Chemie. Neu entwickelt.

Item	**T0** $\alpha = .63$	**T1** $\alpha = .66$	**T2** $\alpha = .62$	**T3** $\alpha = .67$
Mir ist bewusst, dass Englisch die Sprache der Wissenschaft ist und Fachliteratur überwiegend auf Englisch ist	$\mathbf{r}_{it} = .44$ $\mathbf{a} = .54$	$\mathbf{r}_{it} = .55$ $\mathbf{a} = .52$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .48$	$\mathbf{r}_{it} = .54$ $\mathbf{a} = .55$
Im Zuge der Globalisierung kann es durchaus sein, dass meine zukünftigen Kollegen nicht alle die deutsche Sprache beherrschen	$\mathbf{r}_{it} = .34$ $\mathbf{a} = .61$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .64$	$\mathbf{r}_{it} = .31$ $\mathbf{a} = .48$	$\mathbf{r}_{it} = .40$ $\mathbf{a} = .64$
Ich will mal einen chemischen Beruf ausüben. In dieser Branche wird viel Englisch gesprochen	$\mathbf{r}_{it} = .41$ $\mathbf{a} = .57$	$\mathbf{r}_{it} = .35$ $\mathbf{a} = .67$	$\mathbf{r}_{it} = .34$ $\mathbf{a} = .62$	$\mathbf{r}_{it} = .34$ $\mathbf{a} = .69$
Viele Experimentieranleitungen sind auf Englisch geschrieben	$\mathbf{r}_{it} = .47$ $\mathbf{a} = .52$	$\mathbf{r}_{it}$ .53= $\mathbf{a} = .53$	$\mathbf{r}_{it} = .49$ $\mathbf{a} = .49$	$\mathbf{r}_{it} = .56$ $\mathbf{a} = .52$

Table A.0.9.: Items und Cronbach's α Werte zur Skala Druckempfinden. In Anlehnung an Rodenhauser [25].

Item	**T0** $\alpha = .76$	**T1** $\alpha = .78$	**T2** $\alpha = .81$	**T3** $\alpha = .82$
Dadurch, dass das Schülerlabor bilingual ist, habe ich Bedenken, ob ich einen bilingualen Kurs sprachlich hinbekomme	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .67$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .66$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .69$ $\mathbf{a} = .72$
Dadurch, dass das Schülerlabor bilingual ist, kann ich mein volles Potential im Fach Chemie nicht ausschöpfen	$\mathbf{r}_{it} = .57$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .58$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .66$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .79$
Dadurch, dass das Schülerlabor bilingual ist, fühle ich mich durch die Fremdsprache unter Leistungsdruck gesetzt	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .61$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .66$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .71$ $\mathbf{a} = .73$

Table A.0.10.: Items und Cronbach's α Werte zur Skala Fachinteresse Englisch. Übernommen von Krapp [602].

Item	**T0** $\alpha = .73$	**T1** $\alpha = .76$	**T2** $\alpha = .75$	**T3** $\alpha = .77$
Mir macht es Spaß, mich mit Inhalten auf Englisch zu beschäftigen	$\mathbf{r}_{it} = .61$ $\mathbf{a} = .61$	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .64$	$\mathbf{r}_{it} = .69$ $\mathbf{a} = .65$
In meiner Freizeit mach ich für Englisch auch Dinge, die ich nicht	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .60$	$\mathbf{r}_{it} = .67$ $\mathbf{a} = .64$	$\mathbf{r}_{it} = .68$ $\mathbf{a} = .61$	$\mathbf{r}_{it} = .67$ $\mathbf{a} = .66$
Was ich in Englisch lerne, ist für mich wichtig	$\mathbf{r}_{it} = .39$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .43$ $\mathbf{a} = .77$	$\mathbf{r}_{it} = .46$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .48$ $\mathbf{a} = .76$
Wenn ich mich mit Englisch beschäftige, vergesse ich manchmal alles um mich herum	$\mathbf{r}_{it} = .47$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .43$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .47$ $\mathbf{a} = .77$

Table A.0.11.: Items und Cronbach's α Werte zur Subskala Interesse/Vergnügen zur tätigkeitsbezogenen intrinsischen Motivation. Angelehnt an Wilde et al. [468].

Item	**T0** $\alpha =$	**T1** $\alpha =$	**T2** $\alpha = .83$	**T3** $\alpha = .87$
Das Experimentieren im Schülerlabor hat mir Spaß gemacht	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .73$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .75$ $\mathbf{a} = .81$
Ich fand die Tätigkeit im Schülerlabor sehr interessant	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .72$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .76$ $\mathbf{a} = .80$
Die Tätigkeit im Schülerlabor war unterhaltsam	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .64$ $\mathbf{a} = .83$	$\mathbf{r}_{it} = .72$ $\mathbf{a} = .83$

Table A.0.12.: Items und Cronbach's α Werte zur Subskala wahrgenommene Kompetenz zur tätigkeitsbezogenen intrinsischen Motivation. Angelehnt an Wilde et al. [468].

Item	**T0** $\alpha =$	**T1** $\alpha =$	**T2** $\alpha = .82$	**T3** $\alpha = .85$
Mit meiner Leistung im Schülerlabor bin ich zufrieden	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .84$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .88$
Bei der Tätigkeit im Schülerlabor stellte ich mich geschickt an	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .72$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .77$ $\mathbf{a} = .75$
Ich glaube, ich war bei der Tätigkeit im Schülerlabor ziemlich gut	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .73$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .78$ $\mathbf{a} = .74$

Table A.0.13.: Items und Cronbach's α Werte zur Subskala Druck/Anspannung zur tätigkeitsbezogenen intrinsischen Motivation. Angelehnt an Wilde et al. [468].

Item	**T0** $\alpha = =$	**T1** $\alpha =$	**T2** $\alpha = .72$	**T3** $\alpha = .74$
Bei der Tätigkeit im Schülerlabor fühlte ich mich unter Druck gesetzt	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .59$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .59$
Bei der Tätigkeit im Schülerlabor fühlte ich mich angespannt	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .56$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .58$
Ich hatte Bedenken, ob ich die Tätigkeit im Schülerlabor gut hinbekomme	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .47$ $\mathbf{a} = .76$	$\mathbf{r}_{it} = .46$ $\mathbf{a} = .79$

Table A.0.14.: Items und Cronbach's α Werte zur Subskala wahrgenommene Wahlfreiheit zur tätigkeitsbezogenen intrinsischen Motivation. Angelehnt an Wilde et al. [468].

Item	T0 $\alpha =$	T1 $\alpha =$	T2 $\alpha = .79$	T3 $\alpha = .79$
Ich konnte meine Tätigkeit im Schülerlabor selbst steuern	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .52$ $\mathbf{a} = .84$	$\mathbf{r}_{it} = .50$ $\mathbf{a} = .84$
Verglichen zum Chemieunterricht konnte ich bei der Tätigkeit im Schülerlabor wählen, wie ich mache	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .70$ $\mathbf{a} = .64$	$\mathbf{r}_{it} = .69$ $\mathbf{a} = .64$
Verglichen zum Chemieunterricht konnte ich bei der Tätigkeit im Schülerlabor so vorgehen, wie ich es wollte	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .69$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .71$ $\mathbf{a} = .62$

Table A.0.15.: Items und Cronbach's α Werte on zur Skala extrinsischen Motivation Englisch. Übersetzt und angelehnt an Noels et al. [485].

	T0	T1	T2	T3
Item	$\alpha = .70$	$\alpha = .77$	$\alpha = .75$	$\alpha = .77$
Ich will im Fach Englisch gut sein, um später einen angesehenen Beruf zu erlangen	$\mathbf{r}_{it} = .57$ $\mathbf{a} = .58$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .67$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .75$
In der Arbeitswelt wird es immer wichtiger die englische Sprache zu beherrschen	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .56$	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .69$
Viele Menschen auf der Welt sprechen Englisch, deshalb muss ich es auch beherrschen	$\mathbf{r}_{it} = .45$ $\mathbf{a} = .67$	$\mathbf{r}_{it} = .58$ $\mathbf{a} = .64$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .68$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .75$
Ich will im Fach Englisch eine gute Note, um später ein hohes Gehalt zu bekommen	$\mathbf{r}_{it} = .35$ $\mathbf{a} = .58$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .40$ $\mathbf{a} = .79$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .75$

Table A.0.16.: Items und Cronbach's α Werte zur Skala epistemische Komponente des aktuellen Interesses. Neu entwickelt.

Item **Der Besuch im Schülerlabor hat mein Interesse an folgenden Fragen gesteigert:**	**T0** α =	**T1** α =	**T2** α = .71	**T3** α = .72
... wie der Stand zur Nanotechnologie ist	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .50 **a** = .65	$\mathbf{r}_{it}$ = .46 **a** = .69
... wie man Nanogold herstellt	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .48 **a** = .66	$\mathbf{r}_{it}$ = .46 **a** = .62
... wie man den Lotos-Effekt nachahmen kann	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .54 **a** = .62	$\mathbf{r}_{it}$ = .52 **a** = .65
... wie man ein UV/Vis-Spektrometer bedient	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .49 **a** = .66	$\mathbf{r}_{it}$ = .49 **a** = .67

Table A.0.17.: Items und Cronbach's α Werte zur Skala emotionale Komponente des aktuellen Interesses. Übernommen von Engeln [14] und Pawek [15].

Item	**T0** α =	**T1** α =	**T2** α = .67	**T3** α = .69
Beim Experimentieren bin ich auf neue Ideen gekommen	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .48 **a** = .58	$\mathbf{r}_{it}$ = .42 **a** = .65
Die Arbeit mit Geräten, die auch in der Forschung verwendet werden, brachte mir keinen Spaß	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .59 **a** = .52	$\mathbf{r}_{it}$ = .63 **a** = .53
Die Experimente haben mir keinen Spaß gemacht	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .48 **a** = .59	$\mathbf{r}_{it}$ = .59 **a** = .56
Die Durchführung der Experimente war langweilig	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = **a** =	$\mathbf{r}_{it}$ = .31 **a** = .72	$\mathbf{r}_{it}$ = .59 **a** = .75

Table A.0.18.: Items und Cronbach's α Werte zur Skala wertbezogene Komponente des aktuellen Interesses. Übernommen von Engeln [14] und Pawek [15].

Item	**T0** $\alpha =$	**T1** $\alpha =$	**T2** $\alpha = .64$	**T3** $\alpha = .76$
Das eigenständige Experimentieren war mir wichtig	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .35$ $\mathbf{a} = .67$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .74$
Dass wir im Schülerlabor Experimente durchgeführt haben, erscheint mir sinnvoll	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .49$ $\mathbf{a} = .51$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .65$
Dass wir im Schülerlabor Experimente durchgeführt haben, ist mir persönlich wichtig	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .41$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .63$

Table A.0.19.: Items und Cronbach's α Werte zur Skala Authentizität (Laborvariable). Übernommen von Pawek [15].

Item	**T0** $\alpha =$	**T1** $\alpha =$	**T2** $\alpha = .76$	**T3** $\alpha = .80$
Ich habe heute einen Einblick in den Berufsalltag von Wissenschaftlern bekommen	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .62$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .68$ $\mathbf{a} = .68$
Ich habe heute ein Gefühl dafür bekommen, wie Forschung funktioniert	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .63$ $\mathbf{a} = .64$	$\mathbf{r}_{it} = .68$ $\mathbf{a} = .68$
Ich habe heute etwas über die Ziele naturwissenschaftlicher Forschung gelernt	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .56$ $\mathbf{a} = .80$

Table A.0.20.: Items und Cronbach's α Werte zur Skala Betreuung (Laborvariable). Übernommen von Pawek [15].

Item	**T0** $\alpha =$	**T1** $\alpha =$	**T2** $\alpha = .70$	**T3** $\alpha = .70$
Ich hatte die Möglichkeit, den Betreuern des Schülerlabors Fragen zu stellen	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .48$ $\mathbf{a} = .66$	$\mathbf{r}_{it} = .50$ $\mathbf{a} = .64$
Ich habe das Gefühl, dass die Betreuer von den Naturwissenschaften fasziniert sind	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .51$ $\mathbf{a} = .63$	$\mathbf{r}_{it} = .47$ $\mathbf{a} = .67$
Die Arbeitsatmosphäre während des Experimentierens fand ich gut	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .57$ $\mathbf{a} = .53$	$\mathbf{r}_{it} = .59$ $\mathbf{a} = .51$

Table A.0.21.: Items und Cronbach's α Werte zur Skala Herausforderung (Laborvariable). Übernommen von Pawek [15].

Item	**T0** $\alpha =$	**T1** $\alpha =$	**T2** $\alpha = .57$	**T3** $\alpha = .69$
Die Experimente waren eine Herausforderung für mich	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .40$ $\mathbf{a} = .$	$\mathbf{r}_{it} = .40$ $\mathbf{a} = .$
Das Finden der Erklärungen für die Experimente war eine Herausforderung	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .$

Table A.0.22.: Items und Cronbach's α Werte zur Skala Zusammenarbeit (Laborvariable). Übernommen von Engeln [14] und Pawek [15].

Item	T0 $\alpha =$	T1 $\alpha =$	T2 $\alpha = .63$	T3 $\alpha = .65$
Ich habe während des Experimentierens gut mit meinen Mitschülerinnen und Mitschülern im Team zusammengearbeitet	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .38$ $\mathbf{a} = .61$	$\mathbf{r}_{it} = .43$ $\mathbf{a} = .61$
Ich habe während der Experimente meinen Mitschülerinnen / Mitschülern etwas erklärt oder mir ist von ihnen etwas erklärt worden	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .39$	$\mathbf{r}_{it} = .53$ $\mathbf{a} = .47$
Ich habe während des Experimentierens mit meinen Mitschülerinnen und Mitschülern über naturwissenschaftliche Sachverhalte diskutiert	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .42$ $\mathbf{a} = .56$	$\mathbf{r}_{it} = .45$ $\mathbf{a} = .59$

Table A.0.23.: Items und Cronbach's α Werte zur Skala Verständlichkeit (Laborvariable). Übernommen von Engeln [14] und Pawek [15].

Item	T0 $\alpha =$	T1 $\alpha =$	T2 $\alpha = .61$	T3 $\alpha = .62$
Ich hatte genügend Kenntnisse, um die Experimente erfolgreich durchzuführen	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .56$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .57$
Ich konnte die Aufgaben, die mir heute gestellt wurden, gut bewältigen	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .39$	$\mathbf{r}_{it} = .55$ $\mathbf{a} = .43$
Ich habe die Anleitungen zum Experimentieren gut verstanden	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .33$ $\mathbf{a} = .58$	$\mathbf{r}_{it} = .39$ $\mathbf{a} = .55$
Das Finden der Erklärungen für die Experimente war eine Herausforderung	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .30$ $\mathbf{a} = .60$	$\mathbf{r}_{it} = .30$ $\mathbf{a} = .62$

Table A.0.24.: Items und Cronbach's α Werte zur Skala Alltagsbezug (Laborvariable). Übernommen von Pawek [15].

Item	T0 $\alpha =$	T1 $\alpha =$	T2 $\alpha = .61$	T3 $\alpha = .62$
Ich konnte eine Bedeutung der durchgeführten Experimente für das alltägliche Leben erkennen	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .56$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .57$
Ich habe einen Eindruck über die Bedeutung der Forschung für mein alltägliches Leben bekommen	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .39$	$\mathbf{r}_{it} = .55$ $\mathbf{a} = .43$
Ich habe heute etwas über die Bedeutung von Naturwissenschaften für unseren Alltag gelernt	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .33$ $\mathbf{a} = .58$	$\mathbf{r}_{it} = .39$ $\mathbf{a} = .55$
Ich habe heute etwas über die Bedeutung von Naturwissenschaften für unsere Gesellschaft gelernt	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .30$ $\mathbf{a} = .60$	$\mathbf{r}_{it} = .30$ $\mathbf{a} = .62$

Table A.0.25.: Items und Cronbach's α Werte zur Skala Vorbereitung. Übernommen von Glowinski [12].

Item	T0 $\alpha =$	T1 $\alpha =$	T2 $\alpha = .61$	T3 $\alpha = .62$
Ich habe mich im Unterricht und/oder durch Hausaufgaben auf das Thema vorbereitet	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .56$	$\mathbf{r}_{it} = .36$ $\mathbf{a} = .57$
Ich wurde, im Nachhinein gesehen ausreichend auf den Besuch im Schülerlabor vorbereitet	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} =$ $\mathbf{a} =$	$\mathbf{r}_{it} = .60$ $\mathbf{a} = .39$	$\mathbf{r}_{it} = .55$ $\mathbf{a} = .43$

Table A.0.26.: Items und Cronbach's α Werte zur Skala Selbstkonzept Chemie. In Anlehnung an Engeln [14].

Item	T0 $\alpha = .81$	T1 $\alpha = .79$	T2 $\alpha = .80$	T3 $\alpha = .80$
Bei manchen Sachen in Chemie, die ich nicht verstanden habe, weiß ich vornherein:Das verstehe ich nie	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .74$	$\mathbf{r}_{it} = .66$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .67$ $\mathbf{a} = .72$	$\mathbf{r}_{it} = .69$ $\mathbf{a} = .71$
Obwohl ich mir bestimmt Mühe gebe, fällt mir das Fach Chemie schwer	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .75$	$\mathbf{r}_{it} = .65$ $\mathbf{a} = .71$	$\mathbf{r}_{it} = .72$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .70$ $\mathbf{a} = .70$
Ich finde es wichtig, mich mit Fragestellungen aus der Chemie auseinanderzusetzen	$\mathbf{r}_{it} = .75$ $\mathbf{a} = .69$	$\mathbf{r}_{it} = .76$ $\mathbf{a} = .65$	$\mathbf{r}_{it} = .70$ $\mathbf{a} = .70$	$\mathbf{r}_{it} = .69$ $\mathbf{a} = .71$
Das Fach Chemie liegt mir nicht besonders	$\mathbf{r}_{it} = .45$ $\mathbf{a} = .83$	$\mathbf{r}_{it} = .35$ $\mathbf{a} = .84$	$\mathbf{r}_{it} = .37$ $\mathbf{a} = .85$	$\mathbf{r}_{it} = .38$ $\mathbf{a} = .85$

Table A.0.27.: Faktorenanalyse (Hauptkomponentenanalyse mit Varimax -Rotation) zur Motivation bilingualer Chemieunterricht. Items mit der höchsten Faktorenladung sind fettgedruck ($n = 387$).

Item	T0		T1		T2		T3	
	Fact. 1	Fact. 2	Fact. 1	Fact. 2	Fact. 1	Fact. 2	Fact. 1	Fact. 2
mb1.1		.592	.472			.450		.415
mb1.2	.302	**.717**		.821		.776		.833
mb1.3		.786		.835		.657		.716
mb1.4	.419	**.433**	.310	**.601**		.757		.746
mb1.5	.686		**.680**	.306	.796		.804	
mb1.6	.626		.381	**.413**	.627		.677	
mb1.7	.578		.724		.559		.529	
mb1.8	.726		.786		.711		.770	

B. Questionnaires of the Interventional Study

Questionnaire Pre-pretest T0 and Pretest T1

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Liebe Schülerin, liebe Schüler,

herzlich willkommen im **LMUchemlab**! Das Schülerlabor möchte Schulklassen die Möglichkeit bieten, Experimente aus aktueller Forschung an modernen Materialien zu erleben. Um die Wirkung dieser Erfahrung auf euch Schülerinnen und Schüler nachzuvollziehen und um das Schülerlaborprogramm weiter auf euch anzupassen, benötigen wir Deine Hilfe! Alles was Du tun müsst, ist den folgenden Fragebogen gewissenhaft auszufüllen!

Der vorliegende Fragebogen dient lediglich der Erfassung Deines Eindrucks vom Schülerlabor und hat keinerlei weitere Funktion, die in irgendeiner Weise Deine Schulnoten beeinflussen würde. Die Fragebogenerhebung findet zu vier Zeitpunkten statt. Die Fragebögen sind anonym, ein Rückschluss auf Deine Person ist ausgeschlossen. Dennoch ist es wichtig, dass die Fragen bei der Auswertung einem Fragebogen eindeutig zugeordnet werden können. Damit das möglich ist, bitten wir Dich aus den in der Tabelle erfragten Aspekten ein Kürzel zu bilden.

2. Buchstabe des Vornamens des Vaters	**3. Buchstabe des Vornamens der Mutter**	**1. Buchstabe des Mädchennamens der Mutter**	**3. Buchstabe des Namens der Oma (väterlicherseits)**	**Eigener Geburtsmonat z.B. 03 für März oder 11 für November**

Bitte beantworte die Dir vorliegenden Fragen ehrlich und sorgfältig, nur so kann das LMUchemlab auf Verbesserungsvorschläge reagieren. Bei den Fragen handelt es sich um Single Choice Fragen, also setze bitte bei jeder Frage klar ein Kreuz auf die vorgesehenen Kreise, nicht dazwischen!!

Dauer: ca. 20 Minuten

Unmittelbar nach dem Schülerlaborbesuch, sowie sechs bis acht Wochen darauf wird die Befragung wiederholt.

Für Rückfragen zu dieser Untersuchung stehe ich Dir gerne unter der angeführten E-Mail-Adresse zur Verfügung. Vielen Dank im Voraus für Deine Mithilfe!

Mit freundlichen Grüßen

S. Hollweck

Sezen Hollweck

Sezen.hollweck@cup.uni-muenchen.de

Ludwig-Maximilians-Universität München

Butenandt Straße 5-13

81377 Großhadern

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Fragen zu Deiner Person			
PBD 1.1	Ich bin	männlich O	weiblich O
PBD 1.2	Meine Muttersprache ist	deutsch O	andere: ___________
PBD 1.3	Ich besuche die Jahrgangstufe 10 | 11 | 12 O O O		
PBD 1.4	Ich bin ____ Jahre alt.		
PBD 1.5	Ich habe schon einmal an einem bilingualen Zug/Unterricht an meiner Schule teilgenommen	ja O	nein O
PBD 1.5.1	**Wenn ja:**	Ich besuche schon das __. Jahr einen bilingualen Zug/Unterricht an meiner Schule	
PBD 1.6	Ich habe schon mal an einem englischsprachigen Auslandsaufenthalt teilgenommen	ja O	nein O
PBD 1.7	Welche Note hattest Du in Chemie im letzten Zeugnis?	1 | 2 | 3 | 4 | 5 | 6 O O O O O O Ich hatte keinen Chemieunterricht O	
PBD 1.8	Welche Note hattest Du in Englisch im letzten Zeugnis?	1 | 2 | 3 | 4 | 5 | 6 O O O O O O	

Gib bitte an, in wieweit folgende Aussagen auf Dich zutreffen:

Gib bitte an, wir oft Du die folgenden Dinge, die mit Chemie zu tun haben, in Deiner Freizeit tust:		**sehr oft**	**oft**	**manch-mal**	**selten**	**nie**
FCH 1.1	Naturwissenschaftliche Fernsehsendungen ansehen, die mit Chemie zu tun haben	O	O	O	O	O
FCH 1.2	Bücher lesen, die Themen aus dem Bereich der Chemie behandeln	O	O	O	O	O
FCH 1.3	In Zeitungen oder Zeitschriften Berichte über chemische Themen lesen	O	O	O	O	O
FCH 1.4	Mich im Internet (z.B. YouTube) mit chemischen Themen zu beschäftigen	O	O	O	O	O

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Wie groß oder gering ist Dein Interesse für die folgenden Themen aus der Chemie?		**sehr groß**	**groß**	**mittel**	**gering**	**sehr gering**
ICH 1.1	Ich will mehr über analytische Messmethoden erfahren z.B. über die Funktionsweise eines UV/Vis Spektrometers	O	O	O	O	O
ICH 1.2	Ich will mehr über den Themenbereich Nanotechnologie lernen, z.B. zum Einsatz in Lebensmitteln	O	O	O	O	O
ICH 1.3	Mich interessieren Themen aus der anorganischen Chemie, wie das Themenfeld der Elektrochemie	O	O	O	O	O
ICH 1.4	Ich will mehr zur organischen Chemie erfahren, z.B. zu pharmazeutischen Stoffen	O	O	O	O	O

Gib bitte an, wir oft Du die folgenden Dinge, die mit Englisch zu tun haben, in Deiner Freizeit tust:		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
FEN 1.1	Mir macht es Spaß, mich mit Inhalten auf Englisch zu beschäftigen	O	O	O	O
FEN 1.2	In meiner Freizeit mach ich für Englisch auch Dinge, die ich nicht machen muss	O	O	O	O
FEN 1.3	Was ich in Englisch lerne, ist für mich wichtig	O	O	O	O
FEN 1.4	Wenn ich mich mit Englisch beschäftige, vergesse ich manchmal alles um mich herum	O	O	O	O

Wenn Du Dich am Englischunterricht beteiligst, aus welchen Gründen tust du es?		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
IME 1.1	Ich will Englisch lernen, weil ich denke, dass es gut für meine persönliche Entwicklung ist	O	O	O	O
IME 1.2	Ich lerne gern Englisch, weil ich es gut finde mich in der Kultur und der Geschichte des Landes der Fremdsprache auszukennen	O	O	O	O
IME 1.3	Ich lerne gerne die englische Sprache, weil ich es mag, eine schwierige Aufgabe in der Fremdsprache zu lösen	O	O	O	O
IME 1.4	Ich höre mich gerne selbst Englisch sprechen, weil es sich gut anfühlt die Sprache zu verwenden	O	O	O	O
EXM 1.1	Ich will im Fach Englisch gut sein, um später einen angesehenen Beruf zu erlangen	O	O	O	O
EXM 1.2	In der Arbeitswelt wird es immer wichtiger die englische Sprache zu beherrschen	O	O	O	O
EXM 1.3	Viele Menschen auf der Welt sprechen Englisch, deshalb muss ich es auch beherrschen	O	O	O	O
EXM 1.4	Ich will im Fach Englisch eine gute Note, um später ein hohes Gehalt zu bekommen	O	O	O	O

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Wie sehr stimmst Du folgenden Aussagen über die Bedeutung der Sprache Englisch in der Naturwissenschaft zu? Die englische Sprache zu beherrschen ist wichtig, weil…		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
EMB 1.1	mir bewusst ist, dass Englisch die Sprache der Wissenschaft ist und Fachliteratur überwiegend auf Englisch ist	O	O	O	O
EMB 1.2	im Zuge der Globalisierung es durchaus sein kann, dass meine zukünftigen Kollegen nicht alle die deutsche Sprache beherrschen	O	O	O	O
EMB 1.3	ich mal einen chemischen Beruf ausüben will. In dieser Branche wird viel Englisch gesprochen	O	O	O	O
EMB 1.4	viele Experimentieranleitungen auf Englisch geschrieben sind	O	O	O	O

Wie sehr stimmst Du folgenden Aussagen zu?		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
IMB 1.1	Mich interessieren in der Chemie fachwissenschaftliche Artikel aus aller Welt	O	O	O	O
IMB 1.2	Ich sehe es als eine machbare Herausforderung, Chemie auf Englisch zu lernen	O	O	O	O
IMB 1.3	Mir würde Chemie auf Englisch mehr Spaß machen	O	O	O	O
IMB 1.4	Wäre das Schülerlabor auf Englisch, würde ich die Sprache sinnvoll nutzen lernen	O	O	O	O

Wenn Du Dich am Chemieunterricht beteiligst, aus welchen Gründen tust du es? Weil ich…		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
IMC 1.1	die Dinge verstehen möchte	O	O	O	O
IMC 1.2	mich gerne im Chemieunterricht beteilige	O	O	O	O
IMC 1.3	gerne knifflige Probleme löse	O	O	O	O

Wenn Du Dich am Chemieunterricht beteiligst, aus welchen Gründen tust du es?		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
EMC 1.1	Weil ich keine schlechte Note bekommen möchte	O	O	O	O
EMC 1.2	Weil von mir erwartet wird, dass ich gut aufpasse	O	O	O	O
EMC 1.3	Weil ich möchte, dass man mich für einen guten Schüler/ eine gute Schülerin hält	O	O	O	O

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Wie sehr stimmst Du folgenden Fragen zu?		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
GS 1.1	Manche Leute haben eine besondere Begabung eine Fremdsprache zu lernen	O	O	O	O
GS 1.2	Leute die gut in Mathe oder einer Naturwissenschaft sind, haben Schwierigkeiten im Lernen einer Fremdsprache	O	O	O	O
GS 1.3	Mädchen lernen Sprachen besser als Jungs	O	O	O	O
GS 1.4	Es ist einfacher in der englischen Sprache zu lesen und zu schreiben, als es zu sprechen und zu verstehen	O	O	O	O
GS 1.5	Es ist einfacher Englisch zu sprechen als es zu verstehen	O	O	O	O
GS 1.6	Das wichtigste beim Fremdsprachenlernen ist das Lernen von neuen Vokabeln	O	O	O	O
GS 1.7	Das Lernen einer Sprache unterscheidet sich vom Lernen anderer Schulfächer	O	O	O	O
GS 1.8	Ich bin zu schüchtern um Englisch mit anderen Leuten zu sprechen	O	O	O	O

Wie schätzt Du Dich selbst ein?		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
FC 1.1	Bei manchen Sachen in Chemie, die ich nicht verstanden habe, weiß ich vornherein: „Das verstehe ich nie“	O	O	O	O
FC 1.2	Obwohl ich mir bestimmt Mühe gebe, fällt mir das Fach Chemie schwer	O	O	O	O
FC 1.3	Ich finde es wichtig, mich mit Fragestellungen aus der Chemie auseinanderzusetzen	O	O	O	O
FC 1.4	Das Fach Chemie liegt mir nicht besonders.	O	O	O	O
FE 1.1	Ich bin in Englisch gut	O	O	O	O
FE 1.2	In Englisch schneide ich in den meisten Schularbeiten/Tests gut ab	O	O	O	O
FE 1.3	In Englisch lerne ich schnell	O	O	O	O

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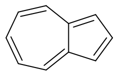
Wäre das Schülerlabor bilingual…		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
DE 1.1	hätte ich Bedenken, ob ich einen bilingualen Kurs sprachlich hinbekomme	O	O	O	O
DE 1.2	könnte ich nicht mein volles Potential im Fach Chemie ausschöpfen	O	O	O	O
DE 1.3	würde ich mich durch die bilinguale Inhalte unter Leistungsdruck gesetzt fühlen	O	O	O	O

Nun ist Dein chemisches Fachwissen ist gefragt! Kreuze auch hier bitte nur eine der folgenden Aussagen an!

FA1.1 Azulen  **zählt zur Klasse der Aromaten, da**	
O	das organische Molekül cyclisch planar ist, ein konjugiertes Ringsystem an delokalisierten Doppelbindungselektronen besitzt und der Hückel-Regel (4n +2) folgt
O	da das anorganische Molekül cyclisch planar ist, ein konjugiertes Ringsystem an delokalisierten Doppelbindungselektronen besitzt und der Hückel- Regel (4n +2) folgt
O	da das organische Molekül cyclisch planar ist, ein konjugiertes Ringsystem an delokalisierten Doppelbindungselektronen besitzt und der Hückel- Regel (6n +2) folgt
O	Azulen ist kein Aromat

FA 1.2 Azulen hat die chemische Summenformel $C_{10}H_8$. Aus welche beiden Systemen setzt sich Azulen zusammen:	
O	2,3,5-Heptatriene und Benzol
O	Cycloheptatrien und Cyclopentadien
O	Cyclooctatetraen und Cyclobutadien
O	Cycloheptatrien und Cyclohexatrien

FA 1.3 Sonnenschutzfilter	
O	absorbieren größtenteils das sichtbare Licht im optischen Spektrums der Sonne
O	bestehen ausschließlich aus Antioxidantien
O	werden nur für kosmetische Zwecke eingesetzt
O	werden im unsichtbaren Licht des optischen Spektrums der Sonne aktiv

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	FA 1.4 Tenside bestehen aus einem Alkyrest und einer Carboxylatgruppe. Damit sind sie in der Lage
O	polare und unpolare Stoffe zu vermengen
O	unpolare Stoffe zu verdrängen
O	sich mit einer der beiden Phasen zu vermischen
O	erhöhen die Grenzflächenspannung einer Flüssigkeit

	FA 1.5 Die Wirkungsweise organischer Filter beruht auf der
O	Absorption von kurzwelligen, energiereichen Strahlung, in der die Moleküle in den angeregten Zustand übergehen. Diese wird in Form von Wärme oder Lichtstrahlung wieder emittiert.
O	Absorption von langwelligen, energiearmen in der die Moleküle in den angeregten Zustand übergehen. Diese wird in Form von Wärme oder Lichtstrahlung wieder emittiert.
O	Durch die Reflektion kurzwelliger, energiereicher Strahlung auf der Haut
O	Durch die Reflektion langwelliger, energiearmer Strahlung auf der Haut

	FL 1.1 Der sogenannte Leidenfrosteffekt zeigt sich, wenn ein Tropfen auf eine sehr heiße Platte fällt und beginnt zu tanzen. Der Effekt
O	ist schon bei 100 °C zu beobachten
O	beruht auf der raschen Verdampfung des Wassertropfens durch eine wärmeleitende Schicht unter dem Tropfen
O	beruht auf der schlechten Leitfähigkeit von Wasser, die das Verdampfen des Wassertropfens auf der heißen Herdplatte verzögert
O	ist abhängig von der hohen Siedetemperatur des Wassers

	FL 1.2 Die Farbigkeit von Goldnanopartikel hängt von der
O	Masse des Goldes ab
O	Geschwindigkeit der Goldnanopartikel in der Lösung
O	Größe der Nanopartikel und damit einhergehend der Wellenlänge des absorbierten Lichtes zusammen
O	Bei farbigen Partikeln handelt es sich nicht um Gold

	FK 1.1 Lotos-Blätter weisen die Eigenschaft auf, Wasser abperlen zu lassen. Wie muss die Beschaffenheit der Oberfläche des Blattes aussehen?
O	Das Blatt hat eine sehr glatte Oberfläche, wodurch der Wassertropfen leicht vom Blatt abperlen kann
O	Die Oberfläche des Blatt ist sehr glatt und von einer dünnen Wachsschicht überzogen, die den Tropfen in seiner runden Form erhält
O	Die Oberfläche ist sehr rau und ist bedeckt von Wachsnoppen, die ein Aufliegen des Wassertropfens auf dem Blatt verhindern, wodurch der Tropfen seine Form behält
O	Die Blattoberfläche hat mit dem abperlenden Wassertropfen nichts zu tun

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FK 1.2 Bei der Kontaktwinkelmessung kann das Aufliegen eines Wassertropfens nachgemessen werden. Dieser hat auf dem Lotosblatt einen Winkel von	
O	ca. 4°
O	ca. 30°
O	ca. 40°
O	ca. 150°

FK 1.3 Um den Lotoseffekt chemisch nachzustellen, wir unteranderem Laurin-Säure verwendet. Was bewirkt der Einsatz von Laurinsäure?	
O	die Oberfläche wird dadurch super-hydrophil
O	die Oberfläche wird super-hydrophob
O	die Oberfläche wird dadurch glatt
O	die Oberfläche wird dadurch sauer

FS 1.1 Warum zerplatzen Seifenblasen so schnell?	
O	aufgrund der Schwerkraft und dem Verdunsten der Wassermoleküle
O	aufgrund der Schwerkraft und der Anziehungskräfte zwischen dem Tensid und dem Stabilisator Xanthan
O	die Luft übt einen Druck auf die Seifenblasenhaut aus, wodurch diese zerplatzt
O	zu wenig Tensid in der Seifenblasenflüssigkeit

SO, GESCHAFFT! DIES WAR DER LETZTE FRAGEBOGEN. NOCHMALS: GANZ HERZLICHEN DANK FÜR DEINE HILFE!

Questionnaire Posttest T2 and Follow-Up T3

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Liebe Schülerin, lieber Schüler,

herzlich willkommen im **LMUchemlab**! Das Schülerlabor möchte Schulklassen die Möglichkeit bieten, Experimente aus aktueller Forschung an modernen Materialien zu erleben. Um die Wirkung dieser Erfahrung auf euch Schülerinnen und Schüler nachzuvollziehen und um das Schülerlaborprogramm weiter auf euch anzupassen, benötigen wir Deine Hilfe! Alles was Ihr tun müsst, ist den folgenden Fragebogen gewissenhaft auszufüllen!

Der vorliegende Fragebogen dient lediglich der Erfassung Deines Eindrucks vom Schülerlabor und hat keinerlei weitere Funktion, die in irgendeiner Weise Deine Schulnoten beeinflussen würde. Die Fragebogenerhebung findet zu zwei Zeitpunkten (inklusive diesem) statt. Die Fragebögen sind anonym, ein Rückschluss auf Deine Person ist ausgeschlossen. Dennoch ist es wichtig, dass die Fragen bei der Auswertung einem Fragebogen eindeutig zugeordnet werden können. Damit das möglich ist, bitten wir Dich aus den in der Tabelle erfragten Aspekten ein Kürzel zu bilden.

2. Buchstabe des Vornamens des Vaters	**3. Buchstabe des Vornamens der Mutter**	**1. Buchstabe des Mädchennamens der Mutter**	**3. Buchstabe des Namens der Oma (väterlicherseits)**	**Eigener Geburtsmonat z.B. 03 für März oder 11 für November**

Bitte beantworte die Dir vorliegenden Fragen ehrlich und sorgfältig, nur so kann das LMUchemlab auf Verbesserungsvorschläge reagieren. Bei den Fragen handelt es sich um Single Choice Fragen, also setze bitte bei jeder Frage klar ein Kreuz auf die vorgesehenen Kreise, nicht dazwischen!!

Dauer: ca. 20 Minuten

Nach acht bis zehn Wochen wird diese Befragung wiederholt.

Für Rückfragen zu dieser Untersuchung stehe ich Dir gerne unter der angeführten E-Mail-Adresse zur Verfügung. Vielen Dank im Voraus für Deine Mithilfe!

Mit freundlichen Grüßen

Sezen Hollweck

Sezen.hollweck@cup.uni-muenchen.de

Ludwig-Maximilians-Universität München

Butenandt Straße 5-13

81377 München

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Welchen Eindruck hat das LMUchemlab auf Dich gemacht? Bitte beantworte folgende Fragen wahrheitsgemäß!

Im Schülerlabor …		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
TIV 1.1	hat mir das Experimentieren Spaß gemacht	O	O	O	O
TIV 1.2	fand ich die Tätigkeit sehr interessant	O	O	O	O
TIV 1.3	Die Tätigkeit im Schülerlabor war unterhaltsam	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
TIK 1.1	Mit meiner Leistung im Schülerlabor bin ich zufrieden	O	O	O	O
TIK 1.2	Bei der Tätigkeit im Schülerlabor stellte ich mich geschickt an	O	O	O	O
TIK 1.3	Ich glaube, ich war beim Experimentieren im Schülerlabor ziemlich gut	O	O	O	O

Im Schülerlabor …		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
TIW 1.1	konnte ich das Experimentieren selbst steuern	O	O	O	O
TIW 1.2	konnte ich, verglichen zum Chemieunterricht, wählen, wie ich es mache	O	O	O	O
TIW 1.3	konnte ich, verglichen zum Chemieunterricht, beim Experimentieren so vorgehen, wie ich es wollte	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen auf Dich zutreffen:		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
TD 1.1	Bei der Tätigkeit im Schülerlabor fühlte ich mich unter Druck gesetzt	O	O	O	O
TD 1.2	Bei der Tätigkeit im Schülerlabor fühlte ich mich angespannt	O	O	O	O
TD 1.3	Ich hatte Bedenken, ob ich die Aufgaben und Experimente im Schülerlabor gut hinbekomme	O	O	O	O

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Gib bitte an, in wieweit folgende Aussagen auf Dich zutreffen:		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
EAI 1.1	Die Arbeit mit Geräten, die auch in der Forschung verwendet werden, brachte mir keinen Spaß	O	O	O	O
EAI 1.2	Die Experimente waren für mich interessant	O	O	O	O
EAI 1.3	Die Experimente haben mir keinen Spaß gemacht	O	O	O	O
EAI 1.4	Während des Experimentierens ist die Zeit sehr langsam vergangen	O	O	O	O
EAI 1.5	Die Durchführung der Experimente war langweilig	O	O	O	O

Im Schülerlabor…		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
WAI 1.1	War mir das eigenständige Experimentieren wichtig	O	O	O	O
WAI 1.2	Experimente durchzuführen, erschien mir sinnvoll	O	O	O	O
WAI 1.3	Experimente durchzuführen, ist mir persönlich wichtig	O	O	O	O
WAI 1.4	war mir die Zusammenarbeit mit den Mitschülerinnen bzw. Mitschülern wichtig	O	O	O	O

Stell Dir vor: Du hast eine knifflige Aufgabe in Chemie gelöst. Warum ist Dir das wahrscheinlich gelungen? Weil…		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
EA 1.1	Du Dich so angestrengt hast	O	O	O	O
EA 1.2	es Zufall war	O	O	O	O
EA 1.3	Du Chemie sehr gut kannst	O	O	O	O
EA 1.4	die Aufgabe einfach war	O	O	O	O

Gib bitte an, wie sehr du folgenden Aussagen zustimmst:		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
EPAI 1.1	Beim Experimentieren bin ich auf neue Ideen gekommen	O	O	O	O
EPAI 1.2	Die Arbeit mit Geräten, die auch in der Forschung verwendet werden, brachte mir keinen Spaß	O	O	O	O
EPAI 1.3	Die Experimente haben mir keinen Spaß gemacht	O	O	O	O
EPAI 1.4	Die Durchführung der Experimente war langweilig	O	O	O	O

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Der Besuch im Schülerlabor hat mein Interesse / Wissen an folgenden Fragen gesteigert…		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
SIW 1.1	…was moderne Materialien sind	O	O	O	O
SIW 1.2	…wie Nanotechnologie in der Kosmetik verwendet wird	O	O	O	O
SIW 1.3	…wie man den Lotos-Effekt nachahmen kann	O	O	O	O
SIW 1.4	… wie man ein UV/Vis-Spektrometer bedient	O	O	O	O
SIW 1.5	…wie Wissenschaftler arbeiten	O	O	O	O
SIW 1.6	…wie man in einem Labor arbeitet	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
LA 1.1	Ich konnte eine Bedeutung der durchgeführten Experimente für das alltägliche Leben erkennen	O	O	O	O
LA 1.2	Ich habe einen Eindruck über die Bedeutung der Forschung für mein alltägliches Leben bekommen	O	O	O	O
LA 1.3	Ich habe heute etwas über die Bedeutung von Naturwissenschaften für unseren Alltag gelernt	O	O	O	O
LA 1.4	Ich habe heute etwas über die Bedeutung von Naturwissenschaften für unsere Gesellschaft gelernt	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
LAU 1.1	Ich habe heute einen Einblick in den Berufsalltag von Wissenschaftlern bekommen	O	O	O	O
LAU 1.2	Ich habe heute ein Gefühl dafür bekommen, wie Forschung funktioniert	O	O	O	O
LAU 1.3	Ich habe heute etwas über die Ziele naturwissenschaftlicher Forschung gelernt	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
VS 1.1	Ich habe mich durch die Videos vorbereitet gefühlt	O	O	O	O
VS 1.2	Ich wurde, im Nachhinein gesehen, ausreichend auf den Besuch im Schülerlabor vorbereitet	O	O	O	O

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Wenn Du Dich am Chemieunterricht beteiligst, aus welchen Gründen tust du es? Weil ich…		**Stimmt gar nicht**	**Stim mt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
IMC 1.1	die Dinge verstehen möchte	O	O	O	O
IMC 1.2	mich gerne im Chemieunterricht beteilige	O	O	O	O
IMC 1.3	gerne knifflige Probleme löse	O	O	O	O
EMC 1.1	weil ich keine schlechte Note bekommen möchte	O	O	O	O
EMC 1.2	weil von mir erwartet wird, dass ich gut aufpasse	O	O	O	O
EMC 1.3	weil ich möchte, dass man mich für einen guten Schüler/ eine gute Schülerin hält	O	O	O	O

Gib bitte an, wie oft Du die folgenden Dinge in Deiner Freizeit tust:		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
FEN 1.1	Mir macht es Spaß, mich mit Inhalten auf Englisch zu beschäftigen	O	O	O	O
FEN 1.2	In meiner Freizeit mach ich für Englisch auch Dinge, die ich nicht machen muss	O	O	O	O
FEN 1.3	Was ich in Englisch lerne, ist für mich wichtig	O	O	O	O
FEN 1.4	Wenn ich mich mit Englisch beschäftige, vergesse ich manchmal alles um mich herum	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
LB 1.1	Ich hatte die Möglichkeit, den Betreuern des Schülerlabors Fragen zu stellen	O	O	O	O
LB 1.2	Ich habe das Gefühl, dass die Betreuer von Naturwissenschaften / Technik fasziniert sind	O	O	O	O
LB 1.3	Die Arbeitsatmosphäre während des Experimentierens fand ich gut	O	O	O	O

Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
LH 1.1	Die Experimente waren eine Herausforderung für mich	O	O	O	O
LH 1.2	Das Finden der Erklärungen für die Experimente war eine Herausforderung	O	O	O	O

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Gib bitte an, in wieweit folgende Aussagen für Dich zutreffen:		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
LV 1.1	Ich hatte genügend Kenntnisse, um die Experimente erfolgreich durchzuführen	O	O	O	O
LV 1.2	Das Finden der Erklärungen für die Experimente war eine Herausforderung	O	O	O	O
LV 1.3	Ich konnte die Aufgaben, die mir heute gestellt wurden, gut bewältigen	O	O	O	O
LV 1.4	Ich habe die Anleitungen zum Experimentieren gut verstanden	O	O	O	O

Wie sehr stimmst Du folgenden Fragen zu?		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
LZ 1.1	Ich habe während des Experimentierens gut mit meinen Mitschülerinnen und Mitschülern im Team zusammengearbeitet	O	O	O	O
LZ 1.2	Ich habe während der Experimente meinen Mitschülerinnen / Mitschülern etwas erklärt oder mir ist von ihnen etwas erklärt worden	O	O	O	O
LZ 1.3	Ich habe während des Experimentierens mit meinen Mitschülerinnen und Mitschülern über naturwissenschaftliche Sachverhalte diskutiert	O	O	O	O

Wie sehr stimmst Du folgenden Aussagen zu?		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
IMB 1.1	Mich interessieren in der Chemie fachwissenschaftliche Artikel aus aller Welt	O	O	O	O
IMB 1.2	Ich sehe es als eine machbare Herausforderung, Chemie auf Englisch zu lernen	O	O	O	O
IMB 1.3	Mir würde Chemie auf Englisch keinen Spaß machen	O	O	O	O
IMB 1.4	Wäre das Schülerlabor auf Englisch, würde ich die Sprache sinnvoll nutzen lernen	O	O	O	O

Gib bitte an, wie oft Du die folgenden Dinge, die <u>mit Chemie</u> zu tun haben, in Deiner Freizeit tust:		sehr oft	oft	manch-mal	selten	nie
FCH 1.1	Naturwissenschaftliche Fernsehsendungen ansehen, die mit Chemie zu tun haben	O	O	O	O	O
FCH 1.2	Bücher lesen, die Themen aus dem Bereich der Chemie behandeln	O	O	O	O	O
FCH 1.3	In Zeitungen oder Zeitschriften Berichte über chemische Themen lesen	O	O	O	O	O
FCH 1.4	Mich im Internet (z.B. YouTube) mit chemischen Themen zu beschäftigen	O	O	O	O	O

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Wie schätzt Du Dich selbst ein?		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
FC 1.1	Bei manchen Sachen in Chemie, die ich nicht verstanden habe, weiß ich vornherein: „Das verstehe ich nie“	O	O	O	O
FC 1.2	Obwohl ich mir bestimmt Mühe gebe, fällt mir das Fach Chemie schwer.	O	O	O	O
FC 1.3	Ich finde es wichtig, mich mit Fragestellungen aus der Chemie auseinanderzusetzen	O	O	O	O
FC 1.4	Das Fach Chemie liegt mir nicht besonders.	O	O	O	O
FE 1.1	Ich bin in Englisch gut	O	O	O	O
FE 1.2	In Englisch schneide ich in den meisten Schularbeiten/Tests gut ab	O	O	O	O
FE 1.3	In Englisch lerne ich schnell	O	O	O	O

Wie sehr stimmst du folgenden Aussagen zu?		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
GS 1.1	Manche Leute haben eine besondere Begabung eine Fremdsprache zu lernen	O	O	O	O
GS 1.2	Eine Sprache zu lernen ist für Kinder einfacher als für Erwachsene	O	O	O	O
GS 1.2	Leute die gut in Mathe oder einer Naturwissenschaft sind, haben Schwierigkeiten im Lernen einer Fremdsprache	O	O	O	O
GS 1.3	Mädchen lernen Sprachen besser als Jungs	O	O	O	O
GS 1.4	Ich habe eine besondere Begabung Fremdsprachen zu lernen	O	O	O	O
GS 1.5	Leute, die mehr als eine Fremdsprache sprechen sind sehr intelligent	O	O	O	O
GS 1.6	Jeder kann eine Fremdsprache lernen	O	O	O	O
GS 1.7	Jemand der mehr als eine Sprache beherrscht, tut sich leicht eine Fremdsprache zu lernen	O	O	O	O
GS 1.8	Leute aus meinem Heimatland sind gut im Fremdsprachenlernen	O	O	O	O

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Wie groß oder gering ist Dein Interesse für die folgenden Themenbereichen aus der Chemie?		sehr groß	groß	mittel	gering	sehr gering
ICH 1.1	z.B. zu analytischen Messmethoden, wie der Funktionsweise eines UV/Vis- Spektrometers	O	O	O	O	O
ICH 1.2	z.B. zum Themengebiet der Nanotechnologie, wie dem Einsatz in Lebensmitteln	O	O	O	O	O
ICH 1.3	z.B. zur anorganischen Chemie, wie die Elektrochemie	O	O	O	O	O
ICH 1.4	z.B. zur organischen Chemie, über pharmazeutische Arzneimittel	O	O	O	O	O

Ich beteilige mich am Englischunterricht, weil…		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
IME 1.1	ich denke, dass es gut für meine persönliche Entwicklung ist	O	O	O	O
IME 1.2	ich es gut finde mich in der Kultur und der Geschichte des Landes der Fremdsprache auszukennen	O	O	O	O
IME 1.3	ich es mag, eine schwierige Aufgabe in der Fremdsprache zu lösen	O	O	O	O
IME 1.4	es sich gut anfühlt die Sprache zu verwenden	O	O	O	O
EXM 1.1	ich später einen angesehenen Beruf erlangen möchte	O	O	O	O
EXM 1.2	es in der Arbeitswelt immer wichtiger wird die englische Sprache zu beherrschen	O	O	O	O
EXM 1.3	viele Menschen auf der Welt Englisch sprechen	O	O	O	O
EXM 1.4	ich eine gute Note will	O	O	O	O

Wäre das Schülerlabor bilingual (Deutsch/Englisch) gewesen…		Stimmt gar nicht	Stimmt wenig	Stimmt ziemlich	Stimmt völlig
DE 1.1	hätte ich Bedenken gehabt, ob ich einen bilingualen Kurs sprachlich hinbekomme	O	O	O	O
DE 1.2	hätte ich mein volles Potential im Fach Chemie nicht ausschöpfen können	O	O	O	O
DE 1.3	hätte ich mich durch die Fremdsprache unter Leistungsdruck gesetzt gefühlt	O	O	O	O

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Wie sehr stimmst Du folgenden Aussagen über die Bedeutung der Sprache Englisch in der Naturwissenschaft zu? Die englische Sprache zu beherrschen ist wichtig, weil…		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
EMB 1.1	mir bewusst ist, dass Englisch die Sprache der Wissenschaft ist und Fachliteratur überwiegend auf Englisch ist	O	O	O	O
EMB 1.2	es im Zuge der Globalisierung durchaus sein kann, dass meine zukünftigen Kollegen nicht alle die deutsche Sprache beherrschen	O	O	O	O
EMB 1.3	ich mal einen chemischen Beruf ausüben will. In dieser Branche wird viel Englisch gesprochen	O	O	O	O
EMB 1.4	viele Experimentieranleitungen auf Englisch geschrieben sind	O	O	O	O

Stell Dir vor: Du hast eine knifflige Aufgabe in Chemie nicht gelöst. Warum ist Dir das wahrscheinlich nicht gelungen? Daran, dass…		**Stimmt gar nicht**	**Stimmt wenig**	**Stimmt ziemlich**	**Stimmt völlig**
MA 1.1	es Zufall war	O	O	O	O
MA 1.2	die Aufgabe sehr schwer war	O	O	O	O
MA 1.3	Du Chemie nicht gut kannst	O	O	O	O
MA 1.4	Du Dich nicht genug angestrengt hast	O	O	O	O

Nun ist Dein chemisches Fachwissen ist gefragt! Kreuze auch hier bitte nur eine der folgenden Aussagen an!

FA 1.2 Azulen hat die chemische Summenformel $C_{10}H_8$. Aus welche beiden Systemen setzt sich Azulen zusammen:	
O	2,3,5-Heptatriene und Benzol
O	Cycloheptatrien und Cyclopentadien
O	Cyclooctatetraen und Cyclobutadien
O	Cycloheptatrien und Cyclohexatrien

FL 1.2 Die Farbigkeit von Goldnanopartikel hängt von der…	
O	Masse des Goldes ab
O	Geschwindigkeit der Goldnanopartikel in der Lösung
O	Größe der Nanopartikel und damit einhergehend der Wellenlänge des absorbierten Lichtes zusammen
O	Bei den farbigen Partikeln handelt es sich nicht um Gold

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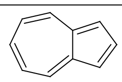
	FK 1.1 Lotos-Blätter weisen die Eigenschaft auf, Wasser abperlen zu lassen. Wie muss die Beschaffenheit der Oberfläche des Blattes aussehen?
O	Das Blatt hat eine sehr glatte Oberfläche, wodurch der Wassertropfen leicht vom Blatt abperlen kann
O	Die Oberfläche des Blatt ist sehr glatt und von einer dünnen Wachsschicht überzogen, die den Tropfen in seiner runden Form erhält
O	Die Oberfläche ist sehr rau und ist bedeckt von Wachsnoppen, die ein Aufliegen des Wassertropfens auf dem Blatt verhindern. Dadurch behält der Tropfen seine Form
O	Die Blattoberfläche hat mit dem abperlenden Wassertropfen nichts zu tun

	FL 1.1 Der sogenannte Leidenfrosteffekt zeigt sich, wenn ein Tropfen auf eine sehr heiße Platte fällt und beginnt zu tanzen. Der Effekt…
O	ist schon bei einer Temperatur von 100 °C in der Pfanne zu beobachten
O	beruht auf der raschen Verdampfung des Wassertropfens durch eine wärmeleitende Schicht unter dem Tropfen
O	beruht auf der schlechten Leitfähigkeit von Wasser, die das Verdampfen des Wassertropfens auf der heißen Herdplatte verzögert
O	ist abhängig von der hohen Siedetemperatur des Wassers

	FS 1.1 Warum zerplatzen Seifenblasen so schnell?
O	Aufgrund der Schwerkraft und des Verdunstens der Wassermoleküle
O	Aufgrund der Schwerkraft und der Anziehungskräfte zwischen dem Tensid und dem Stabilisator Xanthan
O	Luft übt einen Druck auf die Seifenblasenhaut aus, wodurch diese zerplatzt
O	Das Tensid verhindert grundsätzlich eine Seifenblasenbildung



	FA1.1 Azulen [Strukturformel] zählt zur Klasse der Aromaten, da
O	das organische Molekül cyclisch planar ist, ein konjugiertes Ringsystem an delokalisierten Doppelbindungselektronen besitzt und der Hückel- Regel (4n +2) folgt
O	da das anorganische Molekül cyclisch planar ist, ein konjugiertes Ringsystem an delokalisierten Doppelbindungselektronen besitzt und der Hückel- Regel (4n +2) folgt
O	da das organische Molekül cyclisch planar ist, ein konjugiertes Ringsystem an delokalisierten Doppelbindungselektronen besitzt und der Hückel- Regel (6n +2) folgt
O	Azulen ist kein Aromat

	FK 1.3 Um den Lotoseffekt chemisch nachzustellen, wird unteranderem Laurin-Säure verwendet. Was bewirkt der Einsatz von Laurinsäure?
O	Die Oberfläche wird dadurch super-hydrophil
O	Die Oberfläche wird super-hydrophob
O	Die Oberfläche wird dadurch glatt
O	Die Oberfläche wird dadurch sauer

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FA 1.3 Sonnenschutzfilter…	
O	absorbieren den größten Teil des sichtbaren Lichts im optischen Spektrums der Sonne
O	bestehen ausschließlich aus Antioxidantien
O	werden nur für kosmetische Zwecke eingesetzt
O	werden im unsichtbaren Licht des optischen Spektrums der Sonne aktiv

FA 1.4 Tenside bestehen aus einem Alkyrest und einer Carboxylatgruppe. Damit sind sie in der Lage…	
O	polare und unpolare Stoffe dauerhaft ohne Phasentrennung zu vermischen
O	unpolare Stoffe zu verdrängen
O	sich mit einer der beiden Phasen zu vermischen
O	die Grenzflächenspannung einer Flüssigkeit zu erhöhen

FA 1.5 Die Wirkungsweise organischer Filter beruht auf der…	
O	Absorption kurzwelliger, energiereicher Strahlung, in der die Moleküle in den angeregten Zustand übergehen. Diese Energie wird in Form von Wärme oder Lichtstrahlung wieder emittiert.
O	Absorption langwelliger, energiearmer Strahlung, in der die Moleküle in den angeregten Zustand übergehen. Diese wird in Form von Wärme oder Lichtstrahlung wieder emittiert.
O	der Reflektion kurzwelliger, energiereicher Strahlung auf der Haut
O	der Reflektion langwelliger, energiearmer Strahlung auf der Haut

FK 1.2 Bei der Kontaktwinkelmessung kann das Aufliegen eines Wassertropfens nachgemessen werden. Dieser hat auf dem Lotosblatt einen Winkel von…	
O	ca. 4°
O	ca. 30°
O	ca. 40°
O	ca. 150°

C. Materials Used in the Bilingual Module at the LMU*chemlab*

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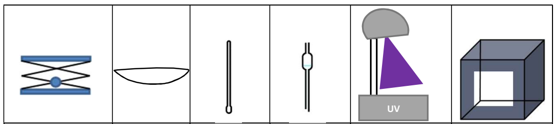
Investigating Sunscreens

Have you ever asked yourself how the **active ingredients** of different sun care products work? No matter how the chemical composition looks like, their main task is to protect our skin from damaging **radiation** emitted by the sun. The ultra violet light lies around 100 and 400 nm. Therefore, sun care products need substances that protect our skin from energy-rich, non-visible UV radiation.

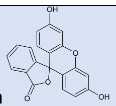
Look at the required equipment below. Can you think of an experiment proving, that the 4 lotions are able protect from damaging UV radiation?

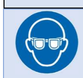
Required Equipment:



Hydraulic lift	Watch glass 4x50 mL	Stirring rod 4x	Pipette 4x	UV-lamp	Black box

Supplies: Sample 1, 2, 3 and 4, fluorescein solution

Fluorescein 	H: 319	P: 305, 351, 338
Lotion 1-4	H: -	P: -



Experiment (sketch):

1

Observation: ____

____

Transfer your results into the following table!

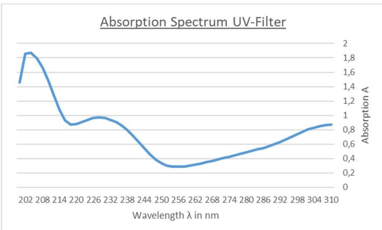
	Lotion 1	Lotion 2	Lotion 3	Lotion 4	Blank Test
Fluorescence ?					
UV-protection? Sunscreen?					

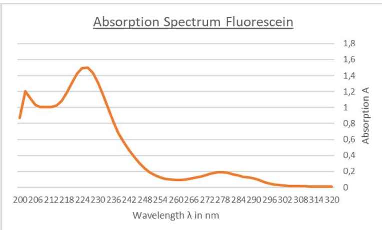
Opinion: ____

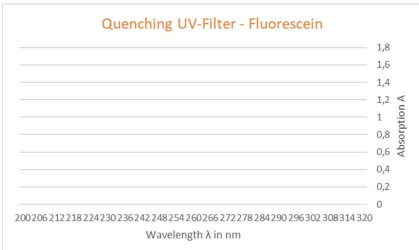
____

Fluorescein, a **fluorophore** and coloring agent, is also frequently used as an indicator. Fluorescence appears through the **emission** of energy of excited electrons returning back to their ground state. This emission takes place as long as the fluorescing molecules are excited trough light **absorption**. By adding the sunscreen to the coloring agent, emission of light is hindered. This is what is known to be a “quenching“ effect.

Identify the wavelengths in which the quenching of the fluorescein molecules occurs!





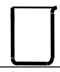


2

In this section, we will have a closer look on the mechanisms of how different sunscreens work on our skins. Basically, there are two types of sun protection that can be differentiated according to the way they work: A distinction is made between sun blocker and sun screen. This is determined by the used **active ingredients** which work differently to protect our skin from harmful UV rays.

Name the columns of the table below according to your current findings!

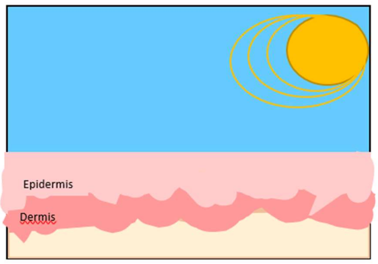
Required Equipment:

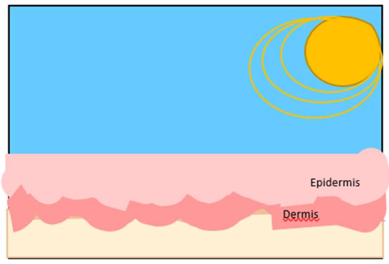
		
Watch glass 4x	Beaker 4x50 mL	Stirring rod 4x

Supplies : Sample 1, 2, 3 and 4, distilled water

Sunscreen				
Composition/ active ingredient (see back of flask): organic/ inorganic?				
UV-light reflection/absorption?				
Consistency/can be wiped up?				
Appearance				

3





Sunscreen				
Mode of action of the UV-filter				

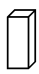
Explanation:

In this part, we are using an UV/visible spectrometer in order to detect the exact solar protection of each lotion. With this analytical method we can make accurate statements at what wavelength the UV filter of the lotion works.

First name the columns according to the observed effectiveness of the UV-filter (see your findings from above)!

Record with the UV/Vis-spectrometer an absorption spectrum of each of the 4 lotions and draw each graph into one of the fields below. Think of an explanation why many sunscreens have a combination of different active ingredients!

Required Equipment:

		
Cuvette 5x	Pipette 5x	UV/Vis-spectrometer

Supplies: Sample 1, 2,3 and 4 in propan-2-ol (isopropanol)

4

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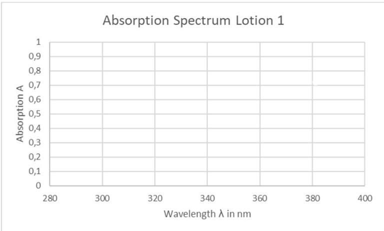
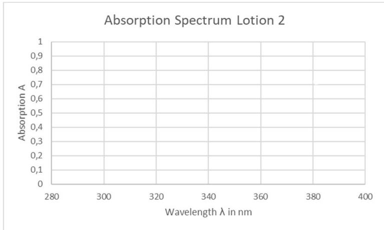
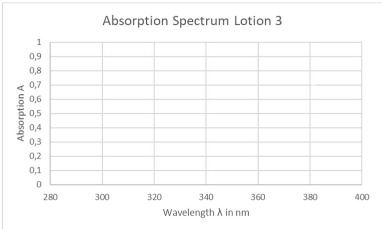
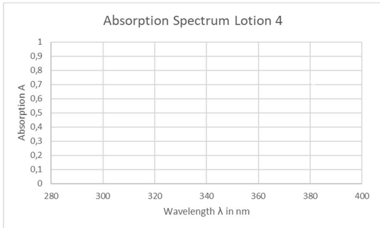
Procedure: Record a spectrum of each of the 4 samples. You need to first measure the solvent (blank test). Use the following samples where each of the observed lotions is solved in propane-2-ol (isopropanol).









Explanation: ____

____

Active ingredient	**A substance in a drug that has an (positive) effect on biological cells**	**Wirkstoff**
emission	**An electron that has reached an excited state releases energy to return to its ground state**	**Emission**
Electromagnetic radiation	**All different kinds of energy released from the sun, for example: radio waves, X-rays…**	**Strahlung**
absorption	**An electron takes up the energy coming from electromagnetic radiation**	**Absorption**
fluorophore	**A chemical substance that glows when exposed to high energy radiation such as UV-light**	**Fluorophor**

Signed by the supervisor: ___________________________________

5

Experimental Station: Generating a Micro- and Nanostructured Copper Surface

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Generating a Micro- and Nanostructured Copper Surface

By using suitable chemicals, a **hydrophilic** copper plate can be modified in a way that it shows **super-hydrophobic** properties, and with that having a **self-cleansing** effect. The production of technical surfaces is inspired by nature. Therefore, the lotos-effect is a perfect example for a biomimetic design which is a scientific discipline where humans learn from nature, in order to produce new products or optimize existing ones (Greek word stem, *bio* = life, ancient Greek *mimesis* = to imitate). In this experimental station, we will generate a micro- and nanostructured copper plate and find out, what the requirements are to get a super-hydrophobic surface!

Pretrial

Required Equipment: sand paper 1000 grit, 2 pasteur pipettes, 2x 50 mL beaker glasses, dist. water, copper plates

Supplies:

Isopropyl alcohol (propan-2-ol) C_3H_8O	H: 225-319-336	P: 210-233-240-305+351+338-403+235

Procedure:

1. Sand the copper plate with a sand paper
2. Clean the copper plate with isopropyl alcohol
3. To proof the ability of wetting and its self-cleaning power, drop some distilled water on the copper plate

Observation of the ability of wetting: To proof the self-cleaning properties of the copper plate, a contaminant (for example chalk powder) is applied on the copper plate. After that, a water drop is added with a pipette on the surface. The surface shows self-cleansing abilities when the surface is cleaned completely by the water drops.

Observation: ____

____

1

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Experiment – step 1

Required Equipment: 400 mL beaker glass, pasteur pipette, tweezers, 50 mL beaker glass, dist. water, copper plates

Supplies:

Potassium persulfate **$K_2S_2O_8$ (0,1 mol/L)**	H: 272, 302, 314, 334, 335	P: 220, 261, 280, 305+351+338, 342+311
Sodium hydroxide **NaOH (2 mol/L)**	H: 314	P280, 305+351+338, 310

Procedure:

1. Transfer the copper plates from the pretrial into the NaOH/$K_2S_2O_8$-solution at room temperature for about 10 minutes until you receive a total deep black surface.
2. Carefully remove without damaging the surface, the copper plate out of the solution using a tweezer. Rinse it with distilled water using a pasteur pipette and let it dry.
3. To proof the ability of wetting and its self-cleaning power, drop some distilled water on the copper plate.

Observation: ____

____

Experiment – Step 2

Required Equipment: 400 mL beaker glass, pasteur pipette, tweezers, 50 mL beaker glass, copper plates from experiment no. 1 – *step 1*

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Supplies:

Ethanol lauric acid-solution (5 mmol/L) $C_{12}H_{24}O_2$	H: 225, 318	P: 280, 305+351+338, 308+311
Acetone C_3H_6O	H: 225, 319, 336	P: 210, 261, 305+351+338

Procedure:

1. Transfer the processed copper plate into the ethanolic lauric acid for about 10 minutes.
2. Carefully remove without damaging the plate surface the copper plates out of the solution using a tweezer. Rinse it with acetone using a Pasteur pipette and let it dry.
3. To proof the ability of wetting and its self-cleaning power, drop some distilled water on the copper plate.

Observation: ____

____

Tasks

Measurement

1. **Complete the table**:

θ (contact angle with a water drop)	Surface properties
0° - 30°	
30° - 90°	
90° - 120°	
> 120°	
~ 150°	

3

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2. **Choose a few of the present samples and measure the contact angle of these samples. Enter those values into the table**:

Surface	Contact angle θ [°]	Surface properties
Nano textile		
Plant (for example Indian cress)		

3. **The reaction between the copper plate and the NaOH/$K_2S_2O_8$ solution in the first step forms the salt $Cu(OH)_2$. Formulate the complete reaction equation and determine the oxidation states of copper!**

____

Describe the surface character of the copper plate after applying this step!

____

____

____

4. **Outline how the lauric acid has to attach to the copper plate so that a spheric water drop can form on it!**

4

hydrophilic	**Ionic or polar covalent compound. Can be solved in water, polar**	**hydrophil**
hydrophobic	**Covalent compound. Can't be solved in water, nonpolar**	**hydrophob**
Self-cleaning	**Ability of a material to clean itself due to its structure where no dirt can stick on the surface**	**selbstreinigend**
Contact angle	**Is the angle measured through a liquid on a surface, quantifying the wetness of the surface**	**Kontaktwinkel**
Oxidation state	**Describes the electron transfer in a redox reaction**	**Oxidationszahl**

Signed by the supervisor: ___________________________________

5

Experimental Station: Synthesis of Gold-Nanoparticles

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Synthesis of Gold-Nanoparticles

Gold always fascinated people due to its appearance – the **noble metal** is famous for its golden yellow color. In this experiment you will find out if gold-nanoparticles show the same properties as the gold you know from your everyday life!

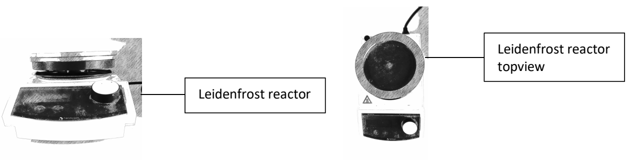
Experiment

Required equipment: Aluminum disc and aluminum ring, heat plate, beaker glasses, 3 syringes with a wide canula (10 mL, 5 mL, 1 mL), spray bottle

Supplies:

Aurochloric(III)-acid solution ($HAuCl_4$)	H: 314-317	P: 280-301 + 330 +331-302 + 352-305 + 351+ 338-308 + 310
Trisodium citrate dihydrate **$C_6H_5Na_3O_7$**	H: -	P: -
		
		

Experimental assembly of the Leidenfrost reactor:



Procedure:

1. **Proof the temperature of the Leidenfrost reactor first**: Only when the water drops float on the surface of the hot plate the Leidenfrost temperature is reached. The temperature lies around **300 °C**.
2. **Start the procedure now by adding the given approaches (see table below).** Always give the auric acid solution dropwise with a syringe immediately after adding the demin. water and the citrate solution to the aluminum disc. Before evaporating on the plate, remove the drop with a tissue from it.

Observation: ____
____
____

1

Observed data

Complete the table:

	(Demin. water)	Citrate-solution	Auric acid-solution	Observation
Experiment I	(10 mL)	10 mL	0,2 mL	
Experiment II	(10 mL)	4,5 mL	0,3 mL	
Experiment III	(10 mL)	1,5 mL	0,4 mL	

Tasks

1. Write down the equation of the occurring autoprotolysis of water in the Leidenfrost reactor!

   ____

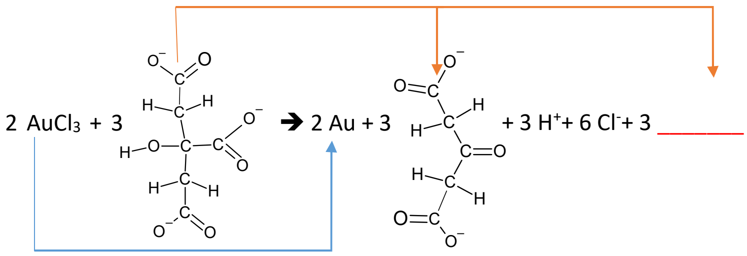
2. Explain the correlation in the change of the particle size and the observed color change. Try to quantify your observation!

   ____

   ____

   ____

3. A gas is produced as a byproduct. This is obvious due to the occurring strong bubble formation in the drop during the reaction. What kind of gas could this be? A redox reaction is taking place here. Determine the **oxidation states** of all reaction partners as well as the **reducing- and oxidizing agent**!



Oxidation state	Describes the electron transfer in a redox reaction	Oxidationszahl
Reducing agent	A compound loses electrons while it gets oxidized	Reduktionsmittel
Oxidizing agent	A compound gains electrons while it gets reduced	Oxidationsmittel

Signed by the supervisor: ___________________________________

3

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Determining the Thickness Layer of a Bubble

Many people cannot picture what "nano" means. However, most people probably know though, that the term refers to "small" or "little". In your chemistry class you've probably came across the concept of wavelength of the visible light which lies around 400 to 750 nanometers. One nanometer makes up a billionth of a meter or a millionth of a millimeter which is still very hard to imagine. A human hair has approximately the thickness of 100 micrometers which is 100 000 nanometers(!). In this experiment we will investigate something you already know from your childhood and which is way thinner than the human hair: We will have a closer look on the layer of a bubble. Can you think of a way how to measure it?

Tasks

First read the experimental instruction (**procedure**). Answer the following questions:

1. Which parameters of the bubble are measured?

   ____

   ____

2. Name one more physical variable (independent from this experiment!), which cannot be measured directly and think of a way how to measure that variable indirectly.

   ____

   ____

Experiment

Required Equipment:	Precision scale, measuring cylinder25 mL, straw, ruler, plastic container with a lid, calculator
Supplies:	Green bubble liquid

1

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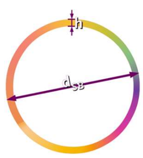
Procedure: The thickness of the bubble layer (h) can only be determined indirectly. Therefore, the diameter of a bubble needs to be measured (d_{SB}), and the mass of the soap needs to be (m_{SB}) determined. With a known mass and the density of the bubble solution (ρ_{Fl}) the volume of the bubble (V_{SB}) can be calculated which further helps to calculate the mean layer thickness (h).

Density of the bubble solution: Put an empty measuring cylinder on the scale and tare it to zero. Fill the measuring cylinder with _____ ml (=VFl) bubble liquid and measure it (mFl). The density (ρFl) is defined as the quotient of mass (mFl) and volume (VFl).

Measuring and scaling the bubble: *You should consider and plan the following steps before starting the procedure. The bubble does not have to stay intact after measuring the diameter. Repeat this part when you can't produce a bubble. However, keep in mind that you have to measure the mass of the plastic container ($m_{container}$) again.*

1. Weigh the mass of the plastic container($m_{container}$) by using a scale.
2. Quickly dip the straw with its end into the bubble solution. Now blow through the straw with the intention to form a bubble.
3. Use a ruler to measure the diameter of the bubble (d_{SB}) (try to be as exact as possible and measure centimeter-perfect). Try to estimate the diameter as accurate as possible and do not burst the bubble. It doesn't matter if the bubble has already come off the straw while you measure it.
4. Now catch the bubble in the plastic container and immediately put the lid on the container. The bubble should not burst **until** it is in the plastic container. Again weigh the container on the scale (m_{sum}).



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Measurement Data

Variable	Value	Value	Unit
V_{FL}			mL
m_{FL}			g
$m_{Container}$			g
m_{Sum}			g
d_{SB}			cm

Name	Numeric	Decimal power
-	1	10^0
deci	0,1	10^{-1}
centi	0,01	10^{-2}
milli	0,001	10^{-3}
mikro	0,000 001	10^{-6}
nano	0,000 000 001	10^{-9}

Calculations

For an easier calculation it helps to write down the values of a parameter using decimal power instead of its numeric values.
The density of the bubble solution ρ_{Fl} is calculated as follows:

$$\rho_{FL} = \frac{m_{FL}}{V_{FL}} = \frac{\qquad\qquad g}{\qquad mL} = \qquad\qquad \frac{g}{mL}$$

The mass of the bubble is calculated by the difference between $m_{container}$ und m_{ges}:

$$m_{SB} = m_{Sum} - m_{Container} = \qquad g - \qquad g = \qquad g$$

Knowing the density, the volume of the bubble solution can be calculated:
Tip: 1 mL equals 1 cm^3

$$V_{SB} = \frac{m_{SB}}{\rho_{FL}} = \frac{\qquad g}{\qquad \frac{g}{mL}} = \qquad mL = \qquad cm^3$$

As the thickness of a bubble layer (h) compared to the diameter of a soap bubble (d_{SB}) is very small, a simplification of the volume of the bubble layer (V_{SB}) can be done calculated of the product of the surface of the sphere and the thickness of the layer h.

$$V_{SB} = 4 * \pi * r_{SB}^2 * h \qquad (1)$$

As the radius is half of the diameter the formula can be further simplified:

$$V_{SB} = \pi * d_{SB}^2 * h \qquad (2)$$

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Then, for the thickness of a bubble layer this means:

$$h = \frac{V_{SB}}{\pi * {d_{SB}}^2} = \frac{\qquad cm^3}{\pi * (\qquad cm)^2} = \qquad cm = \qquad nm$$

Tasks

1. Which simplification was done in the calculation?

____

____

2. Can you think of any other thing or phenomenon that are in the size of the layer thickness of a bubble?

____

____

3. However, as you've probably noticed, the measurements are frequently liable to errors. You can determine the overall error by estimating how correct you have measured the parameters. Estimate how correct your measurements were for volume and diameter. We also take an inexactness of the scale into account that is 0,001 g determined by the manufacturer. Transfer your estimation into the following table. Use Excel to calculate the error.

Parameter	Estimated deviation	Unit
V_{FL}		cm^3
d_{SB}		cm

4. What other opportunities are there to improve the results?
Tip: Think of what influence the parameter diameter has on the overall mistake.

____

____

Signed by the supervisor: ________________________________

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Production of an After-Sun Care

Let's imagine all your creaming with sunscreen has not (can you think of a reason why?) helped, you burnt your skin from sun bathing! There is only one remedy to it: you need a cooling after-sun lotion! The **anti-inflammatory** ingredient **azulene** is an important component in the cosmetics industry. By using Nano-particles this nonpolar molecule, a carbohydrate, can be solved in a polar solution. You should know from your chemistry class that this is normally not possible as a Latin sayings tells: *„Similia similibus solvuntur"*

Now you produce the azulene loaded Nano-micelles according to the following instructions!

Required Equipment:

Beaker 1x50 mL	Scale 1x	Thermometer 1x

Supplies: Distilled water; azulene ($C_{10}H_8$)

Pretrial: Transfer 30 mL distilled water into a beaker glass and add 10 mg of azulene crystals to it.

Observation: ______________________________

Explanation: ______________________________

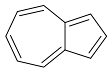
Producing an Anti-inflammatory Active Agent from Azulene as an After-sun Care

Required Equipment:

Scale 1x	Measuring cylinder 50 mL 1x	Hot plate 1x	Stand, clip, closure 1x	Beaker 50 mL 1x
Flea 1x	Thermometer 1x	Filter paper 1x	50-mL-erlenmeyer flask 1x	Glass funnel 1x

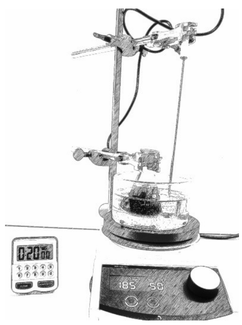
1

Supplies: Cocamidopropylbetaine 30% (detergent); Azulene ($C_{10}H_8$)

Cocamidopropylbetaine (CAPB) (30 %) (detergent) $C_{19}H_{38}N_2O_3$	H: 318, 412	P: 305, 351, 338, 280, 310, 273
Azulene ($C_{10}H_8$) 	H: -	P: -
		
		

Procedure:

1. **Production of azulene loaded nano micelles:**



Transfer 10 mL of the tenside (CAPB) into a beaker glass and add 10 mg azulene to it. Stir the mixture at around 50 °C for 10 minutes. Add another 30 mL distilled water to the beaker. Keep the temperature constant and stir the solution for another 20 minutes.

2. **Filtering the Nano-micelles**:

Filter the solution into a 50- mL- Erlenmeyer flask using a glass funnel and filter paper.

Observation: ____

Explanation: ____

____

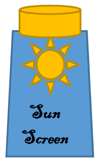
____

Other than azulene, its isomer naphthalene as substance category appears to build a suitable UV protection. Thus, loaded in Nano micelles it is also soluble in water and therefore has a cooling effect to counteract against the heat buildup that one senses after applying regular sunscreen!

Now let's have a closer look on the structure of the azulene molecules. It's a non-polar **hydrophobic** molecule with the formula $C_{10}H_8$. Azulene appears as blue crystals.

Draw all possible resonance structures for the molecule azulene. Also, think of how its isomer naphthalene could look like!

Resonance structures azulene:



Isomers:

In the course of time or at temperatures around 350 °C, azulene **rearranges** into the more stable naphthalene.

Draw all resonance structures of naphthalene!

Resonance structures naphthalene:

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Compare the resonance structures of naphthalene and azulene. It will help you to explain why naphthalene is more stable than azulene!

Explanation:

The hydrocarbon's color might help you understand why azulene cannot be used for sun protection. However, coloring is quiet extraordinary for such a small organic molecule. Reason for this lies in the structure of azulene. The five and seven membered ring show an energy difference as the five membered ring is electron rich whereas the seven membered ring is electron deficient. Accordingly, one electron is pushed from the seven membered to the five membered ring. A **dipole moment** is created. Bonding electrons can be excited more easily through electromagnetic radiation. Consequently, light from a longer wavelength is absorbed.

Draw the ionic resonance structures of the ionic azulene form!

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Recently, there has been many critics concerning the use of Nano-particles in sun protection. It has been argued that the risk on the use of nano-dimensional ingredients have not yet been comprehensively answered.

Read the text passage from a scientific journal below. Discuss, if these conclusions are justified!

Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness

Sunscreens should provide protection against the adverse effects of both UVB and UVA radiation.[8] In the last decennia, only sunscreens containing both UVB and UVA filters, are being produced. Minerals like zinc oxide (ZnO) and titanium dioxide (TiO_2) are frequently used as inorganic physical sun blockers. They are preferred above organic compounds that solely absorb UV radiation.[9] Advantages offered by sunscreens based on inorganic compounds comprise absence of skin irritation and sensitization, inertness of the ingredients, limited skin penetration, and a broad spectrum protection.[10] The natural opaqueness of these microsized sunscreen components is eliminated without reducing their UV blocking efficacy by utilizing nanosized ZnO and TiO_2 particles.[11]

Safety

The International Agency for Research on Cancer (IARC) has recently classified TiO_2 as an IARC group 2B carcinogen, possibly carcinogenic to humans.[60,61] The IARC conclusions are based on evidence showing that high concentrations of pigment-grade and ultrafine TiO_2 dust cause respiratory tract cancer in rats. The IARC considered the observations as relevant to humans since some biological events that cause lung cancers in the rats appear to be similar to those seen in humans working in a dusty environment. ZnO, on the other hand, is by the FDA "generally recognized as safe" when used as a UV filter according to cosmetics directives.[62] Although both the US Environmental Protection Agency and the European Community (within the *Registration, Evaluation, Authorisation and Restriction of Chemical Substances* law) have taken actions to manage NP risks, there are still no official safety regulations for NPs in particular.

Smijs, T., Stanislav, P.. Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness. In: Nanotechnology, Science and Applications.2011

anti-inflammatory	**Reduces pain or swelling**	**entzündungshemmend**
Resonance structures	**Description of bonding in molecules or ions where more than one Lewis structure can be drawn**	**Grenzstrukturen**
hydrophobic	**Can't be solved in water**	**hydrophob**
rearrangement	**Reaction in organic chemistry where a structure changes to form an isomer**	**Umlagerung**
hydrocarbon	**A molecule consisting only of hydrogen and carbon**	**Kohlenwasserstoff**
Dipole moment (molecular)	**Electrons are unequally shared because of different electronegativity causing charge separation within a molecule**	**Dipolmoment**

Signed by the supervisor: ________________________________

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