Digital Skills of Teachers and Learners

The Investigation and Connection of both Perspectives

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Tamara Maximiliane Francesca Kastorff

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Prüfungskommission

Erstgutachter: Prof. Dr. Karsten Stegmann

Zweitgutachter (extern): Prof. Dr. Jörg Zumbach

Drittgutachter: Prof. Dr. Bernhard Schmidt-Hertha

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Für meine Mama

Zusammenfassung

Lehrkräfte sind durch die Integration der digitalisierungsbezogenen Kompetenzen in den Lehrplan dafür verantwortlich, diese an Lernende zu vermitteln, wodurch Forscherinnen und Forscher fordern, die Auswirkungen des digitalisierungsbezogenen Professionswissens von Lehrkräften auf die digitalisierungsbezogenen Kompetenzen der Lernenden genau zu untersuchen (Lachner et al. 2019; Lorenz et al., 2019; Lucas et al., 2021; Schmid et al., 2021). Um die Auswirkung des digitalisierungsbezogenen Professionswissens von Lehrkräften auf die digitalisierungsbezogenen Kompetenzen der Lernenden jedoch genauer zu untersuchen, müssten zunächst im Rahmen dieser Dissertation die Auswirkungen der Coronapandemie auf die Technologieverwendung von Lernenden als auch die valide Messung des digitalisierungsbezogenen Professionswissen von Lehrkräften eingehend untersucht werden, da dies noch nicht hinreichend in der empirischen Bildungsforschung umgesetzt wurde.

Die Forschung zu digitalisierungsbezogenem Professionswissen von Lehrkräften und den digitalisierungsbezogenen Kompetenzen von Lernenden hat besonders im Hinblick auf die Coronapandemie und die damit einhergehenden weltweiten Schulschließungen an Bedeutung gewonnen, woraus sich aufgrund der aktuellen Forschung weitere Forschungsbedarfe entwickelt haben, die im Rahmen der vorliegenden Dissertation näher untersucht werden. Diese beziehen sich zum einen (1) auf die Auswirkungen der Coronapandemie auf die Technologieverwendung von Lernenden, da diese eine maßgebliche Determinante der digitalisierungsbezogenen Kompetenzen von Lernenden darstellt und durch die Coronapandemie unausweichlich wurde, um sowohl den schulischen als auch privaten Alltag aufrechtzuerhalten. Des Weiteren (2) steht die Messung des digitalisierungsbezogenen Professionswissens von Lehrkräften im Vordergrund. Mit der validen Messung des digitalisierungsbezogenen

Professionswissens von Lehrkräften ergeben sich beispielsweise Potenziale zur Entwicklung von zielgerichteten Interventionen, um dieses zu fördern. Zuletzt (3) sind Lehrkräfte durch die Integration der digitalisierungsbezogenen Kompetenzen in den Lehrplan dafür verantwortlich, diese an Lernende zu vermitteln, wobei die Auswirkungen des digitalisierungsbezogenen Professionswissens von Lehrkräften auf die digitalisierungsbezogenen Kompetenzen der Lernenden untersucht werden.

Im Rahmen dieser Dissertation wurden entsprechend drei Studien durchgeführt, um Kenntnisse in den aufgezeigten Forschungsbereichen zu gewinnen. In der ersten Studie dieser Dissertation sind wir der Frage nachgegangen, wie Lernende Technologien vor und während der Coronapandemie verwendet haben. Internationale Mittelwertvergleiche zeigen, dass Lernende Technologien bis jetzt nur selten in der Schule für schulbezogene Zwecke verwendet haben (Schaumburg et al., 2019), was darauf hindeutet, dass die Verwendung von Technologien noch nicht zentral im Schulalltag verankert ist. Durch die weltweite Schulschließung durch die Coronapandemie im Frühjahr 2020 und die damit einhergehende zwingende Technologieverwendung von Lernenden und Lehrenden für schulbezogene Zwecke kann jedoch angenommen werden, dass sich die Coronapandemie maßgeblich auf die Technologieverwendung der Lernenden ausgewirkt hat. Diese Annahme ist besonders dahingehend interessant, da die vorangegangene Forschung zeigen konnte, dass sich eine zielgerichtete Technologieverwendung positiv auf die digitalisierungsbezogenen Kompetenzen von Lernenden auswirken kann (Senkbeil, 2017), was zudem eine unabdingbare Prämisse darstellt, um erfolgreich am späteren professionellen Leben teilzuhaben (Fraillon et al., 2020). Während Lernende (N = 643) noch vor der Coronapandemie im Jahr 2019 angaben, Technologien sehr heterogen hinsichtlich schulspezifischer und privater Kontexte zu verwenden, konnten wir mittels einer

repräsentativen Telefonbefragung Lernende in der Sekundarstufe in Bayern vor und während der Coronapandemie (N = 644) und der damit einhergehenden Schulschließung im Frühjahr 2020 befragen, inwiefern sie Technologien für den sozialen und schulischen Gebrauch verwenden. Die Lernenden wurden mittels latenter Profilanalyse in unterschiedliche Profile anhand ihrer Angaben zur Technologieverwendung eingeteilt. Unsere Ergebnisse zeigen, dass die Technologieverwendung der Lernenden homogener im Hinblick auf schulspezifische Anwendungen während der Coronapandemie 2020 geworden ist. Das bedeutet konkret, dass Lernende vermehrt angaben, Technologien für schulspezifische Zwecke, wie beispielsweise die Recherche im Internet oder zum Lernen, zu verwenden, was Hinweise darauf geben kann, dass sich auch die digitalisierungsbezogenen Kompetenzen der Lernenden während der Coronapandemie positiv entwickelt haben. Dennoch zeigen unsere Befunde auch, dass Lernende aus bildungsfernen Familien besonders gefährdet sind($B = 0.79$, $p < .05$) , der nun durch die Coronapandemie noch schneller voranschreitenden Digitalisierung hinterherzuhinken, da diese Lernenden besonders häufig in Profilen vertreten waren, die angaben, Technologien eher für soziale, anstatt für bildungsrelevante Aktivitäten zu nutzen, was sich negativ auf die digitalisierungsbezogenen Kompetenzen von Lernenden auswirken kann (Senkbeil, 2017).

Auch die Forschung zu digitalisierungsbezogenem Professionswissen von Lehrkräften hat nicht nur seit Beginn der Coronapandemie deutlich an Relevanz gewonnen. Eine genaue Betrachtung dieser Forschung zeigt jedoch deutlich, dass oftmals lediglich die Selbstwirksamkeit der Lehrkräfte hinsichtlich des technologischen Wissens, also des Wissens und der Fähigkeiten mit und über den Umgang mit digitalen Technologien (Lachner et al., 2019), erhoben wird, eine Messung des tatsächlichen objektiven technologischen Wissens von Lehrkräften bleibt meist unberücksichtigt. Die

Nutzung von Selbsteinschätzungsinstrumenten ist in der Forschung weitverbreitet, da die Annahme zugrunde liegt, dass man mittels Instrumenten zur Selbsteinschätzung Rückschlüsse auf die Selbstwirksamkeit und damit auf das tatsächliche technologische Wissen schließen kann (Hatlevik & Hatlevik, 2018). Aktuelle Studien zeigen jedoch, dass die Ergebnisse zwischen Selbsteinschätzungen und objektiven Bewertungsmaßnahmen des technologischen Wissens von Lehrkräften nur schwach bis gar nicht korrelieren, was auf eine systematische Verzerrung von Selbsteinschätzungen hindeutet (Parry et al., 2021; Baier & Kunter, 2020; Drummond & Sweeny, 2017).

Gleichzeitig sind Kenntnisse über das tatsächliche digitalisierungsbezogene Professionswissen von Lehrkräften gerade im Hinblick auf die Coronapandemie und den damit einhergehenden Distanzunterricht unabdingbar, um entsprechende Interventionen zu etablieren, die das digitalisierungsbezogene Professionswissen gezielt fördern. Um Kenntnisse über das digitalisierungsbezogene Professionswissen von Lehrkräften zu gewinnen, eignen sich objektive Bewertungsmaße. Die Erhebung mittels objektiver Bewertungsmaße lässt sich jedoch aus verschiedenen Gründen wie beispielsweise dem Umfang der Testung sowie der Akzeptanz der Probandinnen und Probanden nicht in jedem Fall zufriedenstellend umsetzen. Dementsprechend wird häufig auf Instrumente zur Selbsteinschätzung zurückgegriffen, um Kenntnisse über das digitalisierungsbezogene Professionswissen von Lehrkräften zu gewinnen, was jedoch oftmals zu verzerrten Ergebnissen führt. Entsprechend stellt sich im Rahmen der zweiten Studie dieser Dissertation die Frage, inwieweit Selbsteinschätzungsinstrumente konzipiert werden können, um das Ausmaß möglicher Verzerrungen zu minimieren. Metaanalytische Befunde konnten bereits zeigen, dass die Ergebnisse von Selbsteinschätzungen dann stärker mit objektiven Bewertungsmaßstäben korrelieren,

wenn die Instrumente zur Selbsteinschätzung konkrete kontextspezifische Informationen enthalten (Talsma et al., 2018).

Mit der Bereitstellung kontextspezifischer Informationen, wie beispielsweise konkreter Szenarien in Selbsteinschätzungsinstrumenten, wird für die Probandinnen und Probanden ein konkreter Kontext geschaffen, in dem sie ihr eigenes Wissen und ihre Fähigkeiten einschätzen können, um so systematische Verzerrungen von Selbsteinschätzungen durch das Fehlen von Kontextinformationen zu vermeiden. Die Ergebnisse zeigen, dass die szenarienbasierte Selbsteinschätzung hinsichtlich der Teilkomponente *Bedienen und Anwenden von Technologie* (β = 0.25, SE = 0.13, p =.05) die objektive Bewertung des technologischen Wissens von (angehenden) Lehrkräften (N = 75) signifikant vorhersagt(R^2 = 0.23). Entsprechend lässt sich zusammenfassend für die zweite Studie dieser Dissertation festhalten, dass die szenarienbasierte Selbsteinschätzung ein geeignetes Hilfsmittel darstellen kann, um näher an die Ergebnisse der objektiven Bewertungsmaße zu gelangen. Insgesamt weisen die Ergebnisse darauf hin, dass die Kontextinformationen den Probandinnen und Probanden besonders für operative Fähigkeiten im Umgang mit Technologien geholfen haben, die eigenen Fähigkeiten genauer einzuschätzen, sodass eine Über- oder Unterschätzung der Fähigkeiten mittels szenarienbasierter Selbsteinschätzung reduziert werden konnte (Sailer et al., 2021a).

Während sich Forschungsbedarfe im Hinblick auf die Messung des digitalisierungsbezogenen Professionswissens von Lehrkräften sowie die Auswirkungen der Coronapandemie auf die Technologieverwendung von Lernenden zeigten, fordern Forscher zudem, die „Verbindung“ zwischen dem digitalisierungsbezogenen Professionswissen von Lehrkräften und den digitalisierungsbezogenen Kompetenzen von Lernenden zu untersuchen. Mit der Integration von digitalisierungsbezogenen

Kompetenzen in den Lehrplänen (z.B. Siddiq et al., 2016) sind Lehrkräfte dafür verantwortlich, digitalisierungsbezogene Kompetenzen an die Lernenden zu vermitteln. Die dritte Studie dieser Dissertation untersucht, inwiefern sich das digitalisierungsbezogene Professionswissen von Lehrkräften (*N*= 220), mediiert über das Professionswissen zum Einsatz von Technologien im Unterricht, auf die digitalisierungsbezogenen Kompetenzen von Lernenden (*n* = 1620) in der Sekundarstufe auswirkt. Die Ergebnisse einer Mehrebenenanalyse im Rahmen dieser Dissertation sind jedoch sowohl hinsichtlich der Auswirkungen des Professionswissen von Lehrkräften (*b* = -.08, *t*(692) = 1.66 .01, *p* >.05) als auch des Professionswissen zum Einsatz von Technologien im Unterricht (*b* = -0.05, *t*(690) = -1.83 *p* >.05) auf die digitalisierungsbezogenen Kompetenzen von Lernenden nicht signifikant.

Insgesamt deuten die Ergebnisse dieser Dissertation darauf hin, dass sich die Coronapandemie nachhaltig auf die Technologieverendung von Lernenden ausgewirkt hat, was künftig in weiterer Forschung berücksichtigt werden sollte. Zudem stellt die Technologieverwendung im Unterricht eine relevante Determinante dar, um digitalisierungsbezogene Kompetenzen von Lernenden zu fördern. Auch wenn kein signifikanter Effekt des digitalisierungsbezogenen Professionswissen von Lehrkräften auf die digitalisierungsbezogenen Kompetenzen von Lernenden gefunden werden konnte, so zeigen die Ergebnisse der drei Studien dieser Dissertation dennoch, dass der Einsatz von Technologien im Unterricht gefördert werden sollte, sodass Lehrkräfte künftig eine schülerzentrierte Technologieverwendung im Unterricht etablieren um künftig den curricularen Vorgaben gerecht zu werden, die fordern, dass Lernende und Lehrende für das Leben und Lernen in der digitalen Gesellschaft vorbereitet werden.

Summary

Teachers are responsible for teaching digital skills to learners by integrating them into the curriculum, prompting researchers to call for a close examination of the impact of teachers' digital skills on learners' digital skills (Lachner et al. 2019; Lorenz et al., 2019; Lucas et al., 2021; Schmid et al., 2021). However, in order to examine this relationship in more detail, this dissertation would first need to examine in depth the impact of the COVID–19 pandemic on learners' digital media use as well as the valid measurement of teachers' digital skills, as this has not yet been sufficiently implemented in empirical educational research.

Research regarding digital skills of teachers and learners has become increasingly important, especially in light of the COVID–19 pandemic and the accompanying global school closures. Nevertheless, there are some areas of teachers' and learners' digital skills that demand clarification. Accordingly, few researchers have addressed the problems particularly in the areas of 1) the impact of the COVID–19 pandemic on learners' digital media use, as school closures made the use of digital media in home and school daily life inevitable, 2) the measurement of teachers' digital skills to gain knowledge in educational science and to develop targeted interventions to promote teachers' digital skills, and 3) the impact of teachers' digital skills on learners' digital skills.

Accordingly, as outlined in this dissertation, three studies were conducted to gain insights into the highlighted research areas. In the first study in this dissertation, we examined how learners used digital media before and during the COVID–19 pandemic. International mean comparisons suggest that learners rarely used digital media in school for school-related purposes (Schaumburg et al., 2019), suggesting that the digital media use is not yet central to everyday school life. However, given the global school closures due to COVID–19 pandemic in the spring/summer of 2020 and the accompanying

imperative for learners and teachers to use digital media for school-related purposes, it is reasonable to assume that the COVID–19 pandemic has influenced learners' digital media use.

The assumption of the impact of the COVID–19 pandemic on learners' digital media use is particularly interesting, as previous research has shown that purposeful digital media use can have a positive impact on learners' digital skills (Senkbeil, 2017), which is also an indispensable premise for successful participation in later professional life (Fraillon et al., 2020). While learners reported using digital media heterogeneously in relation to school and private contexts before the COVID–19 pandemic in 2019(N = 643), we asked learners in secondary schools in Bavaria before and during the COVID–19 pandemic (N = 644) and the accompanying school closure in spring 2020 via a representative telephone survey to what extent they use digital media for both social and school purposes. Learners were classified into different profiles based on their digital media use responses using Latent Profile Analysis. Our results show that learners' digital media use became more homogeneous in terms of school-related purposes during the COVID–19 pandemic in 2020. Specifically, learners increasingly reported using digital media for school-related purposes, such as researching on the Internet or learning. This may suggest that learners' digital skills may also have developed positively during the COVID–19 pandemic. However, our results also show that learners from low-education families (B = 0.79, p <.05) are particularly at risk of being left behind by the even faster pace of digitization, as learners from low-education families were particularly likely to be represented in profiles that reported using digital media for social rather than school activities, which may have a negative impact on learners' digital skills (Senkbeil, 2017).

Research on teachers' digital skills has also gained much momentum, especially since the onset of the COVID–19 pandemic. However, a closer look at research on

teachers' digital skills reveals that research often examines teachers' self-efficacy in technological knowledge, i.e., knowledge and skills with and about using digital media (Lachner et al., 2019). The establishment of self-assessment instruments is widely recognized in educational science, based on the assumption that inferences can be made from teachers' self-efficacy with regard to their actual technological knowledge (Hatlevik & Hatlevik, 2018). Nevertheless, recent studies show that the results between self-assessments and objective assessment measures of teachers' technological knowledge are weakly to poorly correlated, suggesting a systematic bias in self-assessments (Parry et al., 2021; Baier & Kunter, 2020; Drummond & Sweeny, 2017). At the same time, knowledge of teachers' actual, objectively measured digital skills professional knowledge is essential, especially in light of the COVID -19 pandemic and related distance learning, to determine appropriate interventions to target teachers´ digital skills. However, for a variety of reasons, such as the scope of the test and the acceptability of test takers, using objective assessment measures may not be sufficiently feasible in practice in every case. Accordingly, the first study in this dissertation addresses the question of the extent to which self-assessment instruments can be designed to minimize the extent of possible bias. Meta-analytic findings have already shown that self-assessment results correlate more strongly with objective measures of assessment when self-assessment instruments include concrete context-specific information (Talsma et al., 2018). By providing context-specific information, such as concrete scenarios in self-assessment instruments, subjects are provided with a concrete context, potentially avoiding systematic bias in self-assessments due to the absence of contextual information. The results show that the scenario-based self-assessment regarding the subcomponent, *operating and using digital media* ($\beta = 0.25$, SE = 0.13, $p = .05$) significantly predicts the objective assessment of technological knowledge ($R^2 = 0.23$) of $N = 75$ (prospective) teachers.

In summary, scenario-based self-assessment may be an appropriate tool for getting closer to the results of the objective assessment measures. Overall, the results suggest that, especially for technical operational skills, the contextual information helped subjects to assess their own skills more accurately, so that over- or underestimation of subjects' skills or knowledge can be prevented by the scenario-based self-assessment (Sailer et al., 2021a).

While research is needed on measuring teachers' digital skills and the impact of the COVID–19 pandemic on learners' digital media use, scholars also call for investigating the "connection" between teachers' digital skills and learners' digital skills (e.g., Guggemos & Seufert, 2021). With the integration of digital skills into curricula (e.g., Siddiq et al., 2016), teachers have the responsibility to foster learners´ digital skills. The third study in this dissertation examines the extent to which teachers' digital skills (n = 220), mediated by their professional knowledge regarding the high-quality use of digital media in instruction, affects students' digital skills(n = 1620). The results of multilevel analysis show that neither teachers' digital skills (b = -.08, t(692) = 1.66 .01, p >.05) nor teachers' professional knowledge regarding the high-quality use of digital media in instruction (b = -0.05, t(690) = -1.83 p >.05) have a significant impact on students' digital skills.

Overall, the results of this dissertation suggest a lasting impact of the COVID -19 pandemic on learners' use of digital media, which should be considered in further research in the future. Furthermore, the use of digital media in the classroom is an important determinant of the advancement of learners' digital skills. Although no significant effect of teachers' professional knowledge of digital skills on learners' digital skills was found, the results of the three studies in this dissertation nevertheless indicate that the use of digital media in the classroom should be promoted so that teachers in the future establish

student-centered use of digital media in the classroom to meet the requirements of curricula that demand that learners and teachers be prepared for teaching and learning in the digital society.

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1. General Introduction

1.1 Aim and structure of the thesis: The digital skills of teachers and learners

The COVID-19 pandemic has demonstrated that digital skills are essential for teaching and learning. Digital media has always offered learners who are unable to attend classes in person an opportunity to participate in educational processes remotely. In March 2020, however, many classes around the world were held exclusively online to allow educational processes to continue in the face of COVID-19 restrictions. Accordingly, for both teachers and learners, digital skills were a *sine qua non* for active and successful participation in learning processes. Teachers were encouraged to implement digital learning scenarios and establish distance learning protocols by using conferencing tools. In order to participate successfully in distance learning, learners had to contribute to classes online and actively participate in learning management systems. Although studies on the effects that the COVID-19 pandemic has had on teaching and learning processes are still pending (e.g., Dorn et al., 2020; Sun et al., 2020; Zhu & Liu, 2020), the digital skills of teachers and learners have been crucial during the COVID-19 pandemic, as these skills have been a key factor for sustaining the education system. However, what about the digital skills of teachers and learners in the light latest research results in educational science? In this regard, Scheiter (2021) notes that there are two strands of current research in educational science. The first strand relates to learners' perspectives on digital skills and their use of digital media. The learner’s perspective has been studied extensively in educational science; large-scale studies such as the International Computer and Information Literacy Study [ICILS] and the Programme for International Student Assessment [PISA] have regularly focused their assessments on the objective assessment of learners' digital skills and digital media use.

Research on learners' digital skills has shown that a learner's socioeconomic status plays a fundamental role. Learners who come from families of a higher socioeconomic status consistently perform better than learners from less privileged families (e.g., Fraillon et al., 2020; Senkbeil, 2017). These findings are related to the digital divide (van Dijk, 2020), whereby learners from families of a lower socioeconomic status have fewer resources at home to purchase digital media equipment and are therefore at a disadvantage compared to their more privileged peers; learners of lower socioeconomic status may have fewer digital media at home and are correspondingly less likely to use them for study-related purposes, leading to lower digital skills (Senkbeil, 2017).

To counteract the digital divide, some countries have implemented countermeasures, such as equipping local schools with digital media and offering less privileged learners regular access to digital media for learning-related purposes (OECD, 2019). Despite these measures to better equip schools with digital media, the question remains: to what extent have the COVID-19 pandemic and the resultant school closures around the world affected the digital divide and the use of digital media by learners? A large proportion of learners, especially less privileged learners, were suddenly forced to rely on the (often insufficient) learning resources they had at home to participate in distance learning. Moreover, while the digital media use among adolescents had been studied extensively prior to the COVID-19 pandemic, the extent to which the pandemic and the use of digital media to facilitate the continuation of school and social life fundamentally altered learners' use of digital media remains an open question; this question requires a reconsideration of the findings of large-scale studies, such as the recent ICILS study in 2018.

Accordingly, the first study in this dissertation addresses the use of digital media by secondary school learners before and during the COVID-19 pandemic. One aim is to

gain insights into how the COVID-19 pandemic may have changed adolescents' digital media use and how this might relate to their digital skills. Additionally, the first study investigates the extent to which personal factors such as socioeconomic status are related to adolescents' use of digital media. The goal is to develop targeted interventions, such as financial support for schools and curricula development, based on the study's results.

The second study in this dissertation addresses the digital skills of teachers. To successfully sustain teaching and learning processes, learners and teachers alike must possess digital skills. As the domain of the learner has been extensively researched, large-scale studies that provide objective data about learners' digital skills are available; these data illustrate the status quo of learners' digital skills and their use of digital media. Out of two strands currently being investigated in educational science posed by Scheiter (2021), the second strand, relating to teachers' digital skills, offers a different picture (Scheiter, 2021). According to teachers' digital skills, the body of research on teachers is a younger research discipline; teachers have not yet been as comprehensively researched as learners. Furthermore, teachers' digital skills are usually surveyed in educational science; sample sizes in these studies are usually smaller and rely on subjective self-assessment instruments (see Scott, 2021 for a review). Obtaining holistic, objective measurements of teachers' digital skills is typically challenging, as doing so is very complex and time-consuming; many are reluctant to participate in such studies as a result (Kleinert et al., 2015). Self-assessments serve as an alternative approach because they are less complex and may therefore lead to fewer responses. Although self-assessments can be used to measure teacher self-efficacy and thus can provide important information for educational science (Hatlevik et al., 2018), previous research has shown that the results of self-assessments of teachers' digital skills do not correlate significantly with objective assessments (e.g., Baier & Kunter, 2020; Drummond & Sweeny, 2017). This suggests a

systematic bias in self-assessment instruments that may result from ambiguous item formulations such as "I am good with digital media." Subjects may have heterogeneous understandings of what specific abilities these prompts pertain to and thus have problems correctly assessing their abilities. According to Scheiter (2021), using concrete scenarios, such as those found in scenario-based self-assessment instruments, could be a way to help teachers accurately represent their own abilities in an action-oriented and situated test format. This would be preferable to the often vague and therefore problematic item formulations in typical self-assessment tools. Given the obstacles to establishing objective assessment measures in education and the promising opportunities for enriching self-assessment items via scenarios, the second study in this dissertation examines the extent to which context specificity in scenario-based self-assessments can help reduce self-assessment bias. We investigate the extent to which certain approaches to measuring teachers' digital skills can be used to more accurately identify gaps in teacher education and training. These findings could be used to ensure that teachers have sufficient digital skills to meet curriculum requirements. In addition, the second study is expected to contribute valuable insights in respect of a current trend in educational science: the further development of self-assessment instruments to match the results of objective assessment measurements more closely.

The third study in this dissertation combines learners’ and teachers’ digital skills. Both are of paramount importance to implementing and sustaining teaching and learning processes, especially in the age of distance learning. Learners must acquire digital skills to successfully participate in society; this reality is specified in the curricula of some countries, such as Germany (The Standing Conference of the Ministers of Education and Cultural Affairs (KMK), 2016). Schools and teachers are thus responsible for teaching digital skills to learners. According to Scheiter (2021), it is therefore not only of great

importance to study both learners and teachers individually but also to link both strands of study in educational science; one must link teachers' responsibility for teaching digital skills to learners and study the impact of teachers' digital skills on the learners' digital skills. In large-scale studies like ICILS's, teacher-specific factors – such as self-efficacy in using digital media – have always been investigated. Nevertheless, earlier research has indicated that teachers' *professional* knowledge of the subjects they teach (e.g., mathematics) has a major impact on learner performance (Baumert et al., 2010). One can assume the same is true for interdisciplinary skills such as digital skills. Based on the relevance of digital skills from both the teacher's and learner's perspectives, this dissertation provides evidence and potential applications for both teachers and learners. First, it examines learners' use of digital media before and during the COVID-19 pandemic. Second, it explores the extent to which scenario-based self-assessment to assess teachers can be more closely aligned with the results of objective assessment. The goal of this inquiry is to identify gaps and opportunities in teacher education and training to ensure that teachers have sufficient digital skills to meet curriculum and educational policy requirements. Finally, this dissertation investigates the extent to which teachers' digital skills have a direct effect on learners' digital skills.

1.2 Conceptual clarification of digital skills

Increasing levels of digitization are having major effects on important sectors of society. The process of digitization is widely understood as the process by which digital media are increasingly replacing analog processes, opening new perspectives in all areas of society, science, and education (KMK, 2016). With respect to the field of education, digital media have advanced to the point where they are firmly anchored in curricula (Siddiq et al., 2016). Researchers and educational practitioners agree that the integration of digital media into curricula offers incredible opportunities; teaching-learning processes

can be revolutionized and further developed, allowing learners to experience situations through digital media in the classroom (Petrovic, 2019) and better understand contexts and processes in a number of ways (e.g., through simulations; Stinken-Rösner, 2020). Unfortunately, the integration of digital media into curricula also poses a challenge (KMK, 2016; Scheiter, 2021). By integrating digital media into curricula, schools are responsible for providing learners with the digital skills they need to participate successfully in a digital society (Fraillon et al., 2020). For example, teaching and learning processes in the classroom must be adapted and further developed; this requires digital skills on the part of teachers, and these skills therefore must be taught in teacher education and training (KMK, 2016).

However, one might ask what exactly digital skills are. On the surface, the term "digital skills" implies an ability to use digital media on a operational level. The technical operational handling of digital media is a necessary but not sufficient component of digital skills; one needs additional skills to navigate the increasing digitization of all areas of society and the education system (e.g., Fraillon et al., 2020; Senkbeil et al., 2013; Siddiq et al., 2016). In its strategy paper, "Education in the Digital World", the KMK (2016) identifies six areas of competence based on three internationally recognized frameworks. These frameworks relate to corresponding research areas, and they require learners to have sufficient digital skills to participate in society successfully. The three frameworks are: 1) DigComp, 2) Kompetenzorientiertes Konzept für die schulische Medienbildung and 3) the ICILS. According to the KMK frameworks, the following six digital skills are necessary for successful participation in a digitized society (2016):

(1) Searching, processing, and retaining information through digital media.
(2) Communicating, cooperating, interacting, collaborating, and sharing with peers and familiarizing oneself with and adhering to the rules of dealing with peers.

(3) Developing and producing information via digital media, as well as processing and integrating information in accordance with legal requirements.
(4) Understanding how to safely handle digital media and protect one's personal data, privacy, and health.
(5) Solving technical problems, using tools, and identifying one's deficits in dealing with digital media and looking for solutions to those deficits.
(6) Critically analyzing and reflecting upon information retrieved via digital media.

In summary, digital skills include more than technical operating skills; key digital skills also include those related to the critical, meaningful, and reflective use of digital media, particularly in respect of the opportunities and risks for learners (KMK, 2016, 2019; Fraillon et al., 2020; Scheiter, 2021). By integrating digital media into teaching and curricula, schools have assumed responsibility for teaching digital skills to learners. Based on the educational mandate, "Education in the Digital World" (KMK, 2016), learners' digital skills should not be taught as a separate and distinct course or subject. Instead, these skills should be taught cross-sectionally such that the learning process is an integral part of all subjects. Schools must actively integrate digital media into the classroom and teach digital skills to learners based on the KMK's (2016) competence areas.

The six core competencies are mediated by the KMK's (2016) two overarching educational goals, which relate to learners and teachers. First, learners should be taught digital skills early in the first few years of school. This would help them engage with digital media in a critical and reflective way. Second, teachers must acquire the qualifications they need to impart digital skills to the learners and further develop their skills with respect to teaching in digital learning environments. If one examines the KMK's (2016) two educational goals, which result from education in the context of

increasing digitalization, one can identify two perspectives that are of increasing importance in recent research (see e.g., Lucas et al., 2021; Scheiter, 2021). On the one hand, learners should have the opportunity to learn with digital media and build their digital skills. On the other hand, teachers must adapt their digital media-based teaching approaches to curriculum requirements and acquire digital skills that they can pass on to learners in different subjects. Much of the research has focused on the learners' perspective and learning with digital media and has accordingly produced numerous important findings (e.g., Bundsgaard & Gerick, 2017; Lorenz et al., 2019). However, there remains a need to conduct further research into *teaching* with digital media, particularly from teachers' perspectives (Scheiter, 2021).

1.3 Digital skills of teachers

Of the two perspectives related to teaching and learning with digital media, the research on the teachers' perspective remains insufficient (Scheiter, 2021). Recent attempts have focused on determining the frequency of teachers' digital media use in the classroom (see Fraillon et al., 2020) instead of determining how teachers use digital media in the classroom to meaningfully support student learning (Petko et al., 2017; Seufert et al., 2021). The most recent ICILS study (2018) shows that teachers around the world have increased their use of digital media in the classroom since the last ICILS study (2013); and thus Drossel et al. (2020) argue that the digitization of teaching has become much more relevant.

Focusing on the frequency of digital media use, it may at first glance appear plausible that if digital media are used frequently in the classroom, they are likely to be of high value in everyday instruction in a way that benefits student learning. However, there is limited evidence about the relationship between the frequency of digital media use and student learning outcomes. Furthermore, some studies have produced

counterintuitive results; in several studies, the more frequently digital media was used in the classroom, the fewer digital skills learners had (Bundsgaard & Gerick, 2017; Petko et al., 2017). One explanation for the counterintuitive results is that these studies did not effectively measure *how* digital media are used in the classroom; the mere use of digital media in the classroom is not itself a quality criterion (Schmid et al., 2021; Sailer et al., 2021a).

Globally, most teachers report that they use digital media mainly to present information in teacher-centered approaches (Fraillon et al., 2020; Drossel et al., 2020), which aligns with the findings in the recent ICILS study (2018). Accordingly, only one-third of teachers report using digital media to support learners individually or to promote learner collaboration (Drossel et al., 2020). Hence, there is growing concern that digital media's full potential to facilitate teaching and learning processes remains untapped (Lohr et al., 2021) and remains a challenge that requires teachers to possess the requisite digital skills (Scherer & Teo, 2019).

Scholars often refer to the Technological Pedagogical Content Knowledge (TPACK) framework when considering how teachers can use their digital skills to their fullest potential in the classroom to facilitate teaching and learning (Koehler and Mishra, 2006). The TPACK framework, which is based on Shulman's (1986) work, is a widely established framework of pedagogical content knowledge (PCK). It consists of content knowledge (CK) and pedagogical knowledge (PK), which are both key elements teachers must possess to teach learners successfully. Using the TPACK framework, Koehler and Mishra (2006) extend Shulman's (1986) model to include the component of technological knowledge (TK). TK can be defined as teachers' knowledge of technologies such as digital tools and educational technologies (Lachner et al., 2019, p.7); TK has commonalities with the term "digital skills" posed by KMK (2016) and is thus used

interchangeably with that term in this study. The TPACK model includes three components: technological, pedagogical, and content knowledge. These components relate to the successful use of digital media to facilitate teaching and learning processes.

Although the TPACK framework has become established in research and provides a theoretical framework with respect to digital media teaching skills, the framework's factorial structure has yet to be clarified. While the TPACK framework offers theoretical descriptions of seven individual constructs that result from the three higher-order components, these seven constructs have rarely been demonstrated in factorial studies (Scheiter, 2021). For example, both Scherer et al. (2017) and Lachner et al. (2019) identify TK as being mostly independent of the other facets of the TPACK framework. Moreover, these authors found it was not possible to clearly distinguish the other six TPACK components, suggesting that not only are they independent of TK, but they are also strongly interrelated (Lachner et al., 2019; Scheiter, 2021, Scherer et al., 2017,). The TPACK framework has been used widely in research because it systematically compiles the skills teachers need to successfully use digital media in the classroom. However, empirically measuring each TPACK component in a valid way requires further readjustment and research, with TK in particular requiring clarification; research has shown that TK is an independent component of the TPACK framework (Petko, 2020).

Scholars (Backfisch et al., 2020; Scheiter, 2021) have postulated that ambiguous results in relation to the TPACK framework's factorial structure are a result of the quality of the measurement instruments. In most studies of the TPACK framework, subjects' skills were not objectively measured; instead, they were asked to self-assess their skills (Scott, 2021). However, researchers have found no significant correlations between teachers' self-assessments and objective performance with regard to items referring to the

TPACK framework (Drummond & Sweeny, 2017; Kopcha et al., 2014; Hämäläinen et al. 2021, Baier & Kunter, 2021). The weak correlation between self-assessment and objective assessment measures in relation to the TPACK framework can be interpreted in several ways. On the one hand, the so-called Dunning-Kruger effect is often used as an interpretive approach (Dunning et al., 2004). The Dunning-Kruger effect states that unskilled subjects tend to overestimate their abilities, which leads to self-assessment bias. Accordingly, the weak correlations between teachers' self-assessments and objective performance on the TPACK framework are not surprising, as subjects with insufficient abilities tend to overestimate their skills in self-assessments. Furthermore, according to Scheiter (2021) and Backfisch et al. (2020), the use of self-reporting is critical because subjects are often unable to accurately classify their knowledge and skills. These authors argue that, according to Bandura's (1977) social cognitive theory, individuals are more likely to capture their self-efficacy (i.e., confidence in their ability to successfully complete a task) than actual knowledge when self-reporting their knowledge and performance. This may lead to self-assessment bias because a person's self-efficacy does not necessarily correspond with their actual knowledge or skills (Hatlevik et al., 2018).

Consequently, self-assessment instruments have been the focus of recent research, as they show potential for improvement in validly measuring aspects of the TPACK framework (Scheiter, 2021). According to Scheiter, the formulations of items in current self-assessment instruments are often too vague to support concrete statements about one's knowledge or skills. Scheiter argues that vague item formulations in self-assessment instruments, such as "I can use digital media efficiently in the classroom," leave too much room for interpretation for test subjects. This is because teachers tend to orient themselves more towards the theoretical conventions of high-quality instruction using digital media than towards their actual skills.

In summary, there is a discrepancy between the self-assessment of one's skills and the objective measurement of actual skills in relation to the components of the TPACK framework. Research has shown that this discrepancy is largely a result of vaguely worded self-assessment instruments, making it challenging to offer concrete statements about an individual's skills. Given the discrepancy between self-assessments and objective measures, it may be preferable to use objective assessment measures in educational science to better understand teaching-learning processes and to provide tailored teacher education and training in the future. However, implementing objective assessment measures is a major challenge in educational science. On the one hand, designing objective assessment measures is usually very complex and time-consuming; these measures are often very challenging for subjects and lead to study reluctance and dropout that is not present in studies that use self-assessment measures (Kleinert et al., 2015). On the other hand, objective assessment measures are often criticized for their external validity. For example, objective assessment measures that are used to measure digital skills are often imitated by presenting subjects with screenshots of real-life situations when using a computer (e.g., Fraillon et al., 2020). However, according to Siddiq et al. (2016), teachers' actual digital skills should be measured using achievement tests in which teachers work on computers and solve tasks.

Given the discrepancy between the results of subjective and objective assessment measures and the obstacles to integrating more objective assessment measures into educational science, a solution is needed to generate valuable knowledge about teaching and learning processes. According to Scheiter (2021), vignette-based self-assessment instruments might provide an avenue to help teachers accurately represent their skills in an action-oriented and situated test format; this would be preferable to the usually vague and therefore problematic item formulations in regular self-assessment instruments.

Sailer et al. (2021a) suggest a similar approach through their scenario-based assessment of teachers' digital skills. In Sailer et al.'s (2021a) study, subjects were required to assess and rate their knowledge and skills based on a scenario they were presented with. For example, subjects had to assess the extent to which they felt able to implement group work using tablet computers in the classroom. According to the authors, the formulation of a scenario acts as an "anchor" that is not present in regular forms of self-assessment; the scenario can help teachers more accurately and validly self-assess their skills and attitudes (p. 7).

According to Scheiter (2021), the individual components of the TPACK framework represent an important component of teaching with digital media – that is, the teachers' perspective. Although the TPACK framework plays an important role in educational science, numerous studies have revealed ambiguities in the TPACK framework's factorial structure. For example, previous research has presented TK as being independent of the other six TPACK components, implying that it is independent of teaching and learning processes with digital media (Scherer et al., 2017). However, based on the KMK framework (2016), TK – which is synonymous with digital skills – is an indispensable component of successful participation in society and thus must be an integral part of curricula. Therefore, teachers must teach digital skills to learners, which requires that they also possess sound digital skills.

To date, in educational science, the veracity of teachers' digital skills has mostly been assessed using self-assessments. Although self-assessments can generally provide valuable insights for the field of educational science, this type of assessment has often been criticized in recent research as being biased; subjects cannot accurately assess their skills due to vague item formulations (Scheiter, 2021). Since objective assessment measures are often difficult to apply in practice due to subjects' reluctance to take

objective assessment tests, current research aims to enrich self-assessment items with additional information so that subjects can better assess their skills (e.g., by asking subjects how they would respond to a given scenario; Sailer et al., 2021a). Correspondingly, Study 2 of this dissertation compares scenario-based self-assessment and the objective assessment of teachers' TK to investigate this hypothesis.

1.4 Digital skills of learners

Learners' digital skills are indispensable to successful participation in society and success in their professional lives (KMK, 2016, Fraillon et al., 2020, Scheiter, 2021). According to the KMK framework (2016), learners must be able not only to use digital media effectively, but also to critically evaluate and reflect on the information they gain through its use before they enter professional or academic life. However, one might ask whether secondary learners already possess the digital skills they need to participate successfully in society. Through two large-scale ICILS studies, which were conducted in 2013 and 2018, researchers have provided an international overview of secondary learners' digital skills. In the 2018 ICILS study, the researchers divide secondary learners' digital skills into four proficiency levels: level 1 is the lowest proficiency level, while level 4 is the highest proficiency level. Secondary learners at level 1 can, for instance, open an Internet link in a new web browser tab or identify who receives an email by carbon copy (Fraillon et al., 2020, p. 57). Proficiency level 4 secondary learners can, among many other things, evaluate and judge internet sources when they search for or create information (Fraillon et al., 2020, p. 60), which is in line with the KMK (2016) framework. The results of the most recent ICILS study illustrate that of secondary learners around the world, most only demonstrate level 2 skills. This means that secondary learners in the 8th grade can use computers to complete basic information gathering and management tasks (Fraillon et al., 2020, p. 57). This is insufficient considering the increasing importance of proficient digital media use to participate in society successfully (Fraillon et al., 2020, KMK, 2016). Hence, one can conclude that on average, secondary learners' digital skills do not (yet) meet curricula requirements. The reasons why learners do not currently meet the requirements in curricula are manifold; however, studies have shown that personal factors such as socioeconomic status (e.g., Scherer & Siddiq, 2019)

and the typology of digital media usage (Senkbeil, 2017) play an important role when it comes to digital skill-based performance differences.

Regarding the typology of digital media usage, studies have shown that target-oriented digital media use can have a positive impact on learners' digital skills (Senkbeil, 2017; Alkan & Meinck, 2016). This means that those learners who use digital media purposefully for instrumental purposes such as learning or producing information also exhibit higher digital skills. On the contrary, learners who reported that they often used digital media for less targeted purposes such as social communication demonstrated a performance disadvantage in their digital skills.

Based on the finding that target-oriented use of digital media has a positive impact on learners' digital skills, there is great potential for the use of digital media in teaching and learning processes. For example, technologies can be used in a more target-oriented way to help learners acquire digital skills as specified in a particular curriculum. However, target-oriented use of digital media in instruction presupposes that digital media are a daily component of teaching and learning processes. Regarding secondary learners' use of digital media in school, in one study that focused on German learners, learners reported that digital media is rarely used in the classroom (Schaumburg et al., 2019). According to the results of the 2018 ICILS study, almost one-fifth of secondary learners in Germany reported they had never used digital media in school for school-related purposes. Furthermore, with respect to the frequency of digital media use and learners' digital skills in Germany, the 2018 ICILS study contains ambiguous findings. Among secondary learners who reported that they regularly used digital media in school for school-related purposes, the results showed a negative effect of the digital media usage in the classroom on learners' digital skills (Schaumburg et al., 2019). However, the

authors found a positive effect on secondary learners' digital skills when learners reported using digital media *outside* school for school-related purposes.

Research indicates that the typology of digital media use has an impact on learners' digital skills. However, the direction of the impact and its magnitude are generally mixed. According to scholars (e.g., Petko et al., 2017), the ambiguity of the research findings relates to the fact that secondary learners tend to indicate how often they use digital media rather than which activities they use it for; one might thus draw an inference about the quantity rather than the quality of their use of digital media.

Juuti et al. (2022) explain the heterogeneous findings regarding adolescents´ digital media use and their academic achievement, drawing upon Heidegger's (1962) conceptualization. They note that adolescents' use of digital media can be divided into two categories: *readiness-to-hand* and *presence-at-hand.* According to Juuti et al. (2022), digital media is in the foreground during readiness-to-hand use. Readiness-to-hand use includes everyday digital media use like instant messages, which do not require any conscious awareness of the learner. In presence-at-hand digital media use, adolescents use digital media more purposefully. Here, learners shift their attention from digital media itself to the actual activity at hand, such as solving a task. According to Juuti et al. (2022), this type of use should lead to higher academic achievement. Juuti et al. (2022) confirm their hypothesis using a structural equation model. In their study, learners who indicated that they used digital media more purposefully and carefully also demonstrated significantly better academic achievement. Based on Juuti et al.'s (2022) findings, one could argue that the target-oriented use of digital media also has a positive effect on adolescents' digital skills, which curricular guidelines often require (see KMK, 2016). Accordingly, it is important that more attention is paid to how adolescents use digital media rather than how frequently they use it. A more precise picture of how secondary

learners use digital media would provide concrete information about which types of use are beneficial to their digital skills, which would, in turn, lead to relevant findings for teaching research and curriculum development.

However, to obtain concrete insights into the extent to which secondary learners' digital media use affects their digital skills, one must also consider personal factors such as learners' socio-economic status. Both the results of the 2013 and 2018 ICILS studies (Wendt et al., 2014, Senkbeil et al., 2019) show that secondary learners from privileged families (i.e., those who possess a high socioeconomic status and high levels of cultural capital) have a performance advantage with respect to digital skills. Initial attempts to interpret these results align that less privileged families may be unable to raise the capital necessary to provide learners access to digital media and therefore learners from these families perform more poorly in digital skills (OECD, 2019). This has been referred to in educational science as the *digital divide*.

Although schools in many countries have begun to receive financial supports to purchase digital media, which assists in counteracting the digital divide, the COVID-19 pandemic has put all counteracts against the digital divide to the test. Beginning in the spring of 2020, secondary learners around the world were required to participate in remote learning using the digital media they owned. While the long-term impact of the COVID-19 pandemic has yet to be precisely determined (e.g., Dorn et al., 2020), it is plausible that less privileged learners had fewer resources to participate in online instruction. This may have affected their ability to participate or even completely excluded them from lessons. Consequently, further research regarding the impact of the COVID-19 pandemic on the use of digital media and the digital skills of learners is required. In particular, researchers must examine less privileged learners more closely to identify corresponding deficits and, if necessary, to establish target interventions.

In summary, it is of major importance to examine the quality of learners' digital media use, as only the target-oriented digital media use is positively related to learners' digital skills. To obtain meaningful results, however, personal factors such as learners' socioeconomic status must also be taken into account. The COVID-19 pandemic and consequent online instruction in many countries have made this particularly relevant. Accordingly, Study 1 of this dissertation examines learners digital media use prior to and during the COVID-19 pandemic to gain important research insights in this regard.

1.5 Combining the teacher and learner perspectives with respect to digital skills

With the integration of digital skills into curricula, schools have a responsibility to foster learners' digital skills (Seufert et al., 2021). Instruction and teachers' professional knowledge play a crucial role in teaching digital skills to learners. Previous research has shown that teachers' knowledge of the subject matter they teach is critical to learner achievement (see Baumert et al., 2010). However, the relationship between learner achievement and teachers' knowledge cannot be interpreted in isolation because the instructional processes that affect learner achievement are very complex (Charalambos & Hill, 2012). Accordingly, process-related variables such as instructional quality must be included to determine the extent to which teachers' subject-specific knowledge is related to learner achievement. One can assume that teachers with strong knowledge of the subjects they teach (e.g., mathematics) are most likely to offer high-quality instruction given their knowledge of the content (Baumert et al., 2010).

While the relationship between teachers' subject-specific knowledge and learners' subject-specific achievement is relatively well established, the relationship between teachers' cross-curricular skills (e.g., digital skills) and learner achievement remains largely unexplored. Although the impact of teachers' cross-curricular subject knowledge on learners' cross-curricular subject knowledge is generally unexplored, Hillmayr et al.

(2020) highlight the relevance of teachers' knowledge in using digital media in the classroom in their meta-analysis. They note that interventions that provided teachers with training on the use of digital media in the classroom had significantly greater positive effects on learner achievement than studies that did not provide specific training. Although Hillmayr et al.'s (2020) study examines learner achievement in the sciences, the results support that teachers' digital skills and knowledge of digital media use also have a positive impact on learners' digital skills.

In summary, in view of advancing digitalization and the COVID-19 pandemic, teachers' and learners' digital skills are a current topic of great importance in educational science. However, it remains unclear how teachers' digital skills affect learners' digital skills. Previous research has shown that teachers' subject-specific knowledge (e.g., in mathematics) is of great importance to learner achievement; teachers with deep knowledge of the subjects they teach are better aligned with the content they teach, and they thus offer high-quality subject-specific instruction to learners (Baumert et al., 2010). However, the relationship between teachers' and learners' digital skills as mediated through the use of digital media in the classroom is a topic that remains largely unexplored. The third study within the scope of this dissertation examines this topic in greater detail.

2. Study 1: A Typology of Adolescents Technology Use Before And During The COVID-19 Pandemic: A Latent Profile Analysis

With the ongoing digitization of society and education, adolescents' technology use has been attracting widespread interest in educational research. The underlying assumption is that technology has a positive impact on academic achievement. However, research on the use of technology in relation to adolescents' academic achievement has demonstrated remarkable contrast. For example, large-scale studies have often shown a negative relationship between adolescents' technology use and their academic achievement (Bundsgaard & Gerick 2017; Hu, Gong, Lai, & Leung, 2018; Petko, Cantieni, & Prasse, 2017). According to scholars (e.g., Petko et al., 2017; Juuti, Kervinen, & Loukomies, 2022), the diverse evidence related to adolescents' technology use and academic achievement suggests that typologies of adolescents' technology use have been poorly studied.

Accordingly, adolescents are usually asked in studies to indicate how frequently they use technology in general, but they are usually not asked to identify the purpose of their technology use. Nevertheless, the purpose of technology use is presumed to be meaningful (e.g., for study-related purposes) therefore and positively related to adolescents' academic performance. Current empirical research has supported this assumption (Juuti et al., 2022). Adolescents who reported using technology more for study-related purposes and less for social purposes (e.g., communicating with friends and family) showed correspondingly higher digital skills (Senkbeil, 2017). Accordingly, in future educational research, it is important to analyze which types of technology use are prevalent among adolescents in more detail so that the use of different types of technology can be related more accurately to adolescents' academic achievement.

Moreover, typologies of adolescents' technology use are sensitive to adolescents' personal factors, such as gender and socioeconomic status, which is often operationalized as parents' education (e.g., Senkbeil, 2017). Findings on gender differences in types of technology use have been inconclusive so far. For example, Alkan and Meinck (2016) showed that female adolescents are more likely to use technology for social communication compared to male adolescents, whereas Senkbeil (2017) showed that female adolescents are more likely to use technology for target-oriented purposes, such as information retrieval and study-related purposes. However, research on typologies of technology use in relation to parents' education has shown a clearer picture. In relation to adolescents' technology use and parents' education, the digital divide is often referenced (van Dijk, 2020). It can be inferred that socially disadvantaged adolescents are less likely to use technology because they do not have access at home, which has a corresponding impact on their digital skills (OECD, 2019). Therefore, socially disadvantaged adolescents might be at risk of being left behind as society and schools become more digitized. In summary, international research has shown that adolescents' technology use depends on their parents' level of education, whereas findings on gender differences have been ambiguous.

As schools continue to digitize, efforts are being made to address the digital divide by equipping schools so that all students can use technology in a target-oriented manner that is based on the curriculum (Ritzhaupt, Cheng, Luo, & Hohlfeld, 2020; Drossel, Eickelmann, & Vennemann, 2020; Standing Conference of the Ministers of Education and Cultural Affairs [KMK], 2016; KMK, 2019a). Nonetheless, the beginning of the COVID-19 pandemic challenged all efforts to bridge the digital divide: Adolescents relied on technology at home to sustain their learning and social connections during the physical school closures that began in March 2020 (Goh & Sandars, 2020; Beaunoyer,

Dupéré, & Guitton, 2020; Eghtesadi, 2020), which required sound digital skills. Even though the long-term impact of the COVID-19 pandemic on adolescents' technology use has yet to be determined (Goldschmidt, 2020), researchers already agree that students whose parents have low levels of education have a particularly difficult time keeping up with digitization, which has been accelerating due to the COVID-19 pandemic (Thorn & Vincent-Lancrin, 2021). For example, students whose parents have a lower level of education might not be able to participate in online courses because they lack the financial resources and thus the technical equipment at home (Van Lancker & Parolin, 2020).

To shed light on the impact of the COVID-19 pandemic on adolescents' technology use, this paper is organized as follows: First, we used a person-centered latent profile analysis (LPA)approach to examine typologies of adolescents' technology use before (Study 1) and during (Study 2) the COVID-19 pandemic. Second, personal factors, such as adolescents' gender and their parents' education, were associated with the profiles that were based on adolescents' technology use. The results of this study are aimed at expanding the international field of research on the typology of adolescents' technology use in addition to a deeper understanding of the potential impact of the COVID-19 pandemic on the typology of adolescents' technology use.

Typology of adolescents' technology use

How adolescents use technology has been studied for several years and has recently attracted considerable research interest given the ongoing digitization of schools and society (Fraillon, Ainley, Schulz, Friedman, & Duckworth, 2020). With the large-scale International Computer and Information Literacy study [ICILS], researchers were able to provide an international overview of adolescents' personal and study-related technology use. Whereas data from the 2013 ICILS study had already indicated that technology use is an essential part of adolescents' school and personal lives, data from the

current ICILS study 2018 provided a better understanding. As the frequency of technology use was examined in more detail, adolescents in the ICILS study 2018 were more specific about the purposes for which they use technology. Looking more closely at how adolescents use technology, 33% of adolescents reported using technology weekly to create or edit information products, such as using spreadsheets or recording videos or music. Internationally, there were fewer differences between adolescents in participating countries in terms of social communication, but there were significant differences in terms of information sharing, with adolescents in Germany and Denmark reporting a particularly low use of technology for information sharing.

Previous research has shown that types and frequency of adolescents' technology use are also related to adolescents' digital skills (Senkbeil, 2017). This means that adolescents who use technology frequently and in a variety of ways also have higher digital skills. These include operating and using digital media, searching for and processing information, communicating and cooperating with technology, producing media content, and using technology for study-related purposes. These specific areas of digital skills represent the target skills that students need to successfully participate in society and to later participate in professional life (Fraillon et al., 2020). In summary, adolescents use technology frequently for both private and study-related purposes, but technology is still being used significantly more frequently for private purposes than for study-related purposes. Further, the use of technology by adolescents is heterogeneous at the international level, with the exception that most adolescents use technology for social communication (e.g., with friends and family).

Brandtzaeg (2010) addressed the heterogeneity of technology use in a typology framework (MUT) by identifying different typologies of technology use based on the indicators of frequency of use and variety of use, such as (a) nonusers, (b) sporadic, (c)

debaters, (d) socializers, (e) instrumental users, and (f) advanced users. Senkbeil (2017) conducted an empirical examination of Braendzaeg's (2010) MUT framework by using latent profile analysis to identify different types of technology use in adolescents. The results showed that typologies of adolescents´ technology use could be identified as having instrumentalist, social, and versatile reasons for using technology, indicating mixed forms of user types from Braendzaeg's (2010) MUT framework. According to KMK (2016), the *Advanced Users* and *Instrumental Users user types* would be considered user types with strong digital skills because they use technology in a heterogeneous way, where specific areas of skills are covered (e.g., searching and processing information) to successfully participate in society and later professional life (Fraillon et al., 2020). This assumption was also confirmed by Senkbeil´s (2017) study in which adolescents who used technology for instrumental rather than social purposes also showed stronger digital skills.

Personal factors in relation to adolescents' technology use

The latent profiles identified by Senkbeil (2017) and based on Braendzaeg's (2010) MUT framework showed differences in terms of gender and adolescents´ parents' education. Regarding gender, Senkbeil (2017) showed that male adolescents were more likely to be represented in latent profiles that had strong social-interactive motivations for using technology, whereas female adolescents were more likely to be represented in latent profiles of adolescents who reported using technology for instrumental purposes. Overall, more male adolescents were also represented in the *Versatile* latent profile, suggesting that male adolescents were more likely to use technology for multiple purposes compared with female adolescents. The findings are also consistent with Cai et al.'s (2017) meta-analysis on gender and technology use: Female adolescents tend to have less positive attitudes toward technology use compared with male adolescents, as male adolescents are

particularly likely to believe in the benefits of technology use in society, which could explain the increased versatile use of technology on the part of male adolescents.

In relation to parents' education and adolescent technology use, Senkbeil (2017) showed that adolescents with parents with high levels of education are more likely to use technology for study-related purposes, while adolescents with parents with low levels of education are more likely to use technology for social purposes, such as communicating with friends and families. The reasons for the difference in typologies related to technology use and parental education may be varied, but attempts to interpret these findings suggest that less privileged families may not be able to raise the capital to provide their children with access to technology or support in terms of purposeful, study-related technology use (van der Vlies, 2020), and that parents with higher levels of education may be able to help their children use technology in meaningful ways (Ren, Zhu, & Yang, 2022). This difference could lead to less privileged adolescents being excluded from the digitization process, referred to as the digital divide (van Dijk, 2020). The digital divide could particularly affect adolescents who attend schools with lower educational tracks, as their parents often have lower levels of education (Birkelund, Capsada-Munsech, Boliver & Karlson, 2021).

Typology of adolescents´ technology use and the COVID-19 pandemic

With the onset of COVID-19 pandemic, adolescents relied on technology to sustain their social lives (Eghtesadi, 2020) as well as to continue their education (Goh & Sandars, 2020). Accordingly, it can be assumed that adolescents' use of technology changed because of the COVID-19 pandemic. Based on the premise that adolescents' technology use can affect digital skills and that these skills are a component of successful participation in society (Fraillon et al., 2020), two questions arise. First, to what extent did the physical school closures caused by the COVID-19 pandemic change adolescents'

technology use, and second, did the physical school closures further exclude socially disadvantaged adolescents from participating in the teaching and learning process? So far, findings have shown that teachers did not have sufficient digital skills to effectively deliver distance education, and appropriate learning management systems were not available during the physical school closures (Thorell, Skoglund, Giménez de la Pena, Baeyens, Fuermaier, & Groom et al., 2021). These deficiencies in turn could have affected adolescents' technology use. Further, adolescents with parents with low levels of education are particularly at risk of being further affected by the digital divide as these parents are not able to help their children use technology properly during remote learning, thereby exacerbating digital and social inequalities during the COVID-19 pandemic (e.g., Azubuike, Adegboye & Quadri, 2021; Beaunoyer et al., 2020; Thorn & Vincent-Lancrin, 2021).

In summary, the COVID-19 pandemic had a major impact on education, and adolescents' technology use was an indispensable part of sustaining the educational system during the physical school closures in many countries in 2020. Consequently, it may be plausible that during the physical school closures in 2020 due to the COVID-19 pandemic, adolescents were encouraged to use technology for study-related and instrumental purposes. According to common competency models (e.g., KMK, 2016; Krumsvik, 2011), such the study-related and instrumental technology use is beneficial for adolescents' digital skills. By contrast, however, less privileged adolescents may have been at especially high risk of falling behind in school as a result of the COVID-19 pandemic, because, for example, parents with a low educational level were not able to support remote teaching and learning processes or to raise the necessary financial capital to provide the appropriate kinds of technology at home. In summary, it makes sense to ask to what extent adolescents' technology use changed during the COVID-19 pandemic

and the physical school closures in 2020, and to what extent adolescents' personal factors played a role in determining their technology use during the COVID-19 pandemic. Hence, the current study was aimed at providing further valuable insights into the extent to which the COVID-19 pandemic has influenced teaching and learning processes in order to establish appropriate target interventions.

The present study

In the current study, we aimed to investigate the extent to which different profiles could be identified in terms of adolescents' technology use in 2019 (Study1) and during the COVID-19 pandemic and physical school closure in 2020 (Study 2), using two representative samples from the region of Bavaria (Germany). Further, we examined the extent to which the personal factors of gender, the type of school the students attended, and parents' education predicted profile membership. Prior to the COVID-19 pandemic, great efforts were made to prevent socially disadvantaged adolescents from digital exclusion by providing them with adequate school facilities (Hohlfeld, Ritzhaupt, Dawson, & Wilson, 2017; Kim, Yi, & Hong, 2021). However, during the COVID-19 pandemic and the physical school closures in 2020, adolescents consistently relied on the kinds of technology they had at home. Consequently, it is important to ask about the extent to which the physical school closures during the COVID-19 pandemic in 2020 and the corresponding indispensable use of technology changed adolescents' technology use, particularly among adolescents whose parents had low levels of education, as such parents might not be able to provide appropriate technological resources at home. In summary, the following research questions guided the current study:

RQ 1. To what extent can different subgroups of adolescents be identified in terms of technology use before the COVID-19 pandemic in 2019 (Study 1)?

RQ 2. To what extent do the personal factors of gender and the type of school students attended predict students' membership in certain profiles before the COVID-19 pandemic in 2019 (Study 1)?

RQ 3. To what extent can different subgroups of adolescents be identified in terms of technology use during the COVID-19 pandemic and physical school closures in 2020 (Study 2)?

RQ 4. To what extent do the personal factors of gender, the type of school students attended, and parents' educational level predict students' membership in certain profiles during the COVID-19 pandemic and physical school closures in 2020 (Study 2)?

Materials and Method

Sample and Research Design

In this cross-sectional study, we examined two representative independent samples of adolescents from the region of Bavaria (Germany), one before the COVID-19 pandemic (2019) and one during the COVID-19 pandemic (2020). The first sample (Study 1, prior to the COVID-19 pandemic, 2019) included n = 643 adolescents between the ages of 10 and 19 years (M = 13.75, SD = 2.04) of whom 53% were female (n = 343). Of the adolescents surveyed, 32% (n = 204) attended a general secondary school (Mittelschule), 31% (n = 199) attended an intermediate-level secondary school (Realschule), and 37% (n = 240) attended a secondary school in the highest educational track (Gymnasium). The second sample (Study 2, during the COVID-19 pandemic and physical school closures in 2020) included N = 644 adolescents between the ages of 10 and 19 (M = 13.35, SD = 2.21) of whom 55% were female (n = 353). Of the adolescents surveyed, 25% (n = 200) attended a general secondary school, 32% (n = 201) attended an intermediate-level secondary school, and 38% (n = 243) attended a secondary school in the highest educational track. In Study 2, during the COVID-19 pandemic, 24% of parents

(*n* = 157) had a tertiary (university) degree, 33% of parents (*n* = 213) had a postsecondary degree, and 40% (*n* = 264) of parents had a secondary school degree as their highest level of education. All subjects were informed of the purpose of the study, and both the adolescents and their parents explicitly consented to participate in this study

Procedure

Data were collected from both samples via telephone interviews both before the COVID-19 pandemic and during the COVID-19 pandemic (for further and detailed information see Sailer et al, 2021a). Interviews with Study 1 (prior to the COVID-19 pandemic) took place from November to December 2019, with an average duration of 13 min per interview. Interviews with Study 2 (during the COVID-19 pandemic) took place from July to September 2020, with an average duration of 17 min per interview. Interviewees were first asked demographic questions, such as their age, gender, and the type of school they attended. The interview concluded with questions about the interviewee's technology use. The general procedure that was followed in conducting the telephone interviews was the same in the two studies. However, the interviews in Study 2 were conducted during the COVID-19 pandemic and physical school closures, so the interview questions were adapted to home-schooling and included more questions about personal factors.

Measurement of variables

Adolescents' technology use. Adolescents´ technology use was assessed with six self-estimation items following the suggestions made by KMK (2016) or further information provided by Sailer et al (2021a). The items included general technology use, research via technology, communication via technology, collaboration via technology, and production of content via technology. Adolescents were asked to rate their technology use as 0 (*never*), 1 (*seldom*), 2 (*sometimes*), 3 (*often*), and 4 (*very often*) in response to each item

(see Table 1).

Personal factors. One item asked about parents' highest level of education because parents' education provides information about the parents' cultural capital as a certain level of education is required for specific occupations (Palomino, Marrero & Rodriguez, 2019). Further, students were asked about their *gender* and the *type of school* they were attending.

Table 1

Adolescents' Technology Use Before the COVID-19 Pandemic N = 643 (Study 1) and During the COVID-19 Pandemic N = 644 (Study 2)

	Study 1 (pre-COVID) (N = 643)				Study 2 (during COVID) (N = 644)			
Variable	*M*	*SD*	*min.*	*max.*	*M*	*SD*	*min.*	*max.*
General technology usage	3.67	0.60	2.00	4.00	3.70	.68	1.00	4.00
Research via technology	3.45	0.79	1.00	4.00	3.20	1.14	0.00	4.00
Communication via technology	3.84	0.44	2.00	4.00	3.79	.47	1.00	4.00
Collaboration via technology	3.03	1.07	1.00	4.00	3.44	.81	0.00	4.00
Production of content via technology	1.89	1.31	1.00	4.00	2.55	1.30	0.00	4.00
Study-related technology use	3.07	.96	0.00	4.00	3.87	.35	3.00	4.00

Statistical Analysis

To identify typologies of adolescents' technology use before and during the COVID-19 pandemic, a latent profile analysis (LPA) was conducted for both Study 1 (prior to the COVID-19 pandemic in 2019) and Study 2 (during the COVID-19 pandemic in 2020). LPA is used to identify homogeneous subgroups in a heterogeneous population based on underlying similarities using model-based probabilistic clustering (Lubke & Muthen, 2005). It is suitable for continuous data (Hikendorff, Edelsbrunner, McMullen, Schneider, & Trezise, 2018). We identified the optimal number of profiles using the fit

indicators Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample-size-adjusted BIC (SABIC), Consistent Akaike Information Criterion (CAIC), classification certainty (prob min), entropy value, and Bootstrap Likelihood Ratio Test (BLRT), statistically comparing k profiles with k - 1 profiles. Entropy is an indicator of the accurate classification of the latent profile, it ranges from 0 to 1, and it is aimed at identifying models with an entropy of < .80 (Kim et al., 2021). We identified the best-fitting model as the one with lower fit indices: AIC, CAIC, BIC, and SABIC (Nylund, Asparouhov & Muthén, 2007). To determine typologies of adolescents' technology use, we used the means of the six items about general technology use, research via technology, communication via technology, collaboration via technology, production of content via technology, and study-related technology for each profile. Multinomial logistic regression was used to analyze the extent to which personal factors predicted membership in a particular latent profile. We conducted the analysis in R (version 4.1.0) using the *mclust* package (Scrucca, Fop, Murphy, & Raftery, 2016) for LPA and the *nnet* package (Venables & Ripley, 2002) for multinomial logistic regression. We used a built-in imputation method to address missing data using the *mice* package (van Buuren & Groothuis-Oudshoorn, 2011).

Results

Profiles that were identified prior to the COVID-19 pandemic (Study 1)

To answer RQ 1, we conducted a latent profile analysis (LPA) to identify typologies of adolescents' technology use before the COVID-19 pandemic in 2019 (Study 1). To identify the best fitting model, models with one to five profiles were estimated. Table 2 shows the model fit information criteria associated with the models with one to five profiles. The *p*-value (BLRT, $p = .01$) remained significant for two to five latent profiles, and the entropy values were sufficiently high (> .80). Regarding the fit indices

BIC, AIC, CAIC, and SABIC, the five-profile solution showed the lowest and thus the best model fit. The final five profiles prior to the COVID-19 pandemic (Study 1) are shown in Figure 1. Descriptive statistics for the latent profiles identified in Study 1 are summarized in Table 3.

Table 2

Fit Indices for One to Five Latent Profile Solutions for Adolescents' Technology Use Prior to the COVID-19 Pandemic (Study 1, N = 643)

Model	**LL**	**AIC**	**CAIC**	**BIC**	**SABIC**	**BLRT**	**Entropy**	**prob. min**
1 profile	-5471	10966.53	11032	11020.12	10982	-	1.00	1
2 profiles	-5090	10218.28	10322	10303.13	10243	0.01	1.00	1.00
3 profiles	-5049	10149.81	10292	10265.93	10183	0.01	.93	.83
4 profiles	-4980	10026.43	10207	10173.82	10069	0.01	.81	.79
5 profiles	**-4714**	**9472.51**	**9726**	**9686.33**	**9559**	**0.01**	**.84**	**.69**

Note. Bold values indicate the best fitting model.

Figure 1

Five-profile Solution for Adolescents' Technology use Prior the COVID-19 Pandemic (Study 1, *N* = 643)

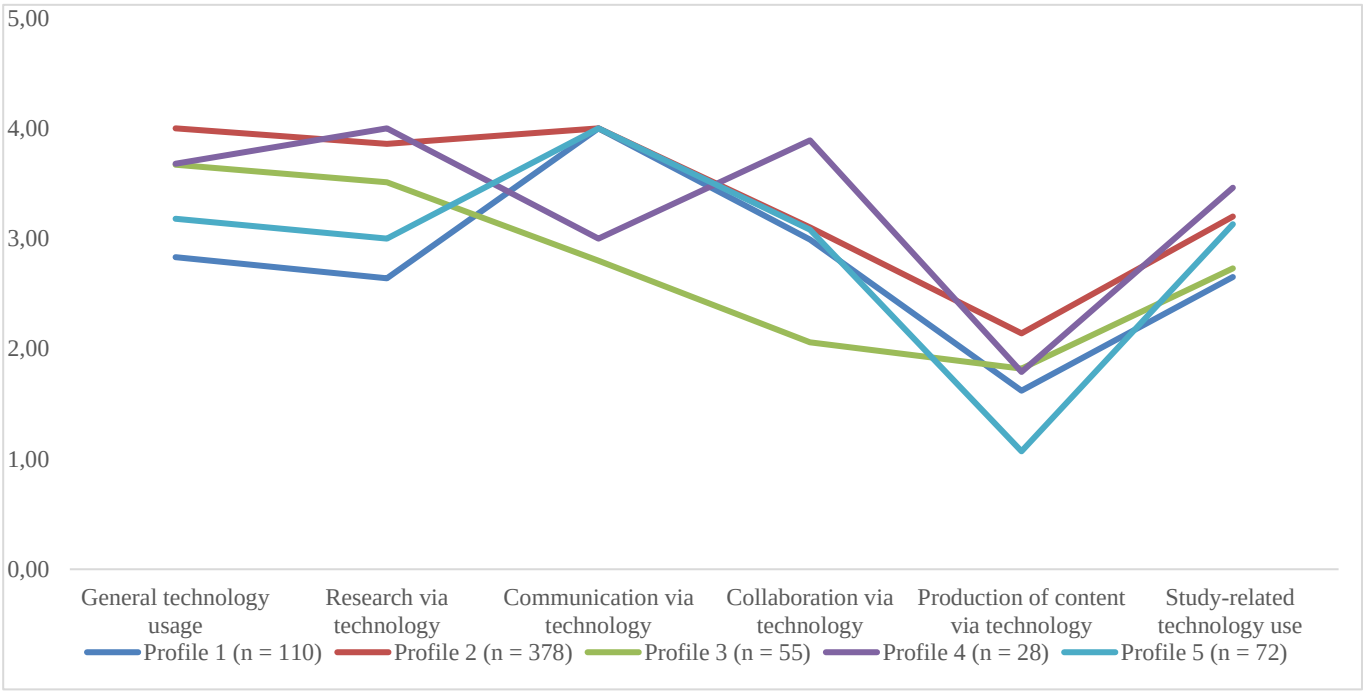


Table 3

Descriptive Statistics for the Latent Profiles Identified in Study 1 (Prior to the COVID-19 Pandemic, N = 643)

Variable	Profile 1 Socializers (*n* = 110)		Profile 2 Average users (*n* = 378)		Profile 3 Investigators (*n* = 55)		Profile 4 Advanced users (*n* = 28)		Profile 5 Social Instrumentalists (*n* = 72)	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Gender										
Female	61	55	198	52	32	58	15	54	37	51
Male	49	45	180	48	23	42	13	46	35	49
Type of school										
General secondary school	39	35	122	32	17	30	5	18	23	32
Intermediate-track secondary school	33	30	112	30	19	35	9	32	22	31
High-track secondary school	39	35	144	38	19	35	14	50	27	37

Profile 1 – Socializers

The adolescents in Profile 1 *Socializers* (*n* = 110) stated that they used technology mostly for *communication via technology* (*M* = 4.00). Moreover, adolescents in Profile 1 were less likely to use technology for instrumental purposes, such as *research via technology* (*M* = 2.64) or *production of content via technology* (*M* = 1.62). Accordingly, Profile 1 was focused purely on the social aspect of communication, and the profile was accordingly labeled *Socializers*.

Profile 2 – Average Users Profile 2 included the largest number of adolescents (*n* = 378). Adolescents in Profile 2 indicated that they used technology frequently for both instrumental (e.g., *research via technology M* = 3.86) and social aspects (*communication via technology M* = 4.00). Accordingly, the adolescents in Profile 2 were referred to as *Average Users*.

Profile 3 – Investigators

Profile 3 included 55 adolescents. The adolescents in Profile 3 showed the highest mean score on the item *research via technology* (*M* = 3.51) and lower mean scores compared with the other profiles on *communication via technology* (*M* = 2.80) and *collaboration via technology* (*M* = 2.06). Accordingly, adolescents in Profile 3 were labeled *Investigators* because they primarily used technology for instrumental purposes rather than for social aspects of technology use.

Profile 4 – Advanced Users

Adolescents in Profile 4 (*n* = 28) frequently used technology not only for instrumental purposes, such as *study-related purposes* (*M* = 3.46) or *research via technology* (*M* = 3.86), but also for social purposes, such as *communication via technology* (*M* = 3.00) and *collaboration via technology* (*M* = 3.89), as in Profile 2 *Average Users*. However, the overall frequency of technology use was higher in Profile 4 for both instrumental aspects and social aspects compared with Profile 2. Accordingly, Profile 4 was designated as *Advanced Users* because the adolescents in Profile 4 additionally had the highest mean score for using technology for *study-related purposes* compared with the other profiles (*M* = 3.46).

Profile 5 – Social Instrumentalists

Adolescents in Profile 5 (n = 72) reported using technology frequently for *communication via technology* (M = 4.00) and *collaboration via technology* (M = 3.08) in contrast to adolescents in Profile 3 *Investigators*. In addition, adolescents in Profile 5 reported frequently using technology for instrumental purposes, such as *study-related purposes* (M = 3.13). Accordingly, the adolescents in this profile were classified as *Social Instrumentalists* because of the frequency of technology use for both social and instrumental purposes.

Personal factors in relation to the profiles identified prior to the COVID-19 pandemic (Study 1)

To address RQ 2, we computed a multinomial logistic regression to determine the extent to which the personal factors of gender and the type of school the students attended predicted their profile membership (see Table 4). With multinomial logistic regression, log odds determine how a 1-unit change in the predictor variables changes the probability of belonging to a particular profile relative to the reference profile. Our results showed that gender was not a significant predictor of membership in a particular profile. However, the type of school attended by the adolescents was a significant predictor of profile membership. The log odds of belonging to Profile 1 (Socializers) versus Profile 4 (Advanced Users) increased significantly (B = 1.63, $p < .01$) when adolescents attended an intermediate-track secondary school instead of a general secondary school. This means that adolescents from general secondary education were more likely to be in Profile 1 (Socializers) than in Profile 4 (Advanced Users). Furthermore, the log odds of being in Profile 1 (Socializers) versus Profile 4 (Advanced Users) increased significantly (B = 1.41, p = .04) when adolescents attended a school in the highest track instead of an intermediate-track secondary school. Accordingly, adolescents from high-track schools

were also more likely to be in Profile 4 (Advanced Users) than in Profile 1 (Socializers). Moreover, the log odds of being in Profile 4 (Advanced Users) versus Profile 5 (Social Instrumentalists) decreased significantly by B = -1.52 (p = .03) when adolescents attended a general secondary school instead of an intermediate-track secondary school. This means that adolescents from general secondary schools were more likely to be in Profile 5 (Social Instrumentalists) than Profile 4 (Advanced Users). Overall, our results show that adolescents from high-track and intermediate-track secondary schools were more likely to be allocated to profiles where adolescents used technology for study-related, instrumental purposes, which confirmed our expectations.

Table 4

Multinomial Logistic Regression Analysis (Study 1, N = 643) on Adolescents' Technology Use Prior to the COVID-19 Pandemic

	Profile 1 vs. Profile 2[a]		Profile 1 vs. Profile 3[a]		Profile 1 vs. Profile 4[a]		Profile 1 vs. Profile 5[a]		Profile 2 vs. Profile 3[a]	
Predictor	B (SE)	*p*	B (SE)	*p*	B (SE)	*p*	B (SE)	*p*	B (SE)	*p*
Gender (1 = female)	.12 (.22)	.58	-.12 (.33)	.71	.03 (.42)	.94	.15 (.30)	.60	-.24 (.29)	.41
Type of school – intermediate-track secondary school (1 = general secondary school)	.75 (.27)	.78	.28 (.40)	.49	1.63(.68)	.01*	.11(.38)	.76	.21 (.35)	.56
Type of school – highest track school	.19 (.25)	.47	.14 (.40)	.72	1.41 (.68)	.04*	.18(.36)	.62	-.04 (.36)	.90
	Profile 2 vs. Profile 4[a]		Profile 2 vs. Profile 5[a]		Profile 3 vs. Profile 4[a]		Profile 3 vs. Profile 5[a]		Profile 4 vs. Profile 5[a]	
Predictor	B (SE)	*p*	B (SE)	*p*	B (SE)	*p*	B (SE)	*p*	B (SE)	*p*
Gender (1 = female)	-.09 (.39)	.82	-.04 (.25)	.88	.15 (.47)	.74	.28 (.36)	.44	.12 (.44)	.77
Type of school – intermediate-track secondary school (1 = general secondary school)	**1.56 (.65)**	**.02***	0.04(.32)	.90	1.35 (.72)	.06	-.17 (.45)	.70	**-1.52 (.71)**	**.03***
Type of school – highest track school	1.22 (.66)	.06	-0.01(.31)	.98	1.26 (.72)	.08	**.**04 (43)	.92	-1.23(.71)	.08

Note. Profile 1= Socializers, Profile 2 = Average Users, Profile 3 = Investigators, Profile 4 = Advanced Users, Profile 5 = Social Instrumentalists. SE = standard error.

[a] Reference profile.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Profiles identified during to the COVID-19 pandemic (Study 2)

To address RQ 3, latent profile analysis models were estimated with one to five profiles (Table 5). The fit indices BIC, AIC, CAIC, SABIC were the lowest for the three-profile solution and therefore, the three-profile solution was considered to have the best fit. Figure 2 shows the final profile solution for adolescents' technology use during the COVID-19 pandemic (Study 2). Descriptive statistics for the latent profiles identified in Study 2 are summarized in Table 6.

Table 5

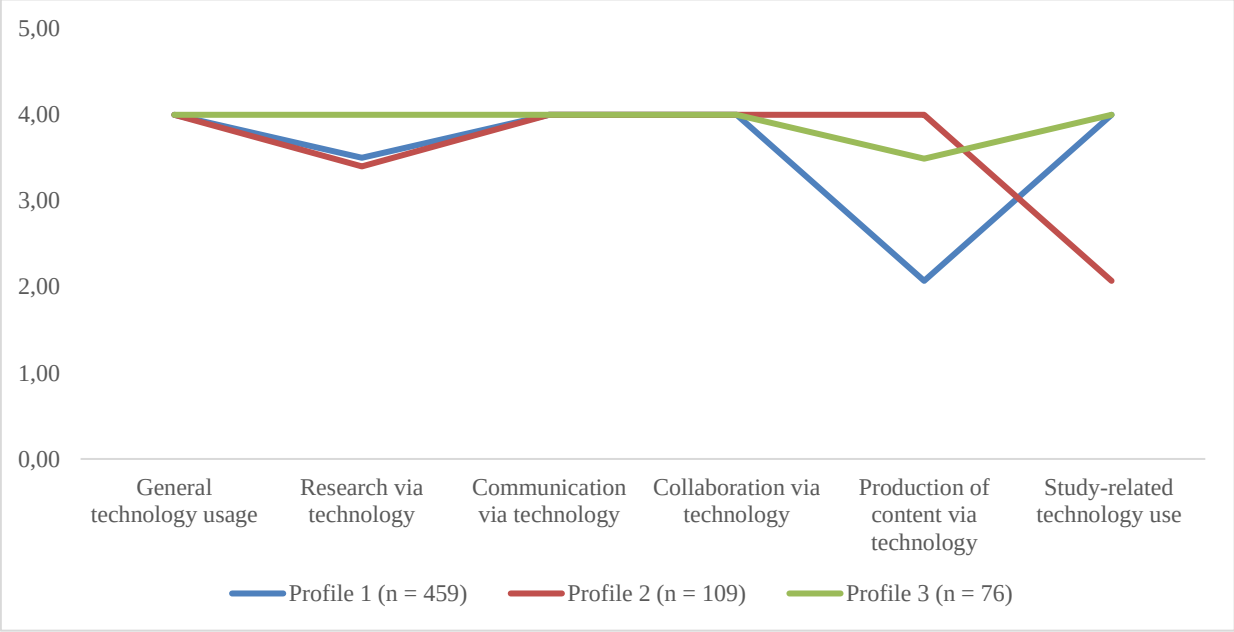
Fit Indices for One to Five Latent Profile Solutions for Adolescents' Technology Use During the COVID-19 Pandemic (Study 2, N = 644)

Model	**LL**	**AIC**	**CAIC**	**BIC**	**SABIC**	**BLRT**	**Entropy**	**prob. min**
1 profile	-5480	100983.55	11049	11037	10999	-	1.00	1.00
2 profiles	-5480	10997.28	11101	11082	11022	0.01	.96	.98
3 profiles	**-4564**	**9180.06**	**9528**	**9296**	**9214**	**0.01**	**.96**	**.90**
4 profiles	-4643	96351.224	9322	9459	9834	.96	.75	.00
5 profiles	-4696	9472.51	9691	9651	9524	0.01	.84	.76

Note. Bold values indicate the best-fitting model.

Figure 2

Three-profile Solution for Adolescents' Technology during the COVID-19 Pandemic (Study 2, *N* = 644)



Note. Mean scores for adolescents' technology use before the COVID-19 pandemic ranged from 0 (*never*) to 4 (*very often*).

Table 6

Descriptive Statistics for the Latent Profiles Identified in Study 2 (During the COVID-19 Pandemic)

Variable	Average Users (*n* = 459)		Profile 2 Social Instrumentalists (*n* = 109)		Profile 3 Advanced Users (*n* = 76)	
	n	*%*	*n*	*%*	*n*	*%*
Gender						
Female	251	55	64	59	38	50
Male		45	45	41		
Type of School						
General secondary school	153	33	26	24	21	28
Intermediate-track secondary school	142	31	36	33	23	30
Highest track school	164	36	47	43	32	42
Parents' education						
Secondary school degree	201	44	40	37	18	24
Postsecondary school degree	141	31	44	40	28	37
Tertiary degree	117	25	25	23	30	42

Profile 1 Average Users

Profile 1 included most of the adolescents in Study 2 (*n* = 459). For adolescents in Profile 1, the frequency of technology use included equal parts instrumental purposes (e.g., study-related technology use *M* = 4.00) and social aspects (e.g., communication via technology *M* = 4.00). Accordingly, the adolescents in Profile 1 were classified as *Average Users*.

Profile 2 – Social Instrumentalists

Adolescents in Profile 2 reported using technology frequently for social purposes, such as communication via technology (*M* = 4.00), collaboration via technology (*M* = 4.00), and instrumental purposes, such as research via technology (*M* = 3.40). However, adolescents in Profile 2 showed a relatively low score compared with adolescents in different profiles on using technology for study-related purposes (*M* = 2.07). Accordingly, adolescents in this profile reported using technology more frequently for social purposes, and therefore, adolescents in Profile 2 were classified as *Social Instrumentalists.*

Profile 3 – Advanced Users

Adolescents in Profile 3 frequently used technology for instrumental purposes, such as study-related purposes (*M* = 4.00) or the production of content via technology (*M* = 3.49), as well as for social communication via technology (*M* = 4.00) and collaboration via technology (*M* = 4.00). Because adolescents in Profile 3 reported using technology more frequently for both instrumental and social purposes compared with Profile 1 *Average Users*, Profile 3 was labelled *Advanced Users.*

Personal factors in relation to the profiles identified during the COVID-19 pandemic (Study 2)

To address RQ 4, the extent to which the personal factors of gender, type of school attended, and parents' educational level predicted membership in specific profiles with respect to technology use during the COVID-19 pandemic, we computed a multinomial logistic regression analysis (Table 7). Neither gender nor type of school was a significant predictor of profile membership during the COVID-19 pandemic and the physical school closures. However, parents' level of education was a significant predictor of profile membership. The log odds of belonging to Profile 2 (Social Instrumentalists) compared with Profile 3 (Advanced Users) increased significantly (B = 0.79, $p < .05$) when parents'

level of education was tertiary rather than postsecondary. That is, adolescents whose parents had a tertiary education were more likely to belong to Profile 3 (Advanced Users) than to Profile 2 (Social Instrumentalists). Overall, adolescents whose parents had a tertiary education used technology in more instrumental and study-related ways, thus confirming our expectations.

Table 7

Multinomial Logistic Regression Analysis (Study 2, N = 644) on Adolescents' Technology Use During the COVID-19 Pandemic

	Profile 1 vs. Profile 2[a]			Profile 1 vs. Profile 3[a]			Profile 2[a] vs. Profile 3		
Predictor	B	SE	*p*	B	SE	*p*	B	SE	*p*
Gender (1 = female adolescents)	-.17	.22	.44	.20	.25	.41	.39	.30	.20
Type of school – intermediate-track secondary school (1 = general secondary school)	.36	.29	.20	.14	.28	.65	-.20	.40	.62
Type of school – highest track school	.46	.28	.10	.16	.28	.60	-.28	.39	.47
Parents' educational level: postsecondary	.34	.26	.19	.51	.31	.10	.16	.37	.66
Parents' educational level: tertiary	-0.03	.29	.91	.60	.32	.06	.79*	.41	.05

Note. Profile 1= Average Users, Profile 2 = Social Instrumentalists, Profile 3 = Advanced Users. SE = standard error.
[a] the reference profile.
* $p < .05$. ** $p < .01$. *** $p < .001$. The model held constant for with and without parent´s educational level as predictor.

Discussion

In this paper, we used latent profile analysis to examine adolescents' technology use in two independent representative samples of adolescents in Bavaria, a region in Germany. Based on adolescents´ response patterns, we identified five latent profiles prior to the COVID-19 pandemic in 2019 (Study 1): *Socializers*, *Average Users*, *Investigators*, *Advanced Users*, and *Social Instrumentalists*. During the COVID-19 pandemic, three latent profiles were identified based on response patterns regarding adolescents' technology use: *Average Users*, *Social Instrumentalists*, and *Advanced Users*.

In addition, we examined the extent to which personal factors, such as gender, type of school attended, and parents' education, predicted profile membership. We found different personal factors were predictors in both samples. Type of school attended was a significant predictor of profile membership prior to the COVID-19 pandemic (Study 1), whereas parents' education emerged as a significant predictor of profile membership among adolescents during the COVID-19 pandemic (Study 2).

Profiles of adolescents' technology use before and during the COVID-19 pandemic

With respect to RQs 1 and 2, five latent profiles related to adolescents' technology use were identified: Socializers, Average Users, Social Instrumentalists, Advanced Users, and Investigators. Regarding the distribution, most adolescents belonged to Profile 2 Average Users (n = 378, 59%) or Profile 1 Socializers (n = 110, 17%). Fewer adolescents were present in the profiles characterized as Social Instrumentalists (n = 72, 11%), Investigators (n = 55, 8%), or Advanced Users (n = 28, 4%).

The identified profiles show heterogeneity among adolescents in their technology use. Most adolescents in the profiles characterized as *Average Users*, *Socializers*, and *Social Instrumentalists* reported using technology primarily for social communication (*M* = 4.00). By contrast, adolescents in the *Investigators* (*M* = 2.8) and *Advanced Users* (*M* = 3.0) profiles reported using technology less for social communication, but primarily for instrumental purposes, such as *research via technology* (Investigators *M* = 3.51; Advanced Users *M* = 4.00). Accordingly, the results are in line with previous research as adolescents are heterogeneous in terms of their technology use, with the exception that using technology for social communication is a relevant component for a large proportion of adolescents (Fraillon et al., 2020).

Moreover, similar to the results from Senkbeil's (2017) study, mixed profile types were identified using Brandzaeg's MUT framework. The mixed profile types were related to the instrumental purposes of technology use. However, whereas Senkbeil (2017) identified *hedonistic instrumentalists* in terms of adolescents' technology use, in this study, we identified *Social Instrumentalists*, meaning that adolescents in this profile use technology primarily for social and instrumental purposes. In contrast to the *Social Instrumentalists* profile, we identified the *Investigators*, a profile that was composed of adolescents who report using technology primarily for instrumental purposes rather than social purposes, but this profile included only *n* = 55 adolescents. Overall, the latent profiles identified prior to the COVID-19 pandemic (Study1) were consistent with previous research.

In Study 2, surveyed during the COVID-19 pandemic and the physical school closures in 2020, three latent profiles were identified: *Average Users* (*n* = 459, 71%), *Social Instrumentalists* (*n* = 109, 17%), and *Advanced Users* (*n* = 76, 12%). Thus, two of the profiles from Study 1 (i.e., *Investigators* and *Socializers*) could no longer be identified

in Study 2. Aside from the fact that the number of profiles decreased compared with the pre-COVID-19 pandemic results (Study 1), the three profiles *Average Users*, *Advanced Users*, and *Social Instrumentalists* could still be identified during the COVID-19 pandemic (Study 2) to characterize response patterns for adolescents' technology use. However, although the response patterns were similar to the profiles identified in Study 1, the responses differed in terms of mean scores: For example, adolescents in the *Average Users* profile in Study 2 had higher overall mean scores during the COVID-19 pandemic and physical school closures than adolescents in the *Average Users* profile in Study 1 before the COVID-19 pandemic. The increase in mean scores related to the response patterns was also observed in Profile 1 *Social Instrumentalists* and Profile 3 *Advanced Users*. Consequently, although the results should be interpreted with caution as no causal conclusions can be drawn, it can be assumed that due to the unavoidable use of technology in distance education and contact restrictions, adolescents' technology use became more target-oriented such as for rather study-related purposes during the COVID-19 pandemic, which may have a positive impact on adolescents' digital skills (Bundsgaard & Gerick, 2017; Senkbeil, 2017). For example, reflecting on the results on adolescents' technology use and the KMK framework (2016) on adolescents' digital skills, a comparison of Studies 1 and 2 shows that adolescents use technology more often in general, but they also use technology more frequently for instrumental purposes, such as *producing content via technology* (M = 2.89 in Study 1, M = 3.55 in Study 2), as well as for *study-related purposes* (M = 4.07 Study 1 and M = 4.87 in Study 2). The increase in the use of technology for instrumental purposes suggests that adolescents' overall digital skills increased during the COVID-19 pandemic, with the instrumental use of technology as a central component of the KMK framework (2016) for adolescents to successfully participate in society and later professional life (Fraillon et al., 2020).

Personal factors as predictors of profile membership prior to and during the COVID-19 pandemic

Multinomial regression revealed that gender was not a significant predictor of profile membership in both Study1 (pre-COVID-19 pandemic) and Study 2 (during the COVID-19 pandemic), which is in contrast with previous research (Alkan & Meick, 2016; Senkbeil, 2017). For example, authors have shown that male adolescents are more likely to use technology for social communication (Alkan & Meick, 2016), and female adolescents are more likely to use technology for target-oriented instrumental purposes (Senkbeil, 2017), which could not be confirmed in our study. The finding that gender was not a significant predictor of profile membership can be interpreted in the light of the results of Siddiq and Scherer's (2019) meta-analysis on the impact of gender on digital skills. The authors were able to show that the impact of gender on digital skills seems to be minimized in general, as technology use by adolescents is ubiquitous both at home and in school. Nevertheless, the type of school the adolescents attended was a significant predictor of profile membership in Study 1, prior to the COVID-19 pandemic in 2019. For example, adolescents from high-track schools were more likely to be represented in profiles where technology was for study-related and instrumental purposes, such as *Social Instrumentalists* and *Advanced Users*, suggesting that adolescents from the highest track schools might also have higher levels of digital skills, a finding that has also been shown in previous research (Lei, Xiong, Chiu, Zhang & Cai, 2021). The educational level of adolescents' parents was not measured in Study 1 (prior to the COVID-19 pandemic), so the results can only be interpreted by making inferences, as adolescents from the highest track schools often also have parents with higher educational levels (Birkelund et al., 2021). Accordingly, it can be assumed that adolescents whose parents have higher educational levels are more frequent and targeted-oriented users of technology and thus have stronger digital skills. The result is also in line with the recent ICILS study, in which

adolescents from the highest track schools show stronger digital skills compared with adolescents from general or intermediate-track secondary schools (Gerick, Eickelmann & Bos, 2017). Interpreting the results in terms of previous research on the digital divide, it can be assumed that parents with a low level of education cannot provide the capital for adolescents to engage in a meaningful use of technology at home for target-oriented instrumental purposes (OECD, 2019). Future financial efforts could therefore focus on equipping schools with devices for students and firmly embedding technology use in the curricula of all types of schools to counteract the digital divide by equipping schools and using technology in the classroom (Kim et al., 2021).

Interestingly, a multinomial regression analysis showed that during the COVID-19 pandemic and physical school closures in 2020 (Study 2), the type of school the students attended was not a significant predictor of profile membership, unlike in Study 1 (pre-COVID-19 pandemic). However, parents' education was a significant predictor: Adolescents whose parents had higher levels of education were also more likely to belong to profiles that reported using technology for rather social than study-related purposes, a finding that is also consistent with previous research (Senkbeil, 2017). The fact that the type of school students attended during the COVID-19 pandemic and the physical school closures in 2020 was not a significant predictor of profile membership can be interpreted to mean that the school closures affected all types of schools equally and that adolescents from each type of school had to get by with the technology they had available at home. The results of our study seem promising: study-related technology use increased overall compared with Study 1 (prior to the COVID-19 pandemic). However, although the study-related use of technology increased overall, adolescents whose parents had higher levels of education were still more likely to be characterized by profiles that reported using technology in a more target-oriented instrumental manner. Hence, there still appears to

be a digital divide that is affecting disadvantaged students whose parents have a low level of education, a trend that is in line with current research regarding the COVID-19 pandemic and social disparities (e.g., Thorn & Vincent-Lancrin, 2021). Hence, future research needs to capture the extent to which the COVID-19 pandemic has had aggravating consequences for students' academic achievement.

Limitations and future directions

Some limitations of the study need to be addressed. First, this study technically included two separate cross-sectional studies, which means that the development of one sample was not examined longitudinally. Accordingly, future studies could be conducted to observe the development of a sample over some period of time. However, we used representative samples to obtain information about adolescents' use of technology before and during the COVID-19 pandemic. In addition, technology use in this study was not specifically divided into home and school purposes, which should be considered in future studies to obtain important insights into adolescents' technology use in school and home settings. Recent studies suggest that self-reported technology use is only moderately correlated with actual technology use as measured by log data (for detailed information, see Parry, Davidson & Sewall, 2021). The reasons for this include the fact that technology use is usually already highly integrated into everyday life and involves various technologies, which makes it difficult for respondents to estimate their own technology use and therefore usually over- or underestimate it. However, in the two studies in this article, a representative sample of adolescents were mostly asked about a specific type of technology use (e.g., collaborating with peers via technology or using technology for study-related purposes), which is not necessarily everyday use activities involving technologies or activities that involve a variety of different technologies. Therefore, we are confident that the adolescents' self-report in our study reflects a reliable picture.

However, further research may combine self-report data and log data to expand our knowledge of student behaviour and technology use (e.g., Ober, Hong, Rebouças-Ju, Carter, Lui & Cheng, 2021). Further, it is important to note that the lowest level of education for any parent in this study was a secondary school degree. This means that there were no adolescents in the present study whose parents had lower or no schooling. Exploring students whose parents had even lower levels of education would also provide important insights for research on the digital divide because such adolescents might be particularly strongly affected by the digital divide.

Our studies included two representative samples for Bavaria, both before and during the COVID -19 pandemic. Nevertheless, it is fair to assume that the results of this study can be generalized for countries that are positioned similarly to Germany in terms of their economy and digital divide (for an overview see Cruz-Jesus, Vicente, Bacao & Oliveira, 2016). Further the COVID -19 pandemic affected most countries to a similar extent between March and September 2020 (Bormann, Brøgger, Pol & Lazarová, 2021), which also supports the generalizability especially regarding the results of the second study (during the COVID -19 pandemic).

Conclusion

In this study, we examined adolescents' technology use before and during the COVID -19 pandemic using the latent profile analysis. We consider our study an advance over previous studies of adolescents' technology use because we systematically contrasted adolescents' technology use before and during the COVID -19 pandemic, given the specifics of the COVID -19 pandemic such as remote classes starting in March 2020. Results from Study 1 (prior to the COVID -19 pandemic) showed that adolescents' technology use was rather heterogeneous in terms of study-related and social purposes. However, the results of Study 2 (during the COVID -19 pandemic) suggest that

adolescents' technology use generally became more target-oriented and frequent during the COVID -19 pandemic and physical school closures in 2020, potentially positively affecting adolescents' digital skills, which are an important component of adolescents' academic performance (Lei et al., 2021). In addition, our findings are particularly relevant because recent studies (e.g., Wang, Xia, Guo, Xu, & Zhao, 2022: Juuti et al., 2022) have shown that adolescents, who use technology in more sophisticated ways, e.g., for information-retrieval and study-related purposes, also show higher academic achievement, which may be particularly relevant to future post-pandemic research on adolescents' technology use and academic achievement. In summary, the results of this study suggest that adolescents are becoming more sophisticated and frequent in their use of technology, which could have a positive impact on digital skills and thus overall academic achievement, consistent with current research. However, personal factors were important, such that adolescents whose parents had higher levels of education were more likely to be among those who used technology in meaningful study-related ways. Although adolescents' technology use generally increased for educational purposes during the COVID -19 pandemic, socially disadvantaged students still appeared to be at risk of being left behind by the even more rapid digitization of the COVID -19 pandemic, which needs to be further explored in future research to develop appropriate targeted interventions to address the digital divide

3. Study 2: Context-specificity to reduce bias in self-assessments: comparing teachers' scenario-based self-assessment and objective assessment of technological knowledge

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Context-specificity to reduce bias in self-assessments: Comparing teachers' scenario-based self-assessment and objective assessment of technological knowledge

Tamara Kastorff[a], Michael Sailer[a,b], Johanna Vejvoda[a], Florian Schultz-Pernice[a], Valentin Hartmann[a], Anna Hertl[a], Sonja Berger[a] and Karsten Stegmann[a]

[a]Ludwig-Maximilians-Universität München, Munich, Germany; [b]Friedrich-Alexander Universität, Erlangen, Germany

ABSTRACT

Previous research has focused on self-assessments rather than objective assessments for assessing teachers' technological knowledge (TK). Notwithstanding, empirical studies have failed to show stable relationships between self-assessments and objective assessments. In this study, we investigate the extent to which scenario-based self-assessments of (student) teachers' (N = 75) TK can serve as anchors by helping them to identify the relevant skills that are required in concrete and authentic situations and might be therefore effective to bring the results of objective and subjective measures closer together using a path analytical model. Overall, the results suggest that scenario-based self-assessment is promising for the approximation of the results of objective assessment measures, especially for operational technical skills.

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The COVID-19 pandemic has severely challenged teachers all over the world. Teachers were required to set up online learning environments and video lessons for distance education, a challenge for which sound technological knowledge (TK) is helpful (Koehler & Mishra, 2009). As the use of technology in teaching and learning processes has been inevitable during the COVID-19 pandemic, teachers' TK became a key requirement for teaching and learning. TK refers to the teachers' knowledge of technologies, such as digital tools and educational technologies (Lachner et al., 2019, p. 7).

Numerous studies have examined teachers' TK by using self-assessment measures, for which teachers rate or indicate how confident they feel about their skills and knowledge (e.g., Mourlam, 2021; Rubach & Lazarides, 2021; Schmid et al., 2020;). Such self-assessments make a valuable contribution to educational research because they are closely related to how teachers intend to use technology in their classrooms (Scherer et al., 2015) and provide rich and meaningful information for educational researchers without much effort (Seufert et al., 2021). Nonetheless, the validity of self-assessments has been criticized. Several authors (Aesaert et al., 2017; Hatlevik et al., 2018; Scherer et al., 2017) have argued that self-assessments capture individuals' self-perceived abilities, knowledge, or skills, which might not be consistent with their *actual* performance. In line with this argument, studies have regularly shown only small linear relationships between self-assessments and objective assessments of teachers' TK (e.g., Akyuz, 2018; Baier & Kunter, 2020; Drummond & Sweeny, 2017), raising questions about whether teachers' perceived ability matches their actual knowledge and skills, and thus establishing a need for more objective assessments to be implemented in educational research (Lachner et al., 2019; Petko, 2020).

However, objective performance tests are often difficult to administer because participants might be reluctant to participate in objective performance tests (Kleinert et al., 2015). Further, objective measurement instruments often address very specific uses of technology, such as asking participants if they can operate a particular program (Petko, 2020). Very specific uses of technology might not provide a comprehensive perspective on the successful use of technology in the sense of the level of technology use that is necessary to function in an information-based society (Fraillon et al., 2020). Further, objective assessment measures of TK can quickly become outdated due to advances in technology (Siddiq et al., 2016).

Because objective assessments are often poorly accepted by participants in practice, and self-assessments suffer from biases due to low correlations between self-assessment and objective assessment measures (e.g., Drummond & Sweeny, 2017), Sailer et al. (2021a) attempted to make self-assessments more accurate. To do so, the authors proposed scenario-based self-assessments to improve the accuracy of self-assessment measures by providing concrete scenarios. These scenarios confront participants with detailed information in a context-specific situation to address the problem of potential self-assessment biases, such as social desirability or ambiguity. The relevance of context-specificity in self-assessments has also been demonstrated in previous research. Talsma et al. (2018) found evidence that more context-specific self-assessment measures have stronger correlations with objective performance measures than less context-specific self-assessment measures do. Thus, scenarios in self-assessments represent a concrete problem-solving scenario that focuses participants' general ability expectations on an example case so that participants can better visualize what the situation or task at hand has at stake (Sailer et al., 2021a).

Given the overt relevance of teachers' TK in times of digitalization and remote learning, and given the current call to identify potential biases in self-assessments in educational science, the main purpose of this study is to analyse the relationship between scenario-based self-assessments and objective assessments of teachers' TK.

In summary, teachers´ TK is of crucial importance in educational science in times of digitalization and remote learning. However, objective assessment measures are often difficult to implement, particularly concerning teachers' use of technology. This study aims to investigate the extent to which scenario-based self-assessments of teachers´ TK can serve as anchors by helping them to identify the relevant skills that are required in

concrete and authentic situations (Sailer et al., 2021a), and might be therefore effective to bring objective and subjective measures closer together (Van Soest et al., 2011).

Technological Knowledge (TK)

Regarding the integration of technology into teaching and learning processes, Koehler and Mishra (2009) proposed the TPACK framework for educational research. The authors established the TPACK framework based on Shulman's (1986) constructs of pedagogical content knowledge (PCK) and extended PCK by adding technology (T). Accordingly, the TPACK framework describes the relationships between the constructs of content, pedagogy, and technology. Within the TPACK framework, TK is an essential component of the successful implementation of technology into teaching and learning processes. Although TK is a central component within the TPACK framework, empirical studies regarding the factor structure of the TPACK framework have shown a different picture. For example, both Scherer et al. (2017) and Lachner et al. (2019) identified TK as primarily independent of the other facets of the TPACK framework, and consequently, the authors assumed that TK might be independent of teaching and learning processes.

Koehler and Mishra (2009) broadly defined TK as “understanding information technology broadly enough to apply it productively at work and in everyday life, recognizing when information technology can assist or impede the achievement of a goal, and continually adapting to changes in information technology” (p. 64). Against the relevance of teachers´ TK, the Standing Conference of the Ministers of Education and Cultural Affairs (KMK) published a strategy for education in a digital world (KMK, 2019a). The Standing Conference of the Ministers of Education and Cultural Affairs (KMK) is an association responsible for education and schools, vocational training, and research (KMK, 2019 b). Therefore, the KMK plays an important role in Germany as an instrument for the coordination and development of education, including in the area of

digitization and the digital skills of students and teachers. According to the KMK (2019a), TK is an essential part of a person's ability to participate successfully in society and later in professional life and is broadly described from a holistic perspective as the *basic digital skills* needed to use technologies to collect, manage, produce, and exchange information. Further, according to the KMK (2019a), basic digital skills encompass core skills concerning the use of technology, such as communicating and collaborating with technology. Such skills are an integral part of teacher education and training (Digital Campus of Bavaria [DCB], 2017).

The basic digital skills can be narrowed down to five core concepts in using technology (KMK, 2019a):

(1) Operating and applying technology. According to the KMK (2019a), operating and applying technology refers to the skills and knowledge needed to operate and apply technology appropriately and purposefully, including knowing the basic principles and functions of technology. In addition, one should be able to optimize one's own use of technology.

(2) Searching for and processing information with technology. Searching for and processing information with technology incorporates the development of search strategies to obtain the desired information and to purposefully select the appropriate information. It also includes the ability to store, summarize, structure, and critically evaluate information in a purposeful manner.

(3) Communicating and collaborating with technology. Collaborating and Communicating with technology describes the ability to use technology to collaborate and communicate with others, a skill that is necessary to successfully participate in society. Collaborating and communicating with technology must also consider rules of engagement and others' personal rights.

(4) Producing and presenting information with technology. According to the KMK (2019a), producing and presenting information with technology refers to selecting and using media products appropriately and considering formal design features and intentions to present adequate information with technology.

(5) Analyzing and reflecting information with technology. Analyzing and reflecting describes the competence to analyze and evaluate the content, design features, and structure of media products, whereby the interest-driven dissemination of media content is recognized and critically evaluated. In addition, one should be able to assess the potential and risks of using media for oneself and society.

The five core components presented by the KMK (2019a) are also well-documented and established in widely accepted theoretical frameworks on basic digital skills, such as the Digital Competence of Educators framework (Ferrari, 2013) or the ICILS framework (Fraillon et al., 2020). In line with the KMK (2019a), the DigCompEdu framework targets the specific basic digital skills of educators as prerequisites for the ability to facilitate student learning (Siddiq et al., 2016).

Consequently, it can be concluded that there are currently two major ways to operationalize TK in educational science. On the one hand, TK is currently assessed from a functional perspective (see Lachner et al., 2019; Senkbeil et al., 2013), including multiple facets concerning the operational use of technology. On the other hand, TK has recently been represented by broader approaches, such as the KMK (2019a), which describes a more holistic use of technology based on five core concepts that people must meet to successfully participate in an information-based society. In the context of this study, we use the terms *TK* and *digital skills* interchangeably, thereby suggesting that people must incorporate qualities from both the technical operational skills and the five

core concepts derived from the KMK framework (2019) in order to successfully participate in an information-based society.

Self-assessment and objective assessment

Whereas there is a large body of research on how teachers self-assess their skills (e.g., Lucas et al., 2021; Scherer et al., 2017), less attention has been paid to teachers' actual performance on objective assessment measures (Seufert et al., 2021; Petko, 2020). In current research practice, teachers' skills are often assessed with self-reports in which teachers indicate how confident they feel about whether they have a particular skill (e.g., Schmid et al., 2021).

Nevertheless, it is important to emphasize that self-assessment is not an accurate measure of an individual's objective performance (Hatlevik, 2018). In line with this, a common issue when assessing skills via self-assessment is that estimations rely on individuals' ability to self-assess accurately. This can be problematic because the ability of individuals to assess their performance validly must be regarded as very heterogeneous (van Vliet et al., 1994; van Soset et al., 2011). Thus, the relationship between self-assessment and objective assessment measures is often weak (Akyuz 2018; Dunning et al., 2004; Drummond and Sweeny, 2017).

Self-assessment measures are also widely applied to measure the construct of *self-efficacy* (Bandura, 1977). Research on self-efficacy has shown that the effectiveness of self-efficacy measures in educational research is highly context-specific (Bandura, 1977; Rohtagi et al., 2016), which suggests that the relevance of context-specificity also applies to self-assessment measures (Sailer et al., 2021a). Moreover, research (e.g., Bandura, 1977) has shown that it is important to distinguish between *general* self-assessment and *domain-specific* self-assessment, which can be described as domain-specific self-efficacy and general self-efficacy. General self-assessment or self-efficacy refer to overarching,

general situations (e.g., "I am good at what I do"; Rohatgi et al., 2016), and domain-specific self-efficacy refers to concrete domains, such as Information Communication and Technology (ICT) self-efficacy (e.g., "I can type terms correctly into search engines"). Scholars already agree that domain-specific self-assessment or self-efficacy measures are more suitable for making concrete statements about a person's self-efficacy in a specific domain than about a person's general self-efficacy (Rohatgi et al., 2016). Moreover, Scherer and Siddiq (2015) showed that teachers' domain-specific information and communication technology (ICT) self-efficacy further consists of three separate constructs: basic operational skills, advanced operational and collaborative skills, and the use of technology for instructional purposes. According to Hatlevik and Hatlevik (2018), Scherer and Siddiq's (2015) findings can be interpreted to mean that domain-specific ICT self-efficacy measures still leave too much room for heterogeneous interpretations of specific tasks related to ICT self-efficacy. Therefore, despite the agreement that domain-specific self-efficacy is more suitable for making concrete statements about a person's self-efficacy, domain-specific self-efficacy (e.g., ICT self-efficacy) might still be too general with regard to context-sensitivity.

The relevance of context-specificity in self-assessment was also supported by the meta-analysis by Talsma et al. (2018) on self-efficacy and academic performance. Accordingly, the authors reported that the more context-specific self-assessment measures are, the more strongly they are correlated with objective assessment measures than less context-specific self-assessment measures. Further, according to Peura et al. (2019), context-specific self-assessment measures have stronger relationships with objective assessment measures than less context-specific self-assessment measures, although few studies have examined this relationship to date. Furthermore, according to Scheiter (2021), item formulations in current self-assessment instruments are often too

vague to make concrete statements about a person's knowledge or skills. According to the author, the vague item formulations in self-assessments, such as "I can use digital media efficiently in the classroom," leave participants too much room for interpretation because teachers tend to orient themselves more toward theoretical conventions of high-quality teaching with digital media than toward actual skills.

Scheiter (2021) postulated that vignette-based items would be a possible solution as they guide teachers to represent their own skills in an action-oriented and situation-based test format, which is an improvement over the usually vague and therefore problematic item formulations used in regular self-assessments. In line with King et al.'s (2004) and King and Wand's (2007) findings, short vignettes can correct for respondents' different understandings of scenarios given that regular self-assessments often lack contextual information, thus resulting in different respondents understanding the same self-assessment question in different ways. Van Soest et al., (2011) were able to validate this assumption empirically: according to the authors, concrete scenarios such as described in vignettes, are suitable in bringing self-assessments in line with objective assessment. Further, on the basis of King et al.'s (2004) assumptions, Sailer et al. (2021a) developed a similar approach with their scenario-based assessments of teachers' digital skills. In Sailer et al.´s (2021) study, participants were placed in a concrete scenario where they were asked to assess their knowledge and skills with respect to a particular scenario, such as the extent to which teachers feel able to implement group work with tablets in the classroom. According to the authors, compared with regular self-assessments, the concrete formulation of a scenario acts as an "anchor" that can help teachers assess their own skills and attitudes more accurately and validly (p. 7).

In summary, scenario-based self-assessment might be a suitable aid for participants to evaluate their skills more accurately in situations in which it is crucial to apply corresponding skills (Sailer et al., 2021a).

The present study

Given the importance of teachers' TK, particularly considering the COVID-19 pandemic and regarding current calls to become aware of potential biases concerning self-assessment, we aim to gain more insight into the relationship between teachers´ scenario-based self-assessments and objective assessments, focusing on TK. To do so, we pose the following research question:

RQ: How can (student) teachers' objectively assessed TK be predicted by scenario-based self-assessments of their TK?

Objective assessment measures are often difficult to implement because subjects are often reluctant to participate in objective assessment studies (Kleinert et al., 2016) and objective assessment measures, especially with regard to TK, are either very specific (Petko, 2020) or quickly become outdated (Siddiq et al., 2021). Therefore, self-assessment measures are often used in educational research to gain information regarding teachers´ digital skills. However, it has been shown that the relationships between self-assessment measures and objective assessment measures related to teachers' digital skills are often non substantial (see Baier & Kunter, 2021; Drummond and Sweeny, 2017), suggesting that individuals' ability to accurately assess their performance must be considered heterogeneous (van Vliet, 1994). Van Soset et al. (2011) provided evidence that concrete scenarios are suitable for matching self-assessments with objective assessment measures related to personal behaviour. Consistent with this, scholars in educational science (Peura et al., 2019; Rohtagi et al., 2016; Scheiter, 2021; Talsma et al., 2018) postulated the assumption that a clear framework or reference, as realised in

scenario-based self-assessment, could provide a clearer context for individuals to assess their actual skills and approximate the results of objective assessment measures more accurately. In line with this assumption, the present study explores the extent to which teachers' scenario-based self-assessment of TK aligns with the results of teachers' objective measurement of TK.

Method

Participants and Procedure

Eighty-one (student) teachers took part in the study. However, data from six participants were removed from the analysis because they did not consent to further data processing. In total, $N = 75$ participants of whom $n = 53$ were in-service teachers and $n = 22$ were student teachers from German universities and schools agreed to allow their data to be processed and participate in the study. The mean age of the participants was $M = 35.87$ ($SD = 9.13$, Range: 20 to 58). The survey design of the study was cross-sectional, and it was conducted through an online survey through UniPark in the winter of 2019. (https://www.unipark.com). The sample included $n = 43$ (57%) female and $n = 32$ (43%) male participants. The in-service teachers predominantly taught in lower track secondary schools (Realschule and Mittelschule, $n = 26$), followed by grammar schools (Gymnasium, $n = 16$), vocational schools ($n = 4$), schools for children with special needs ($n = 3$), elementary schools ($n = 2$), and other schools ($n = 2$). The in-service teachers had an average of 14.53 years of teaching experience (Range: 2 to 44 years). On average, student teachers were in their 7th and 5th semesters of study (Range: 1 to 16 semesters, mode = 13). Participants were invited by email, through distribution lists from their respective networks, or social media posts. After participants gave their consent for data processing, they were first instructed to answer demographic questions. Then, the online survey continued with the self-assessment questionnaire, which

contained scenario-based vignettes, followed by the objective assessment of TK. On average, participants completed the objective assessment and scenario-based self-assessment test in 25 min. Table 1 presents descriptive statistics for the scores related to the objective assessment and the scenario-based self-assessment of TK. On average, (student) teachers scored M = 117.6 (SD = 8.64) out of 136 on the objective assessment test of TK. Their scenario-based self-assessments regarding the five subcomponents ranged on average from M = 1.08 (SD = .73, producing and presenting information using technology) to M = 2.50 (SD = .59, Searching for and processing information using technology) on the five-point Likert scale.

Table 1

Descriptive Statistics for Objective Assessments and Scenario-Based Self-Assessments of TK

	Min.	*Max.*	*M*	*SD*
Technological knowledge (TK) – objective assessment	94.0	130.0	117.6	8.64
Technological knowledge (TK) – self-assessment				
Operating and applying technology	2.17	5.00	4.25	.69
Searching for and processing information with technology	2.50	5.00	4.35	.59
Communicating and collaborating with technology	1.67	5.00	4.18	.83
Producing and presenting information with technology	1.08	5.00	4.18	.73
Analyzing and reflecting information with technology	1.92	5.00	3.91	.79

Measures

Scenario-based self-assessment of TK. One for each of the five subcomponents—were used for the self-assessment of TK (for detailed information about scenario-based self-assessment, see Sailer et al, 2021a). The scenarios included everyday situations that depicted technology use and were based on the five subcomponents. For each scenario, participants were asked to indicate whether they had the knowledge and skills to react adequately to the described situation and, in addition, whether they were able to advise others regarding the situation. The subcomponents were assessed with a total of 60 items, 12 for each of the five subcomponents. Items were rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The five subcomponents included (a) operating and applying technology (Cronbach's $\alpha = .93$), (b) searching for and processing

information with technology (α = .93), (c) communicating and collaborating with technology (α = .86), (d) producing and presenting information with technology (α =. 94), and (e) analysing and reflecting information with technology (α = .94). Tables 2 and 3 present sample items for the subcomponents *operating and applying technology* and *producing and presenting information with technology*.

Table 2

Scenario-Based Assessment Item—Operating and Applying Technology

You are planning a long train journey, and you want to provide yourself with reading material for the ride. To reduce your luggage, you borrow a friend´s tablet to read eBooks on it. However, you have to familiarize yourself with the operation and application of the tablet first, especially pertaining to the circumstances involved in a train ride.

Based on the scenario described above, please rate the following statements on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*)					
	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I have the knowledge to successfully use applications on technical devices	1	2	3	4	5
I can successfully use applications on technical devices	1	2	3	4	5
I am able to support others successfully to use applications on technical devices	1	2	3	4	5

Note. The item was translated from German.

Table 3

Scenario-Based Self-Assessment Item—Producing and Presenting Information With Technology

You want to contribute to the public relations work in your place of employment, so you decide to create an informational video about your work. Your place of employment has diverse, appropriate hardware and software for creating and editing videos.					
Based on the scenario described above, please rate the following statements on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*)					
	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I have the knowledge to create engaging and effective media products	1	2	3	4	5
I can create engaging and effective media products	1	2	3	4	5
I am able to help others create engaging and effective media products	1	2	3	4	5

Note. The item was translated from German.

Objective assessment of TK. In order to comprehensively measure TK of teachers, the constructed test for objective measurement of TK contains questions on both theoretical and applied knowledge of TK of teachers derived from the KMK framework (2019). According to the KMK (2019), teachers should be able to name basic theoretical components of computers and provide information about how computer systems, networks, data, and standard software work. The areas of theoretical knowledge refer to 1) knowledge about the structure and components of a computer, 2) knowledge about software, 3) knowledge about networks, and 4) knowledge in the area of data. In addition, according to the KMK specifications (2019), teachers should also be able to use TK to apply their knowledge in an application-oriented manner in the classroom, e.g., to identify sources of error when using technologies or to use software as needed. Accordingly, the test for the objective measurement of TK contains questions on 1) the use of computer systems 2) the use of software and 3) the use of networks. To ensure the quality and the

validity of the objective assessment test, researchers (N = 2, post-Doc level, N =1 senior Ph.D. student) helped to develop and continuously improve the objective assessment of TK by providing their expert feedback. All items were considered suitable to measure valid TK of (prospective) teachers in feedback loops in the context of expert ratings. The objective test on TK consisted of 34 multiple-choice tasks with four answer options, of which one to four could be correct. Points could also be earned by not checking wrong answers. A total of 136 points were possible. Two sample questions from the objective assessment test are presented in Tables 4 and 5. Based on previous research instruments for the objective assessment of TK (e.g., Test of Technological and information Literacy, TILT; see Senkbeil et al., 2013), the objective assessment test was designed to be unidimensional and to include aspects of knowledge and skills related to TK. To test the one-dimensionality of the objective TK measure, we used the Bayesian Information Criterion (BIC) and the Akaike's Information Criterion (AIC) as indicators of model fit (Rost, 2004). Lower indices indicate better model fit. We compared the one-dimensional model (BIC: 4075; AIC: 3904) with the two-dimensional model (BIC: 4226; AIC: 3901) and the three-dimensional model (BIC: 4313; AIC: 3915). The BIC was lowest for the one-dimensional model. Although the two-dimensional model had a slightly lower AIC, the literature recommends choosing the model with the lower dimension if the difference is less than 10% (Rost, 2004). We therefore conclude, based on the model fit indices, that the one-dimensionality of the objective TK measure is supported. We used Rasch analysis to assess person-ability scores for the objective TK measure. The cut-off values (0.5-1.5) proposed by Linacre (2002) for Infit-MNSQ and Outfit-MNSO 0.5-1.5 are supported. Rasch analysis of the unidimensional model yielded good estimates of item response reliability (WLE) (.73).

Table 4

Example Item From the Objective Test of TK

Tick any of the following statements that are true
a) An HDMI cable can be used to connect to the Internet between the router and the computer.
b) An HDMI cable is used to transmit audio and video signals.
c) A USB key is a type of external data storage.
d) A USB cable can be used to connect computers to external devices.

Note. The item was translated from German. Correct answers are marked in italics.

Table 5

Example Item From the Objective Test of TK

You want to do research on the Internet. How do you proceed?
a) I open a browser window and log in to my email account. Then I enter the search term in the search bar.
b) I open the search function on my computer and enter the search term. A browser window opens with a list of research results.
c) I open a browser window, enter a search engine website, and enter what I want to search for with the search engine.
d) I open my Internet app and then enter search terms in any application.

Note. The item was translated from German. The correct answer is marked in italics.

Statistical analysis

Path analysis was used to test the hypothesized structural relationships between the person-ability score of the objectively assessed and scenario-based self-assessed TK of both in-service teachers and student teachers (using the lavaan package; Rosseel et al., 2021). The goodness-of-fit measures for the path analysis were based on Hu and Bentler's (1999) recommendations: Root Mean Square Error of Approximation (RMSEA) < .06, Standardized Root Mean Square Residual (SRMR) < .08, Comparative Fit Index (CFI) > .90, and Chi-Square (χ^2) > .05. We conducted all analyses in R version 4.0.5.

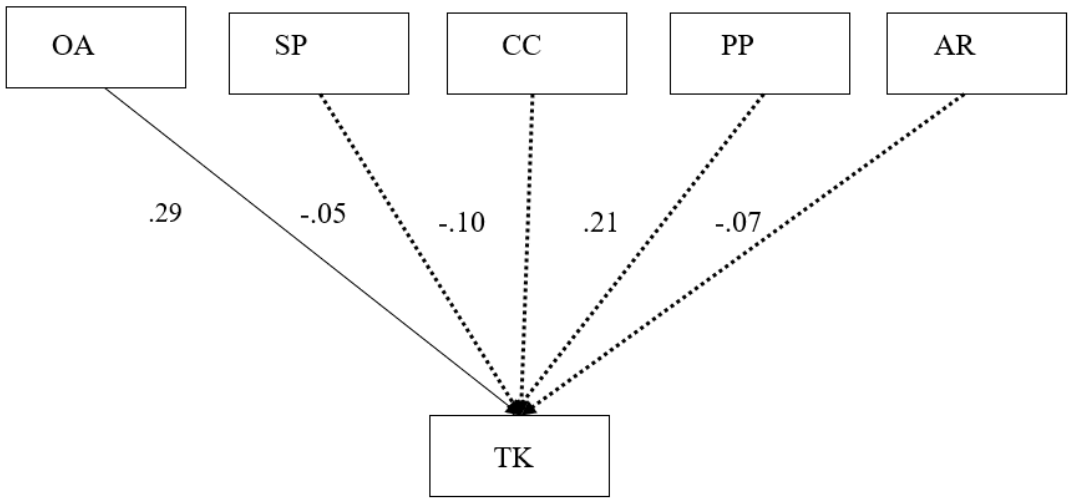
Results

A path analytic model was tested to examine the relationships between the scenario-based self-assessment measures and the objective measure of TK. The model fit indices showed a fully saturated model, $\chi^2(5) = 22.39$, CFI > .99, SRMR < .01, RMSEA < .01, although the *p*-value of the chi-square test was significant. Heene et al.

(2011) showed that unique variances affect the value of the chi-square test of the model when the sample size is small. Therefore, we concluded that the model tested in this study was acceptable. The results showed that scenario-based self-assessment measured with the subcomponent operating and applying technology (β = 0.25, SE = 0.13, p =.05) significantly predicted the objective assessment of TK (R^2 = .23). However, the analysis showed that scenario-based self-assessment measured with the subcomponents producing and presenting information with technology (β = 0.21, SE = 0.12 , p =.08), searching for and processing information with technology (β = -0.05, SE = 0.14, p = .72),), communicating and collaborating (β = -0.10, SE = 0.18, p = .58), and analyzing and reflecting on information with technology (β = 0.07, SE = .11, p = .52) did not significantly predict teachers' objective assessment of TK. All standardized regression coefficients are shown in Figure 1. Table 6 presents correlation coefficients for the five subcomponents of scenario-based self-assessment in TK. All of the six scales (objective assessment of TK and self-assessment of TK) significantly correlated with each other but differed substantially in their magnitude with the range of r = .28 to r = 73. Overall, the results from the path analysis supported the assumption that scenario-based self-assessment items concerning the functional use of technology predicted teachers' objectively assessed TK.

Figure 1

Estimated Model in Which the Subcomponents of the Scenario-Based Self-Assessment of TK Were Used to Predict the Objective Assessment of TK for In-service and Student Teachers



Note. TK = the objective assessment of technological knowledge. The predictors were self-assessed: OA = operating and applying technology; SP = searching for and processing information with technology; CC = communicating and collaborating with technology; PP = producing and presenting information with technology; AR = analyzing and reflecting on information with technology. Nonsignificant paths are represented with dotted lines.

Table 6

Estimated Correlation Matrix of the Five Subscales Regarding the Scenario-Based Self-Assessment and Objective Assessment of TK

		1	2	3	4	5	6
1.	Technological knowledge (TK) – objective assessment	—					
Technological knowledge (TK) – self-assessment							
2.	Operating and applying technology	.46**	—				
3.	Searching for and processing information with technology	.26*	.54**	—			
4.	Communicating and collaborating with technology	.35*	.66**	.64**	—		
5.	Producing and presenting information with technology	.46*	.69**	.52**	.73**	—	
6.	Analyzing and reflecting on information with technology	.36*	.56**	.58**	.69**	.66**	—

* $p < .05$. ** $p < .01$.

Discussion

Previous work has regularly shown that there is no significant relationship between self-assessments and objective assessment measures of teachers' technology use (Akyvuz, 2018, Baier & Kunter, 2021; Drummund and Sweeny, 2017), suggesting that self-assessments may be biased and inaccurate. Based on previous research, scenario-based self-assessment is a promising scaffold to approximate the results of objective assessment measures related to personal behavior, as it is easier for subjects to assess their own behavior in a specific situation than to accurately represent their behavior using self-assessment scales, as their responses may depend on their subjective reality (Van Soset et al., 2011). This assumption has also been postulated by scholars in educational science (Scheiter, 2021; Talsma et al., 2018), as scenario-based self-assessment could be a way

to better assess one's own skills and, accordingly, avoid bias when comparing self-assessment with actual objectively measured skills. Consequently, this study examined how the results of scenario-based self-assessments aligned with the results of objective assessment measures related to teachers TK.

We found that one of the five core components related to teachers' digital skills – *operating and applying technology* – used to measure the scenario-based self-assessment of TK explained a substantial share of the variance (23%) in the TK measure. In addition, we found a tendency for the component *producing and presenting information with technology* subcomponent ($p = .08$), although the results were not significant. According to KMK (2019a, 2019b), the components *operating and applying technology* and *producing and presenting Information with technology* are closely related to operational technical use of technology. According to Fraillon et al. (2020), operational technical use of technology is one of the less demanding levels of skills related to technology use. However, internationally established theoretical frameworks and meta-analyses (Redecker, 2017; Ferrari et al., 2013; Siddiq et al., 2016) have highlighted the relevance of technical operational skills as a prerequisite for successful technology use.

Although the results should be interpreted with caution due to the explorative nature of the study, the significant relationship between the scenario-based self-assessment of the subcomponent *operating and applying technology* and the objective TK measure suggests that scenario-based self-assessment might be an appropriate tool to approach the results objective measures, especially for technical operational skills. Accordingly, the tendency of the subcomponent *Producing and Presenting Information with technology* could also be interpreted towards the same direction, because producing and presenting information with technology makes up a large part of skills regarding the operational technology use (KMK, 2019a).

Because previous research has shown non substantial relationships between self-assessment and objective assessment in educational research (Parry et al., 2021), scholars have often called for increased use of objective assessment instruments (e.g., Lachner et al., 2019) to represent participants' actual abilities. However, there are major criticisms of objective assessments of TK: First, objective assessments of TK tend to be very specific (e.g., about how a particular program works; Petko, 2020). Second, objective assessment tests become outdated very quickly due to technological advances, including those related to teaching and learning processes (Siddiq et al., 2016). Moreover, previous research has already shown that especially more complex skills (e.g., evaluating information using information technologies; Fraillon et al., 2020) are less suitable for measurement with objective measures because objective assessment measures place high demands on test takers' knowledge and skills, often leading to reluctance and dropout compared with self-assessment measures (Kleinert et al., 2015). Furthermore, Siddiq et al. (2016) criticized objective assessment for being limited to restricted response formats (e.g., multiple-choice), which limits the full potential of objective assessment measures. The full potential of objective assessments for digital skills will not be realized until authentic simulations can be created on the computer to assess, for example, the more complex digital skills that are required to successfully participate in an information-based society (Fraillon et al., 2020). However, authentic situations have rarely been implemented in research due to their complexity. Therefore, real-life situations are usually mimicked (e.g., by using screenshots to measure digital skills; Siddiq et al., 2016). Consequently, the objective measurement of digital skills seems to be a challenge for research. Current approaches for objectively measuring teachers' digital skills include analyzing (student) teachers’ lesson plans (e.g., Backfisch et al., 2020). Lesson plan analysis is a valuable measure for providing a proxy for the quality of technology

integration (Backfisch et al., 2020). Nonetheless, lesson plans are an indirect measure that, according to Petko (2020), leaves a great deal of room for heterogeneous interpretations, even though researchers have reported high interrater reliability.

Although more objective assessment measures are often called for in the current literature, they are difficult to implement and often lead to reluctance. However, according to the results of this study, scenario-based self-assessment with a description of a concrete situation seems promising for more closely approximating the results of objective assessment measures. Furthermore, according to Sailer et al (2021a), scenario-based self-assessment has two advantages over regular self-assessment: First, a "common standard" (p. 4) can be achieved for respondents via a specific scenario, so that, for example, social desirability bias can be reduced. Second, vignettes in a scenario-based self-assessment can be used to assess multiple aspects (e.g., situations where relevant knowledge and skill domains need to be applied) rather than only asking the participant to assess their own knowledge or skills.

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Limitations and future directions

Due to the small number of participants and the predominance of in-service teachers in the sample (71%), it was not possible to independently compare objectively assessed TK and the scenario-based self-assessment of TK for in-service teachers and student teachers. Future work should therefore include personal and contextual factors (e.g., see Schmid et al. 2021; Lucas et al., 2021; Aesaert et al., 2017; Ober et al., 2021) to determine whether the findings of this study hold, as this was not possible to do in the current study due to missing values and the small sample size. Second, to draw concrete conclusions about the effectiveness of scenario-based self-assessments, follow-up work could contrast both scenario-based assessment measures and regular self-assessment measures with objective assessment measures. Moreover, longitudinal studies could be conducted to provide detailed insights into the extent to which scenario-based self-assessment measures and objective assessment measures are consistent. Although the objective assessment measure of TK demonstrated good psychometric quality, the objective assessment measure was developed for the purpose of the study to capture the unidimensional functional use of technology and therefore needs to be developed further in future studies. Future studies could also use objective assessment measures that cover multiple dimensions of technology use and compare these with scenario-based self-assessment measures.

Conclusion

Self-assessment has often been criticized in educational research for failing to measure individuals' actual abilities and for being influenced by factors such as social desirability (Hatlevik et al., 2018), resulting in current calls for the use of objective assessments in addition to self-assessment measures (Seufert et al., 2021; Lachner et al., 2019). Nonetheless, objective assessments are difficult to use in practice because

participants are often reluctant to complete them, often resulting in high dropout rates (Kleinert et al., 2015). According to our results, scenario-based self-assessment seems to be a promising approach for providing results that are close to those from objective assessment measures regarding technical operational skills.

4. Study 3: Teachers´ Technological Knowledge (TK) and Technological Pedagogical Knowledge (TPK) – predictors for secondary students´ ICT literacy?

Since information and communication technologies (ICT) literacy is an integral part of the curriculum, teachers are responsible for promoting ICT literacy among secondary students (Guggemos & Seufert, 2021). Accordingly, it is particularly important to address teacher-level factors that may have an impact on secondary students' ICT literacy. Research has already shown that teachers' personal factors, such as their ICT self-efficacy (Drossel et al., 2017) and perceived usefulness of ICT (Scherer et al., 2015), are important determinants of students' ICT literacy. However, despite their scientific relevance, these factors represent teachers' subjective self-assessments or attitudes. Therefore, it is increasingly believed that more objective factors, such as professional knowledge, should be investigated with regard to teachers' competent ICT use and their impact on secondary students' ICT literacy (Schmidt et al., 2021).

Studies have already shown that teachers' objectively assessed, subject-related knowledge—also called content knowledge (CK)—influences students' performance in the respective subject (Baumert et al., 2010). More specifically, scholars have concluded that teachers with high CK are more consistent with the content that they teach during instruction and may, therefore, have students who achieve more in the subject. Furthermore, Baumert et al. concluded that in addition to the relevance of CK, teachers' pedagogical content knowledge (PCK) is also a key determinant of student achievement. PCK refers to instructional quality—that is, a teacher's ability to teach subject-related content in a way that improves student achievement (Shulman, 1986).

However, apart from subject-specific competencies, there is still little knowledge about how teachers' cross-curricular competencies, such as technological

knowledge (TK) or technological-pedagogical knowledge (TPK), affect students' cross-curricular competencies, such as ICT literacy. Considering the importance of instructional quality in relation to technology integration, TPK must be addressed as a link between teachers' TK and students' ICT literacy, as TPK is a prerequisite for the successful integration of ICT into instruction across all content and domains (Lachner et al., 2019). Therefore, teachers need TK and TPK to incorporate technology in the classroom, which could explain the differences in performance of ICT literacy among secondary students. Furthermore, according to Koehler and Mishra (2008), TPK teachers play a central role, as some programs related to technology, such as spreadsheets, were not originally designed for educational purposes but are now embedded in curricula—for instance, the 2016 Standing Conference of the Ministers of Education and Cultural Affairs (KMK).

In summary, previous studies have shown that teachers' professional knowledge is indispensable for students' subject-specific achievements. This is based on the assumption that teachers who are more proficient with subject content are better able to convey it to students in the classroom. Although the importance of teachers' subject-related professional knowledge to student achievement has been demonstrated, little attention has been paid to the relationship between teachers' cross-curricular professional knowledge and student achievement. Thus, this study extends previous research by examining the extent to which teachers' objectively measured TK and TPK can explain achievement differences in secondary students' ICT literacy.

Theoretical Background

In the following chapter, concepts and requirements for ICT literacy of secondary school students are presented. In addition, the Technological, Pedagogical, Content Knowledge (TPACK) framework focusing on TK and TPK is presented,

followed by an overview of how teachers' TK and TPK have been assessed in educational research to date. Finally, the impact of TK and TPK on students' ICT literacy will be discussed.

Secondary Students' ICT literacy

With ICT literacy as a cross-curricular subject, the competent use of ICT has gained considerable attention in educational research. Due to the increasing relevance of competent ICT use in educational research, Siddiq and colleagues (2016) identified a myriad (p. 60) of terms that describe the competent use of ICT, which is also consistent with current publications (see Gnambs, 2021). According to Gnambs (2021), many concepts related to ICT literacy overlap and cannot be distinguished on the basis of clearly defined theories. However, a generally accepted theoretical framework on competent ICT use was developed by the Educational Testing Service (ETS, 2002, p.2) and later used in the National Educational Panel Study (NEPS, see Senkbeil et al., 2013). Within this framework, ICT literacy is defined as the use of digital technology, communication tools, or networks to access, manage, integrate, evaluate, and create information to function in a knowledge society. According to this definition, and in light of the integration of ICT literacy into curricula, ICT literacy is adopted as a cross-curricular competency for secondary school students to acquire important competencies and skills that are relevant in educational and professional environments to successfully participate in society (Fraillon et al., 2020; Senkbeil et al., 2013).

The widely used ETS framework regarding ICT literacy consists of two overarching facets: technological literacy and information literacy (ETS, 2002). Technological literacy refers to competence in the operational use of technology, while information literacy describes the information skills required to use the technology to exchange and evaluate information accordingly (Senkbeil et al., 2013). In addition, ICT

literacy is divided into process components (e.g., access to retrieve information) and five software applications for finding, processing, presenting, and communicating information (e.g., Internet-based search engines and databases). The ICT literacy framework has already been empirically tested (see Senkbeil et al., 2013).

The literature exhibits a high degree of variability in the terms and definitions used to describe the competent use of ICT. Therefore, there is also a high degree of variability in the measurement instruments used to examine competent ICT use. Two prominent large-scale studies that measure secondary students' ICT literacy are the NEPS and the International Computer and Information Literacy Study (ICILS). Both aim to measure secondary students' competent ICT use. The ICILS study uses the term *computer and information literacy* (CIL), which refers to a student's ability to use computer technologies to gather and manage information and to produce and share information (Fraillon et al., 2020, p. 18). Thus, both ICT literacy and CIL refer to the extent to which students can use ICT to manage, evaluate, and communicate information, and thus, we argue that both terms can be used interchangeably, which is also supported by empirical evidence (for an overview, see Senkbeil & Ihme, 2020).

With the large-scale ICILS studies (2013, 2018), researchers were able to provide an international overview of secondary students' ICT literacy. In the ICILS study, the ICT literacy of secondary students was divided into four competence levels, with level one being the lowest and level four the highest. Level one describes the fact that secondary students can, for example, open a link in a new browser tab or identify who is receiving an email by looking at carbon copies (Fraillion et al., 2020, p. 57). The fourth level of proficiency, on the other hand, describes secondary students' ability to evaluate and assess internet sources, for example, when searching for or creating information (Fraillion et al., 2020, p. 60). The most recent results of the ICILS study

(2018) show that most secondary students worldwide only reach the second proficiency level. This means that secondary students in eighth grade can use computers to perform basic and explicit information retrieval and management tasks (Fraillion et al., 2020, p. 57), which is not sufficient for successful participation in society given the growing need for the proficient use of ICT (Fraillion et al., 2020).

Personal Factors and ICT Use in Relation to Secondary Students' ICT Literacy

Essentially, it can be said that the ICT literacy of secondary school students worldwide do not yet meet the requirements contained in the school curricula. The reasons for this can be manifold, but studies have already shown that the socioeconomic status of secondary school students plays an important role when it comes to performance differences in ICT literacy (Scherer & Siddiq, 2019). Both the 2013 ICILS results and the latest ICILS (2018) results (Wendt et al., 2014, Senkbeil et al., 2019) suggest that secondary students from privileged families with high socioeconomic status and high cultural capital have an achievement advantage in ICT literacy. Initial attempts to interpret these results have assumed that less privileged families may not be able to raise the necessary capital to provide students with access to ICT and, therefore, perform worse in ICT literacy, which can be aligned with the "digital divide" (OECD, 2019), excluding less privileged students from the process of digitalization.

Moreover, numerous studies have investigated the extent to which private ICT use and ICT use in instruction are related to secondary students' ICT literacy (Bundsgaard & Gerick, 2017; Lorenz et al., 2019; Senkbeil, 2017, Senkbeil & Ihme, 2017). While it is plausible to assume that those students who often use ICT both privately and in instruction also have higher learning outcomes, this could not always be proven in empirical studies. For example, Petko et al. (2017) used data from the Programme for International Student Assessment (PISA) to show that private ICT use

tended to be positively related to student achievement in science, mathematics, and reading, but ICT use in instruction was not positively related to student achievement in these subjects, which, according to the authors, is consistent with previous findings. Similar findings were also found in the relationship between students' ICT use and ICT literacy. For example, using ICILS data, Bundgsgaard and Gerick (2017) found that students who reported moderately frequent ICT use had higher ICT literacy than those who reported frequent or infrequent ICT use. The authors explain the counter-intuitive nature of their results by stressing that the purpose of ICT use (e.g., for ICT use in instruction and private ICT use) must be examined more closely to make more precise statements about the extent to which students' ICT use affects ICT literacy.

A correspondingly more precise differentiation of ICT use in relation to ICT literacy was pursued by Senkbeil and Ihme (2017) and Senkbeil (2017). The authors were able to show that certain ICT activities, such as the target-oriented use of ICT for information search or for study-related purposes, are positively related to students' ICT literacy. Students' private ICT use, such as for social communication, however, is not positively related to the ICT literacy of students. Thus, according to the authors, it can be concluded that target-oriented ICT use, such as for study-related purposes, is more suitable for acquiring ICT literacy than the use of ICT for private, hedonistic purposes. Overall, it can be concluded that students' ICT use is highly relevant for ICT literacy and should be taken into account when examining students' ICT literacy. However, it is also evident that it is important to distinguish between the type of ICT use—that is, ICT use in instruction or for private activities—as it can be assumed that only a targeted use of ICT has a positive influence on ICT literacy.

Teachers' Technological Knowledge

Again, teachers are responsible for fostering students' ICT literacy (Guggemos & Seufert, 2021). Hence, teachers must be able to use ICT in instruction proficiently to be able to teach students appropriate competencies (Guggemos & Seufert, 2021). Concerning teachers' proficient ICT use, Koehler and Mishra (2009) had a lasting impact on educational research with the TPACK, which stands for *technological pedagogical content knowledge* and represents a framework on how to integrate technology into instruction successfully. The TPACK framework was established based on Shulman's (1986) PCK and represents the extension of PCK with technology (T). Hence, the TPACK framework depicts the complexity of three main components regarding teacher knowledge: content, pedagogy, and technology. According to Koehler and Mishra (2009), TK is a part of the TPACK framework and is an indispensable component of integrating ICT in instruction. According to the authors, teachers' TK "requires a person to understand information technology broadly enough to apply it productively at work and in their everyday lives to recognize when information technology can assist or impede the achievement of a goal and to continually adapt to changes in information technology" (p.64). Therefore, the description of TK by Koehler and Mishra (2009) reveals similarities to general ICT literacy definitions (see ETS, 2002; Lachner et al., 2019). We, therefore, conclude that the term TK is an accurate term to describe the ICT literacy of teachers.

Teachers' Technological-Pedagogical Knowledge

It might be plausible that if teachers want to successfully integrate ICT into teaching and learning, they must have not only sound TK but also high TPK (Lachner et al., 2019). Referring to the TPACK framework, Koehler and Mishra (2008) described TPK as an understanding of how teaching and learning can change when particular technologies are used in particular ways (p. 65). As a result, teachers with a high TPK

should be able to sufficiently assess which ICT resources are appropriate and sufficient for teaching. According to Koehler and Mishra (2008), TPK is essential for teachers because many programs, such as Word or Excel, are commonly used in classrooms, but these programs are not designed for pedagogical purposes (p. 65). However, these programs are important for students' ICT literacy to successfully participate in social and professional life (Fraillion et al., 2020). Based on the assumptions of previous studies (see Baumert et al., 2010; Baier & Kunter, 2020), TPK can be described as the link between teachers' TK and instruction.

With regard to TPK, several studies have examined the frequency of teachers' ICT use in the classroom as a mediator variable that might affect students' ICT literacy (e.g., Gerick et al., 2017; Gerick., 2018) or assessed teachers' TPK via self-assessment, which may not be sufficient to provide a clear picture of the still poorly understood interaction between teachers' competencies and students' achievement (Lachner et al., 2019). However, assessing only the frequency of teachers' ICT use in the classroom might not represent sufficient information about teachers' TPK (Sailer et al., 2021), leaving educational science with a knowledge gap regarding the actual TPK of teachers. Scholars in the field have considered the lack of knowledge about teachers' actual use of ICT in the classroom a major weakness (Lorenz et al., 2019, p. 914) and have called for investigating *how* teachers use ICT in the classroom (e.g., Lucas et al., 2021) and, consequently, teachers' actual, objective assessment of TPK (Lachner et al., 2019). Overall, educational research could benefit from contributions on teachers' actual TPK to gain a clearer picture of how differences in teachers' TPK might lead to differences in student achievement.

The Present Study

Despite the integration of ICT literacy into the curricula, international studies have indicated that secondary school students do not yet meet the requirements in the curricula that are necessary to participate successfully in society and professional life. With the integration of ICT literacy into curricula, teachers became responsible for teaching ICT literacy to secondary school students. Previous studies have shown that teacher-level factors, such as the frequency of media use in class, play a role in students' ICT literacy. However, the measurement of teacher-level factors has been limited to self-reporting and frequency measures, which may affect the validity of the findings. Accordingly, the focus has shifted to teachers' actual professional knowledge, such as TK and TPK, and the extent to which they influence students' ICT literacy. This study aims to fill the research gap on how the objectively measured TK and TPK of teachers predict the ICT literacy of students. While Baumert and colleagues (2010) succeeded at providing evidence that the professional mathematical knowledge of teachers is important to secondary students' achievement in mathematics, it remains to be identified how cross-curricular competencies of teachers, such as TK and TPK, affect the cross-curricular ICT literacy of secondary students. This leads to the following research questions for this study:

RQ1: To what extent does the objectively measured technological knowledge (TK) of teachers predict the ICT literacy of secondary students?

RQ2: To what extent does the objectively measured technological knowledge (TK) of teachers, mediated by technological pedagogical knowledge (TPK), predict the ICT literacy of secondary students?

Based on previous research findings, we assume that secondary students who

have high-performing teachers in TK and TPK themselves perform high regarding ICT literacy.

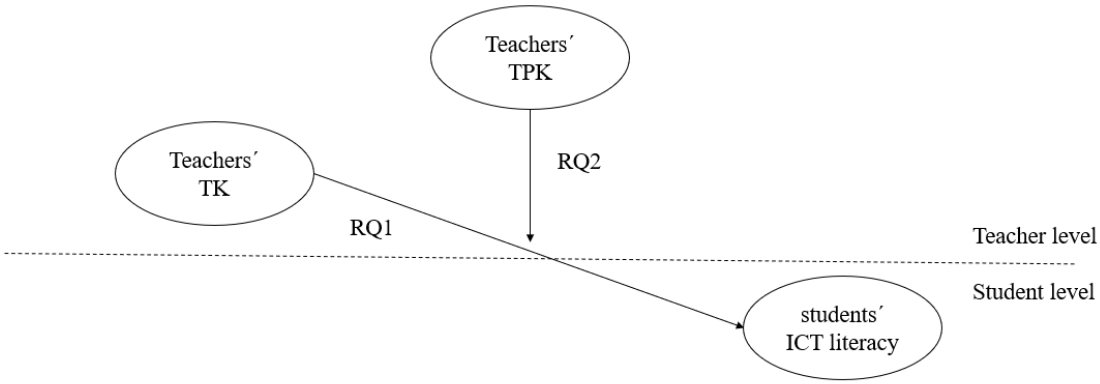

Figure 2: Hypothesized multilevel model of the teacher level (Level 2) and the students' level (Level 1); RQ = Research question**.**

Method

4.1. Research Design and Participants

Participating schools for this study were selected randomly stratified. Schools were stratified by counties and independent cities in Bavaria. The probability of drawing a county or county-free city depends on the number of schools in that county or county-free city, which was determined through publicly available statistics. The selected schools were recruited to participate in the study via official invitation emails from the universities and the ministry. If a school's principal agreed to participate in the data collection, teachers and students were invited. Data collection was conducted at the schools in October 2021 during a regular school day. Students were surveyed in the morning and teachers in the afternoon. Both NEPS tests, i.e., the students' ICT literacy test and the teachers' TK test-were administered on paper. The teachers' TPK test was administered online via Unipark (Questback, 2019). Trained test administrators administered the tests to both students and teachers. A total of 2,421 8th grade students participated in the cross-sectional study as part of the DigitUS project, attending a total of $N = 39$ schools, with $N = 134$ classes taught by $N = 220$ teachers. The majority of the

students visited grammar school (n = 1131), while n = 853 students visited secondary schools and n = 437 lower secondary schools. All students were in eighth grade, so they were all approximately 14 years old. Furthermore, 46% (n = 1,117) indicated themselves as male, and n = 1,143 (47%) indicated themselves as female; 1% of the students indicated themselves as diverse, while 6% did not specify their gender. From the N = 2,421 students, n = 1,620 students completed the ICT literacy test due to planned missing data design, thus representing the sample for this study. Most of the teachers taught biology and mathematics (69%). The other teachers taught mainly languages and social sciences. Finally, the teachers were between 30 and 59 years old. An official ethics committee approved the study.

4.2 Measurement Instruments

Dependent variable – students' ICT literacy. To assess secondary students' ICT literacy, the paper-based test of the NEPS for secondary students was applied (further information can be derived by Senkbeil et al., 2013). The test was provided by the Leibniz Institute for Educational Trajectories. The ICT literacy test of students consists of realistic problems embedded in a range of authentic situations where students were exposed to screenshots of electronic databases or spreadsheets (see Senkbeil et al., 2013, p. 145). The test construction is based on seven process components. Four of the process components (Define, Access, Manage, Create) refer to the facet of technology literacy, whereas the remaining three (Integrate, Evaluate, Communicate) refer to the facet of information literacy. In addition to the process components, the test is guided by a categorization of software applications that are used to locate, process, present, and communicate information (Senkbeil et al., 2013, p. 143). The answer format of the test is based on multiple-choice items.

The NEPS test was assigned to the participants based on their school type. Since the NEPS developed various test booklets for measuring ICT literacy for the ninth grade

with the difficulty levels low, medium, and high, we examined in advance using power analysis which levels of difficulty were suitable for eighth grade in the different schools. After empirical examination, the medium test booklet was used for grammar schools (*Gymnasiums),* and the low-difficulty test booklet was used for the secondary schools (*Realschule)* and lower secondary schools (*Mittelschule).* The NEPS ICT literacy test consists of 36 items. Both difficulty levels, low and medium, included items that were identical but with different levels of difficulty, which allowed for mean-level comparisons (see Fischer, Rohm, Gnambs & Carstensen, 2016). The students had 28 minutes to complete the ICT literacy test.

Control Variables

Gender. To identify students' gender, students were asked whether they specified themselves as female, male, or diverse. *Cultural Capital.* The cultural capital was surveyed via the number of books in the parental home as an indicator of the socioeconomic status of the students (Frallion et al., 2020; Senkbeil et al., 2019). Students had five categories to choose from: 0 to 10 books (1), 11 to 25 books (2), 26 to 100 books (3), 101 to 200 books (4), and more than 200 books (5). We assessed students' ICT use (for further information on the measurement of students' ICT use, see Fraillon et al., 2020) with two subscales that relate to learning processes with ICT: ICT use *for study-purposes* and *for class activities* The scale for study- purposes included items regarding school-related purposes, such as preparing reports or essays or to complete exercises and tasks. Secondary students could answer from "less than once a month" to "every school day". The scale ICT use for class activities included items regarding the use of ICT for learning of ICT (coding) tasks at school, and the use of specialist and general applications in class. Secondary students could answer how often they use ICT for specific purposes from "never" to "in every or almost every lesson".

Independent variable—teachers' TK. To measure teachers' TK, the paper-based Test of Technological and Information Literacy (TILT) of the NEPS for adults was used (for further details, see Senkbeil et al., 2013; Senkbeil and Ihme, 2015). The ICT literacy framework can be applied to constructing ICT literacy tests for all age cohorts (e.g., students and adults; Senkbeil and Ihme et al., 2015, p.3). Therefore, teachers were also presented with multiple-choice items of realistic problems of authentic screenshots—namely, internet browser or spreadsheet—as prompts (see Senkbeil and Ihme et al., 2015, p.3). The tests consisted of 29 items. Teachers had 28 minutes to complete the test.

Independent variable—teachers' TPK. To assess teachers' TPK in the present study, the TPK test of Lachner et al. (2019, p. 16) was administered. The TPK test includes conceptual and situational TPK domains. The conceptual TPK domain includes psychological components in that teachers are instructed to indicate which educational technology is appropriate to support student learning. Furthermore, this domain includes questions regarding technology-related research. Teachers were prompted to assess the degree to which, in the context of current technology-related research, the use of technology in the classroom may have potential. Regarding the situational TPK domain, short vignettes were included in which teachers were requested to assess specific teaching situations in which technologies were used. The final test consisted of 10 items. The original test design suggested a three-dimensional structure, but our data suggested one-dimensionality of the test structure. Therefore, raw scores were transformed into person ability scores using a unidimensional Rasch model. The cut-off values (0.5–1.5) proposed by Linacre (2002) for Infit-MNSQ and Outfit-MNSO 0.5–1.5 were supported. Test fairness across school type and gender was tested with differential item functioning (DIF). The main effect was DIF = -0.33, indicating test fairness of the

items across school type and gender (OECD, 2009). On average, teachers took 15 minutes to complete the TPK test.

4.3 Procedure

Data collection was conducted on both students and teachers on a normal school day. Students were surveyed from 2nd to 4th period, and regular school breaks were observed. The teacher survey took place in the afternoon after school. Students were given various paper-based tests with different tasks through the planned missing design to avoid overload. The teacher survey was paper-based at TK, and the rest of the survey was online in the school's computer lab. By generating class-specific tokens, which were also used to pseudonymize the data, the teachers' data could be matched with the students' data.

4.4. Statistical Analysis

All analyses in this study were performed using the statistical software R (version 4.1.3). Person ability scores for students' ICT literacy, teachers' TK and TPK, and students' ICT use were analysed using the Rasch model (1PL) with the *TAM* package (Robitzsch et al., 2021) to obtain comparable Rasch measurement values (see Table 1). Due to the nested data structure, the data of this study were successively implemented using multilevel analysis with a three-level structure using the package *lme4* (Bates et al., 2015). For interpretability, predictors were centered at the sample mean of each variable using grand mean centering. Level 1 represents the data of the students, Level 2 represents the data of the teachers who teach classes in which the students are enrolled, and Level 3 represents the schools of the students and teachers. To perform the multilevel analysis, a null model (Model 0) was first defined without any additional variables to clarify the need for a multilevel model based on the data structure. In the second model (Model 1), the same model as in Model 0 was implemented, but allowing the intercepts to vary across classes to implement random

effects of the model for the contextual variable. The third model (Model 2) included the control variables from three levels—the student level, teacher level, and school level—to identify the proportion of the included variables to explain additional variance in students' ICT literacy. To determine whether varying intercepts improved the models, the Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used; lower AIC and BIC indicate a better model fit (Rost, 2004). Additionally, model fit was measured by -2 Log Likelihood (-2LL).

Table 1

Descriptive Statistics of the Data

	Min.	*Max.*	*M*	*SD*	*Md*
Student Level (Level 1)					
ICT literacy—person ability scores	-7.85	1.86	-1.37	1.36	-1.45
Number of Books at home[a]	1	5	3.21	1.62	3.00
ICT use for study-related purposes	-4.00	3.62	-0.79	0.82	-0.76
ICT use for class activities	-2.85	0.18	-1.97	0.49	-2.07
Teacher Level (Level 2)					
TK—person ability scores	-1.35	3.08	0.78	0.79	0.78
TPK—person ability scores	-7.42	3.66	0.09	1.41	0.31

Note:[a] Regarding the number of books at home, students had options from five response categories: 0 to 10 books (1), 11 to 25 books (2), 26 to 100 books (3), 101 to 200 books (4), and more than 200 books (5)

Results

The intraclass coefficient (ICC) indicated variance explained by the grouping structure suggesting the need for multilevel analysis. Further, Model fit indices (AIC, BIC, and -2LL) showed improved model fit, allowing intercepts to vary between classes (Model 1) and the final model, including predictor variables (Model 2). Table 2, 3, and 4 show the results of the multilevel analysis (RQ1 and 2) for both, the student (Table 2)- and teacher-levels predictors only (Table 3) and the overall analysis including both, predictors on the teacher-and student-level regarding secondary students ICT literacy (Table 4). Regarding the overall multilevel analysis (Table 4) the personal factors, the amount of books at home had a significant positive effect on students' ICT literacy (b = 0.52, t(1468) = -2.47, p = 0.05). The results showed further that gender hat no significant effect on students' ICT literacy.

Regarding secondary students' ICT use, the results show that ICT use for study-related purposes (b = -0.91, t(1465) = -2.35, p = 0.05) has a negative relationship with secondary students' ICT literacy, which means that students who report using ICT frequently for study-related purposes have lower ICT literacy. In terms of ICT use for class activities, the relationship with students' ICT literacy is also in a negative direction, but this result is not significant in the overall multilevel model. In addition, both TK (b = -.08, t(692) = 1.66 .01, p >.05) and TPK (b = -0.05, t(690) = -1.83 p >.05) did not significantly predict secondary students' ICT literacy (RQ1), nor did the interaction between TK and TPK (RQ2) (b = -.04, t(659) =- 0.05, p >.05). The results remain constant when the multilevel model is analyzed using only student-level variables (Table 2) and teacher-level variables (Table 3) in the context of secondary students' ICT literacy, with the exception that ICT use in class had an significant

negative effect on secondary students ICT literacy in the multilevel model using only student-level variables (b = -.18, $t(1129)$ = -2.15, p <.05).

Table 2

Results from multilevel analysis based on the student-level, with secondary students' ICT literacy as dependent variable and gender, number of books at home, ICT use for study-related purposes, and ICT use for class activities as independent variables.

	Model 0	**Model 1**	**Model 2**
Fixed effects			
Intercept (*SE*)	-1.37***(.03)	-1.59***(.16)	-2.30(0.22)
Gender —Female			Reference
Gender —Male			**0.08 (.04)***
Number of books at home (*SE*)			**0.09 (.02)*****
ICT use for study-related purposes *(SE)*			**-0.18 (.08)***
ICT use for class activities *(SE)*			**-0.07* (.03)**
Numb. Obs.	1620	1470	1141
BIC		3642.74	2732.84
AIC		3621.57	2773.16
-2LL		-1806.78	-1358.42
ICC		0.60	0.57
Marginal R^2/ Conditional R^2		0.00/0.60	0.020/0.617

Note: *p < .05, **p < .01, ***p < .000

Table 3

Results from multilevel analysis based on the teacher-level, with secondary students' ICT literacy as dependent variable, and teachers TK and TPK as independent variables

	Model 0	**Model 1**	**Model 2**
Fixed effects			
Intercept (*SE*)	-1.37***(.03)	1.59***(.03)	0.11*(0.05)
Teachers' TK (*SE*)			.05 (.03)
Teachers' TPK (*SE*)			.02 (.05)
Teachers' TPK : Teachers' TK (SE)			-.03 (.04)
Numb. Obs.	1620	1470	864
BIC		3642.74	2153.07
AIC		3621.57	2153.07
-2LL		-1860.78	-1069.54
ICC		0.60	0.04
MarginalR^2/Conditional R^2		0.00/0.60	0.011/0.598

Note: *p < .05, **p < .01, ***p < .000

Table 4

Results from multilevel analysis with secondary students' ICT literacy as dependent variable and gender, number of books at home, ICT use for study-related purposes, and ICT use for class activities, teachers' TK, and teachers' TPK as independent variables.

	Model 0	**Model 1**	**Model 2**
Fixed effects			
Intercept (*SE*)	-1.37 ***	-1.59 ***	-1.81 ***
Gender —Female			Reference
Gender —Male			0.10 (.05)
Number of books at home (*SE*)			**0.05 (.02) ***
ICT use for study-related purposes *(SE)*			**-0.09 (.03)***
ICT use for class activities *(SE)*			-0.04 (.14)
Teachers' TK (*SE*)			.08 (.07)
Teachers' TPK (*SE*)			-.05 (.03)
Teachers' TPK: Teachers' TK (SE)			-.04 (.09)
N students	1620	1470	693
N classes		131	71
N schools		39	28
BIC		3621.57	1734.61
AIC		3652.74	1784.56
-2LL		-1806.78	-856.30
ICC		0.50	0.59
Marginal R^2/ Conditional R^2		0.00/0.60	0.022/0.611

Note: *$p < .05$, **$p < .01$, ***$p < .000$

Discussion

In the present study, we investigated the extent to which teachers' TK and TPK predict secondary students' cross-curricular ICT literacy. Previous studies (e.g., Baumert et al., 2010) have shown that teachers' subject knowledge is essential to students' performance in the respective subject. Despite earlier results and the high scientific relevance of teachers' professional knowledge in relation to students' achievement, we were unable to replicate this finding in our study for cross-curricular ICT literacy. Neither teachers' TK nor teachers' TPK as an indicator of instructional quality significantly predicted ICT literacy among secondary students.

The results of this study are particularly interesting because teachers are considered "keystone species" (Davis et al., 2013) when it comes to integrating ICT into instruction, which is expected to impact secondary students' ICT literacy (Gerick et al., 2018). Although the results of this study are surprising, earlier research has partially shown similar results. Indeed studies that examined school- and teacher-level characteristics related to secondary students' ICT literacy have already shown that other teacher-level factors, such as teachers' computer use in school or collaboration related to ICT in the classroom, have no or even negative effects on secondary students' ICT literacy (e.g., Drossel & Eickelmann, 2017; Gerick et al., 2017), suggesting that previous investments in improving technology in schools have not paid off in terms of student achievement (Petko et al., 2017). These findings are along the same lines as those of this study: despite the integration of ICT literacy into curricula and the accompanying responsibility of teachers to teach ICT literacy to secondary students, secondary students' ICT literacy does not appear to be influenced by teachers' professional knowledge regarding TK and TPK. Our results also show that ICT use for study-related purposes is negatively associated with secondary students' ICT literacy.

The same direction can be found when secondary students report using ICT frequently for class activities, but this result was no longer significant in the overall multilevel model (Table 4). However, when the predictors were considered only at the student level (Table 2), a significant negative relationship was found between secondary students' ICT literacy and ICT use in class. Although the result sounds paradoxical at first, it is in line with previous research (e.g., Drossel & Eickelmann, 2017; Gerick et al., 2017). While the results should be interpreted with caution, as no causal relationships can be inferred, the findings show that less teacher-level factor, such as teachers' professional knowledge play a role in the genesis of students' ICT literacy, but student-level factors, such as student-centred activities with ICT. Even if the results still point in a negative direction - the more students use ICT for study-related purposes, the less ICT literacy they have - this nevertheless shows a possible starting point for target interventions to promote the ICT literacy of secondary students.

Accordingly, the results indicate that the quality of the ICT use in the classroom might play an important role, and thus the results of this study can be interpreted in the view situational classroom instruction as researchers have already called for ICT use in the classroom to be more closely aligned with student-centred instructional quality aspects (e.g., Lachner et al., 2019; Scheiter, 2021). With this finding, in addition to teachers' professional knowledge of TK and TPK, classroom instruction and ICT for study-related purposes become the focus of further research, as teachers need to initiate appropriate ICT use in the classroom and for study-related purposes, such as exercises, tasks or homework with ICT. The results of this study show not yet the desired promotion of ICT literacy of secondary students, which is contrary to national curricular expectations. Scholars (Backfisch et al., 2020; Depaepe et al., 2020; Kaiser et al., 2017) have already postulated that focusing exclusively on teachers' professional knowledge is

not sufficient to explain differences in student achievement: Rather, situational instructional actions and aspects of instructional quality must be examined simultaneously, as teachers' professional knowledge alone does not necessarily correspond to actual instructional actions. The results of our study point in a similar direction: although TK and TPK have no influence on secondary students' ICT literacy, students' ICT use for study-related purposes, which can be initiated by teachers, does although (yet) in the negative direction. However, a starting point can be identified here to align ICT use in class with more student-centred instructional quality features such as the cognitive activation of students (e.g., Baumert et al., 2010) with specific target interventions in the professional development of teachers, in order to promote the ICT literacy of secondary students in a positive direction. This would be promising, since schools and thus teachers are also responsible to promote the ICT literacy of secondary students in the classroom, which does not yet seem to be sufficiently the case.

Consequently, in order for students to use ICT in the classroom successfully, mere professional knowledge might not always be transformed into actual classroom instruction (Depaepe et al., 2020; Kaiser et al., 2017), whereby other facets, such as self-efficacy and motivation should be taken into account to assess whether teachers implement appropriate learning scenarios in the classroom (Backfisch et al., 2020). Accordingly, it would be profitable for further research to investigate process and situational characteristics of instruction, as well as personal factors of teachers, such as self-efficacy and motivation. Furthermore, the results of our study show that socioeconomic status had a significant effect on students' ICT literacy, which is in line with previous studies in which socially disadvantaged students always performed worse in terms of ICT literacy (e.g., Hatlevik et al., 2015). With the responsibility of schools to specifically promote the ICT literacy of secondary students, there is also the

possibility that students with a low socioeconomic status could acquire ICT literacy in the classroom, as less household-relevant factors (e.g., technical resources) would play a role in the development of secondary students ICT literacy. However, schools must be equally equipped with ICT and use ICT appropriately in teaching and learning processes, what could be investigated in more detail in future research.

In summary, future studies investigating the impact of teachers' cross-curricular knowledge of TK and TPK on students' ICT literacy should take into account situational process components of instruction on the part of teachers in order to gain a more holistic picture of teaching and learning processes with ICT, which seems to be relevant regarding the genesis of secondary students ICT literacy. Moreover, educational science would benefit greatly from qualitative research approaches to further investigate the professional knowledge of teachers and factors that prevent or support teachers to use ICT in the classroom and thus promoting ICT literacy among secondary school students, as well as their ICT use in class and for study-related purposes.

Limitations and Future Directions

A limitation of this study is that no school-level factors, such as ICT equipment, were included in the analysis. However, factors such as ICT support or participation in professional development may be responsible for differences in teachers' ICT use (Gerick et al., 2018; Konstantinidou & Scherer, 2022) and, thus, TK and TPK, which may also affect secondary students' ICT literacy. Future studies should therefore consider other structural factors at the school level. Scholars (e.g., Baier & Kunter, 2020; Lachner et al., 2019; Lorenz et al., 2019; Schmidt et al., 2021) have often demanded the increased use of objective measures in educational science regarding teachers' TK. Even though we agree with this demand, it is important to note that previous studies have shown that self-efficacy measures are an important indicator of whether technology is being actually used in the classroom (e.g., Scherer et al., 2015; Konstantinidou & Scherer, 2022, Backfisch et al., 2020). For example, teachers' motivation and ICT self-efficacy were important predictors of whether teachers frequently use ICT in the classroom (Scherer et al., 2015; Konstantinidou & Scherer, 2022).

Accordingly, self-efficacy and motivation measures could be used alongside objective assessment measures, which were used exclusively in this study, as the mere presence of expertise related to TK and TPK is not necessarily indicative of the actual implementation of technology in the classroom and thus has implications for students' ICT literacy. In addition, other personal factors of teachers, such as teaching experience and subject combination, can be included as control variables in future studies. Beyond that, this study was conducted using a cross-sectional design. Further longitudinal studies can provide more information about the relationship between teachers' TPK and TK, as well as students' ICT literacy.

Conclusions

While previous studies have shown that teachers' subject-specific professional knowledge—for example, in mathematics—has a positive effect on students' performance in that subject, this result could not be replicated for cross-curricular competencies—namely, ICT literacy. Nonetheless, by embedding ICT literacy into the curriculum, teachers are responsible for teaching ICT literacy to secondary students and promoting their own TK and TPK in professional development programs to use ICT effectively in the classroom. Accordingly, the relationship between students' and teachers' cross-curricular competencies, and process and situational aspects of instruction should be further explored to develop targeted interventions for the successful use of ICT in the classroom to promote students' ICT literacy.

5. General Discussion

The central goal of this dissertation was to investigate teachers' and learners' digital skills, and furthermore, to explore the relationship between teachers' and learners' digital skills. To achieve this goal, I first examined learners' use of digital media in the context of the impact of the COVID -19 pandemic (Study 1), as the inevitable use of digital media in the context of the pandemic may have affected learners' digital skills to an extent that previous research needed to be updated. Second, I examined teachers' digital skills in more detail because research on teachers' digital skills is a recent discipline that is often poorly captured due to inadequate research instruments (Scheiter, 2021). Due to the integration of digital skills into curricula, scholars of educational research (e.g., Guggemos & Seufert, 2021; Lachner et al., 2019; Lucas et al, 2021) have called for an investigation of the relationship between teachers' digital skills and learners' digital skills. Therefore, the third study of this dissertation aimed to conduct this investigation.

The studies in this dissertation are organized as follows. Study 1 first focused on learners' use of digital media before and during the COVID -19 pandemic. We hypothesized that the global school closures and lockdowns significantly changed learners' use of digital media and skills. Study 1 found that the COVID -19 pandemic had a major impact on learners' use of digital media. Learners reported that they increased their use of digital media for purposeful purposes during the COVID -19 pandemic. Therefore, in Study 3, I decided to include learners' use of digital media for in-class activities and study-related purposes in the analysis of the relationship with learners' digital skills. In order to examine the relationship between teachers' and learners' digital skills, it was also necessary to gain further insight into teachers' digital skills from Study 2.

The assessment of teachers' digital skills was inadequate due to issues such as biased self-assessment. Previous research suggests that subjects overestimate or underestimate their skills. Study 2 shows that self-assessment instruments with contextual information are appropriate for approximating objectively assessed scores of less complex operational digital skills. However, objective assessment instruments are needed to identify more complex digital skills. While Studies 1 and 2 examined teachers' and learners' digital skills separately, Study 3 combined both perspectives and examined how teachers' digital skills affect learners' digital skills. Building on the findings of Study 1 and Study 2, Study 3 examined learners' use of digital media in the classroom and for private purposes, as well as objective assessment measures to assess the more complex constructs TK and TPK of teachers, as we found that scenario-based self-assessment instruments closely matched the results of objective measures for less complex skills. In the following sections, we discuss the results of all three studies and derive theoretical and practical implications. Finally, the limitations of the study are identified and suggestions for further research are made.

5.1 Summary of the results

Study 1 systematically compared learners' digital media use before and during the COVID-19 pandemic (2019 and 2020, respectively) using the person-centered latent profile analysis approach. Although research on learners' use of digital media is used widely in educational science, the relevance of the research findings remains questionable in light of the COVID-19 pandemic and the resulting use of digital media to sustain social, teaching, and learning processes. Therefore, the main goal of this study was to investigate how the COVID-19 pandemic and resulting increase in digital media use affected learners on the premise that target-oriented digital media use (e.g., for study-related purposes) has

a positive impact on learners' digital skills (Senkbeil, 2017). Two representative samples from Bavaria, a region in Germany, were used for the study.

In addition, we examined the extent to which learners' factors, such as gender and parents' education level, affect learners' digital media use. This provided a link to research on the digital divide (van Dijk, 2020). Learners from educationally disadvantaged families are particularly at risk of not keeping up with the ongoing digitization of the education sector due to issues such as lacking the financial means to use digital media appropriately at home. This can have far-reaching consequences, especially during the COVID-19 pandemic (Thorn & Vincent-Lancrin, 2021). The first study demonstrates that learners' use of digital media became more sophisticated and frequent for all profile groups during the COVID-19 pandemic, with learners increasingly using digital media for study-related purposes or searching for information. The results also reveal that before the COVID-19 pandemic, the type of school learners attended was a significant predictor of profile membership. Learners from schools with lower levels of education were significantly more likely to be in profiles that reported using digital media for less sophisticated and targeted purposes, such as social communication with friends.

Moreover, consistent with research on the digital divide, the results indicate that learners from educationally disadvantaged families were most likely to be represented in profiles that used digital media for less sophisticated purposes, such as social communication with friends during the COVID-19 pandemic in 2020. Interestingly, the results showed that during the pandemic, learners' school type no longer impacted profile membership, indicating that all learners in all types of schools were equally affected by school closures and the use of digital media that accompanied it. Overall, the results suggest that the COVID-19 pandemic positively affected learners' digital media use.

Future studies should consider this issue and develop instruments to capture learners' digital media use.

While learners' digital media use and skills have been studied extensively, especially before the COVID-19 pandemic, there is comparatively little research on teachers' digital skills (Scheiter, 2021). Nevertheless, scholars agree (e.g., Guggemos & Seufert, 2021; Lachner et al., 2019) that firmly embedding digital skills in curricula – not only for learners but also for teacher education and training objectively measuring these skills is of growing interest in educational science. Currently, self-assessment instruments are almost exclusively used to measure teachers' digital skills (e.g., Roussinos & Jimoyiannis, 2019; Schmid et al., 2020) because objective assessment measures of digital skills often lead to higher dropout rates due to the complexity and time involved. High dropout rates and test complexity due to objective assessment measures result in a discrepancy that this dissertation sought to resolve in Study 2.

In Study 2, 53 in-service teachers and 22 student teachers assessed their digital skills using a scenario-based self-assessment instrument and an online multiple-choice competency test. The results show that scenario-based self-assessment is suitable as the results are close to objectively measured technical operational skills, such as the operation and use of digital media. This is consistent with previous research (e.g., Talsma et al., 2018) suggesting that contextual information in self-assessment can prevent a potential bias that leads to over- or underestimating one's competence. In addition, the assumption is that contextual information provides a framework in which it is easier for subjects to correctly assess their competence (Sailer et al., 2021a). Interestingly, scenario-based self-assessment of more sophisticated digital skills, such as evaluating information, did not significantly predict objective performance. This could also be due to the complexity of more sophisticated digital skills that require actual or simulation-based testing (Siddiq et

al., 2016). Overall, the results show that enriching self-assessments with contextual information can bring educational science closer to desired outcomes than objective assessment tests.

Study 3 used the results of Study 1 and Study 2 and combined two perspectives: teachers' digital skills and learners' digital skills. In addition, Study 3 included learners' use of digital media in the analysis because Study 1 emphasized the relevance of learners' use of digital media. Although it was not possible to match learners' digital media use with learners' digital skills in Study 1, it was possible to match learners' digital media use with learners' digital skills in Study 3, which I included accordingly. However, Study 2 also showed that more complex constructs measuring higher level skills were not well suited for scenario-based assessment. Therefore, I decided to assess teachers' professional knowledge with objective instruments in Study 3.

In educational science, teachers' and learners' digital skills are mostly considered separately, and the extent to which teachers' digital skills impact learners has not yet been satisfactorily investigated (Scheiter, 2021). However, with the integration of digital skills into curricula, teachers are responsible for teaching these skills to learners alongside subject content. Therefore, teachers' digital skills play an important role in developing learners' digital skills (Lucas et al., 2021). While previous research has revealed that teachers' subject matter expertise in mathematics positively impacts student achievement in the subject (Baumert et al., 2010), Study 3 examined how teachers' TK affects learners' digital skills, mediated by teachers' TPK. Interestingly, our hypothesis that teachers' digital skills do affect learners' digital skills, including teachers' professional knowledge about the proficient use of digital media in instruction, was not confirmed. This suggests at first glance that teachers' professional knowledge of digital skills does not (yet) play a central role in learners' digital skills. Nonetheless, Study 3 indicates that learners' use of

digital media for study-related purposes is a significant predictor of learners' digital skills, although in a negative direction. However, the use of digital media for study-related purposes must be initiated by teachers and thus offers potential for further research and target interventions, which are presented below.

5.2 Future research and practical implications for learners' digital skills

In this section, two main areas are discussed to derive practical implications and future research opportunities from the results of the studies conducted as part of this dissertation. The first is the classroom perspective, with Study 1 and Study 3 highlighting learners' use of digital media as a promising area of research to promote learners' digital skills, although the potential seems to be not yet fully exploited. Pedagogical and curricular recommendations were also developed based on this research. Second, Learners' private use of digital media is presented in more detail as a potential future research area to learn more about how learners acquire digital skills in private settings.

Learners' digital skills have a firmly integrated place in curricula in Germany (KMK, 2016) and other countries such as Norway (Norwegian Directorate for Education and Training, 2011). Therefore, schools and teachers are responsible for promoting learners' critical, meaningful, and reflective use of digital media and considering the associated opportunities and risks (KMK, 2016, 2019a; Fraillon et al., 2020; Scheiter, 2021). With the integration of digital skills into the curriculum, it seems clear that learners acquire digital skills by using digital media in instruction. However, some educational scholars have found that digital media in teaching has no effect or a negative effect on learners' digital skills (Bundsgaard & Gerick, 2017; Gerick, 2018; Petko et al., 2017). The results of Study 1 and Study 3 are in line with those findings: While Study 1 emphasized the relevance of target-oriented digital media, Study 3 revealed a negative relationship regarding the use of digital media for study-related purposes and learners' digital skills.

Most studies have focused on the teacher perspective to examine the use of digital media in the classroom (e.g., having teachers indicate how frequently they use digital media in the classroom), leading to ambiguous results. Lucas et al. (2021) claim that focusing on teachers' use of digital media in the classroom is too simplistic. Instead, they call for a shift to the student perspective to address the need for more student-centered approaches. With the change to the student perspective, it can be assumed that learners' use of digital media in the classroom can explain performance differences in learners' digital skills. A corresponding shift in the student perspective regarding the use of digital media in the classroom is also supported by Study 1 and Study 3. Accordingly, Study 1 of this dissertation showed that the digital media use of learners changed because they used, due to the COVID-19 Pandemic, digital media for more target-oriented purposes, which is positively related to digital skills (Senkbeil, 2017). While it was not possible to verify in Study 1 whether learners' digital media use had an effect on digital skills due to the data situation, this assumption was verified in study 3 by additionally examining learners' digital media use in relation to their digital skills.

Interestingly, Study 3 revealed that using digital media for study-related purposes had a significant negative effect on learners' digital skills. Accordingly, the results indicate that the use of digital media in the classroom does have an influence on the genesis of learners' digital skills, but that this influence is not yet in the desired direction. Thus, the results follow the calls of previous researchers (e.g., Lachner et al., 2019) that the use of digital media in the classroom needs to be more strongly linked to aspects of instructional quality, which could have a positive impact on learners' digital skills.

Hence, teachers' professional knowledge of instructional quality and learners' learning activities come to the forefront as teachers need to initiate learners' use of digital media in the classroom. Further research could be conducted on teachers' professional

knowledge of the instructional quality characteristics that determine student learning activities with digital media and the extent to which digital media can be successfully used in the classroom.

In summary, Scheiter (2021) postulated that future research should form an intersection between two perspectives of digital skills – learners' skills and teachers' skills. The findings of Study 1 and Study 3 indicate that there is a need for both perspectives to intersect at the instructional level, i.e., teacher-initiated learners' use of digital media in the classroom.

While the use of digital media in instruction plays a significant role in how learners acquire digital skills, Trautwein et al. (2022) postulate that instruction can be divided into "sight" and "deep" structures. Sight structures refer to superficial features of instruction, such as observable learning arrangements and teaching methods (p. 99), while deep structures refer to the learning processes that do not occur visibly. Deep structures include aspects such as learners' cognitive activation and are often referred to as the fundamental dimensions of high-quality teaching. Previous findings have demonstrated that learners' cognitive activation positively impacts student performance in mathematics (Kunter & Voss, 2013) and biology (Förtsch et al., 2016). Therefore, it seems promising to focus future research on fostering cross-curricular skills, such as learners' digital skills, particularly through cognitive activation in instruction.

According to Kunter et al. (2013), cognitive activation occurs when the learning environment encourages learners to reflect and engage deeply with the lesson content (p. 1010). Chi and Wylie (2014) propose the ICAP framework for instructional quality and student cognitive activation, postulating that cognitive processes can be described by four observable learning activities: passive, active, constructive, and interactive. Cognitive processes become more sophisticated as learners move from passive to interactive

learning activities (Sailer et al., 2021b). Thus, when relating the observable learning activity to cognitive processes, the passive perceiver only absorbs information in mental isolation (passive). Therefore, it is less likely that the new information will be linked to prior knowledge. However, when learners are observably active (active) in their learning activities (e.g., taking notes), prior knowledge must first be activated to enable the acquisition of new information. When learners constructively generate new information (constructive), prior knowledge must be activated and integrated into existing knowledge structures (i.e., a conclusion is more likely to be drawn about the newly acquired knowledge). Finally, when learners engage in social interactions (interactive) (e.g., discussing learning content), they are more likely to not only draw inferences about the newly acquired knowledge but also to engage with the learning partner's arguments, which in turn can lead to increased elaboration of the learning content. In terms of the cognitive processes triggered by observable learning activities, the ICAP framework postulates that the more learners tend to work constructively or interactively with the learning content, the more efficient the cognitive process.

Some researchers (Kramer et al., 2019, Lohr et al., 2021, Sailer et al., 2017, Sailer et al., 2021b, Stegmann, 2020) have taken up the ICAP framework and reflected on it as a quality criterion for the use of digital media in instruction. The authors assume that better quality cognitive processes, and thus greater learning success, occur when fewer learners passively receive content using digital media. The more they work constructively and collaboratively with digital media, such as in simulation-based learning or computer-supported collaborative learning (Lohr et al., 2021). In line with this, Stegmann’s (2020) systematic review of meta-analyses, which was based on the ICAP framework, found that using digital media in the classroom positively affects student achievement.

In summary, using digital media in instruction holds promise for examining learner achievement differences in digital skills in more detail. Therefore, it would be interesting to investigate how features of instructional quality, such as cognitive activation, might play a role in digital skill acquisition. The ICAP framework can serve as a starting point as learners are assumed to experience higher cognitive activation when they receive less instructional content via visual, passive learning activities and more when they act in an observably constructive and socially interactive manner (e.g., when learners themselves use digital media for appropriate learning activities such as simulation-based learning or computer-supported collaborative learning).

The results of this dissertation also have implications for future educational strategies. First, the widespread adoption of computer science as a major subject may hold promise for promoting digital skills – which is currently only enshrined as a cross-curricular skill. Study 1 and Study 3 also demonstrate that learners from lower educational-level schools have significantly less adequate digital skills or use digital media for less target-oriented purposes than learners from grammar schools. This is particularly interesting because learners in Bavaria already take computer science as a separate major subject in the 8th grade at the lower secondary schools and secondary schools, but it is not part of the curriculum for learners in the 8th grade at grammar schools (Staatsinstitut für Schulqualität und Bildungsforschung, 2022). Given that learners in (lower) secondary schools tend to enter professional life earlier than learners from grammar schools, it would be advisable to provide special support or interventions to improve the digital skills of (lower) secondary learners since such skills are indispensable for most professions.

In summary, Study 1 and Study 3 suggest that learners' use of digital media in the classroom seems to play an important role in the acquisition of digital skills. Furthermore,

in light of the deep structures of instruction and the need for cognitive activation of learners, it is crucial to shift the perspective from teachers to learners and examine more closely how learners use digital media in the classroom. The results of such an analysis could show that there is an impact on learners' cognitive activation and thus on their digital skills (Lohr et al., 2021; Sailer et al., 2017).

In addition to school-related factors such as instructional quality, personal factors often play a major role in explaining differences in learners' performance in terms of digital skills (e.g., Hatlevik et al., 2015; Scherer & Siddiq, 2019; Siddiq & Scherer, 2019). For example, learners born around the beginning of the century who have grown up with digital media are often considered particularly adept at using digital media and are therefore referred to as "digital natives." However, Kirschner & Bruycekere (2017) found that the notion of digital natives is a myth and that learners do not have sufficient digital skills. This is confirmed by the results of a large-scale ICILS study in 2018. On a five-point competency scale on which the fifth level is highest, learners internationally achieve only level 2. Level 2 competence states that learners can perform basic operational tasks on a computer, such as opening documents, but cannot undertake a targeted search for information or critically evaluate located information (Frallion, 2020). Furthermore, numerous personal factors and characteristics such as gender (Siddiq & Scherer; 2019), language integration at home (Hatlevik et al., 2015), ICT self-efficacy (Hatlevik et al., 2018), private use of digital media (Alkan & Meinck, 2016), as well as measures of socioeconomic status (for an overview see Scherer & Siddiq, 2019) have been used to explain variations in learners' digital skills. However, the results of these studies are inconclusive. For example, while Hatlevik et al. (2018) found that girls have a performance advantage over boys in digital skills, the results of Study 1 follow Siddiq & Scherer (2019) in that gender is not a significant predictor of digital media use and

associated digital skills, while the results of Study 3 showed a performance advantage in favor of boys in digital skills.

However, the inconclusive results do not apply to measures of socioeconomic status: numerous studies have revealed that learners' socioeconomic status plays a central role in their digital skills, which is also reflected in research on the digital divide (van Dijk, 2020). Regarding the digital divide, learners from educationally disadvantaged families have less capital available for technical resources at home, which can significantly affect their digital skills, especially in the context of the COVID-19 pandemic (Thorn & Vincent-Lancrin, 2021). However, Study 1 suggests that the COVID-19 pandemic has positively changed adolescents' use of digital media regarding frequency and type of use, which calls for a corresponding refocusing of previous research findings. Nevertheless, the results of Study 3 show that learners' use of digital media for study-related purposes has a negative impact on their digital skills. This result can also be interpreted in terms of the "digital natives" myth (Kirschner & Bruycekere, 2017), according to which learners clearly need guidance from teachers with sound digital skills in the classroom for digital media to have a positive impact on their digital skills.

Furthermore, in relation to digital skills, both socioeconomic status and learners' private environment are important, as to date, there is comparatively little research on learners' private environment and their digital skills (Hatlevik et al., 2015). However, particularly in light of the consideration of the COVID-19 pandemic and the results of Study 1, it is of utmost importance that *how* learners acquire and develop digital skills is investigated in more detail. This type of study would be more beneficial than large-scale studies such as the ICILS studies examining the status quo of learners' digital skills or the relationship between learners' digital skills and other factors. For example, longitudinal

studies could track learners' acquisition of digital skills or educational software and learning environments could be developed to target learners' digital skills.

In conclusion, more research is needed to gain insights into learners' digital skills systematically. This includes research on how digital skills can be promoted as cross-curricular skills through the high-quality use of digital media in student-centered instruction. Furthermore, research is required on how learners develop digital skills in the private environment rather than research that only identifies factors that influence learners' digital skills. With concrete evidence about the environment in which students acquire digital skills, appropriate interventions can be established to promote them in a targeted manner.

5.3 Future research and practical implications regarding teachers' digital skills

Previous work has documented that teachers' professional knowledge is essential for student achievement. For example, some studies (e.g., Kunter et al., 2013) demonstrate that teachers' high subject-related knowledge (e.g., in mathematics) positively impacts students' achievement in that subject. However, these studies have not focused on digital skills, which are an essential component for both teachers and learners. As research on teachers' digital skills is still the younger discipline compared to learners' digital skills, numerous research gaps need to be explored (Scheiter, 2021). These were targeted in Study 2 and Study 3. Study 2 contributes to the research gaps related to measuring teachers' digital skills by examining the extent to which scenario-based assessment approximates the results of objective assessment measures. Due to the complexity of assessment and test taker acceptance, purely objective assessment measures cannot be satisfactorily implemented in some cases. Study 3 further addressed how teachers' digital skills and the proficient use of digital media in the classroom can affect learners' digital skills. As digital skills are integrated into curricula and teacher

training (KMK, 2019a), teachers must demonstrate they are skilled and pass digital skills on to their learners. Several findings that have practical implications for educational research and the school environment emerged from Study 2 and Study 3. In addition, based on the findings of this dissertation, approaches for further research are described below.

Study 2 indicates that scenario-based assessment is appropriate for obtaining the results of objective assessment measures for specific components of digital skills. These results are promising for educational science and practice. Scenario-based self-assessments can provide valid statements about teachers' operational technical skills, such as operating and applying digital media, and determine targeted interventions to promote these skills. This is particularly relevant because the operational use of digital media can be seen as the "foundation" for the other TPACK components (Scherer et al., 2017) and thus for the successful use of digital media in instruction. However, only teachers who can successfully operate and apply digital media can use it in a targeted manner to promote learners' learning processes.

The study results of Study 2 also show that objective measurement of more complex digital skills, such as searching and processing information, cannot be predicted by scenario-based self-assessment. This suggests that satisfactory assessment of more complex digital skills cannot occur using (scenario-based) self-assessment, which is consistent with the view of other researchers in the field (Backfisch et al., 2020). However, more complex digital skills are an essential part of life in a digital society, and teachers should master them to pass them on to their learners. As research on the suitability of scenario-based assessment to approach objective assessment measures is still sparse, further research in this area is needed. Based on the findings of this dissertation, two areas in particular have promising potential. First, extend scenario-based

self-assessment and (to the extent possible) objective assessment measures to other TPACK components such as TPK or TCK to determine whether such assessment is appropriate to approximate the results of objective assessment measures. Second, it would be useful to conduct studies contrasting self-assessment, scenario-based self-assessment, and objective assessment measures to examine how scenario-based self-assessment is better suited to discovering teachers' actual competencies. Overall, knowledge about teachers' digital skills and ways to measure them are limited, so more approaches are required to learn more about their digital skills.

Based on Study 2, Study 3 used objective measures of performance to measure TK and TPK, which are more complex constructs, and accordingly, based on the results of Study 2 of this dissertation, objective assessment measures for more complex skills should be used. The results of Study 3 were not significant for neither TK nor TPK (i.e., professional knowledge about the qualitative use of digital media) with regard to learners' digital skills. The result is surprising since educational policy – at least in theory – specifies that teachers must acquire appropriate digital skills in training and in-service training to successfully use digital media in the classroom to promote learning processes (KMK, 2016; KMK, 2019a). As discussed in Study 3, one possible theoretical explanation is that digital media do not (yet) play a central role in teaching and learning processes and that neither teachers' TK nor TPK plays a role in the acquisition of digital skills.

Similarly, it would be desirable to foster teachers' TK and TPK so that digital media could play a central role in teaching and learning processes, because as "keystone species" (Davis et al., 2013, p.438), teachers are highly relevant to the successful use of digital media in teaching and learning processes. However, as further elaborated in Study 3, scholars (e.g., Kaiser et al., 2017; Depaepae et al., 2020) postulate that teachers'

professional knowledge alone is insufficient to explain differences in student achievement because it is decontextualized (p.179) professional knowledge that does not necessarily relate to actual situational actions in the classroom. Rather, teachers' situational classroom instruction by teachers and affective-motivational facets are additionally required as they influence actual classroom action that affects student achievement. The results of Backfisch et al.'s (2020) study point in a similar direction: according to the authors, teachers' motivational beliefs (such as self-efficacy) play a crucial role in the effective use of digital media in the classroom, which can also be expected to benefit learners' digital skills performance.

With the results from Study 2 and Study 3 of this dissertation, it would be correspondingly promising to investigate other aspects of the TPACK model such as TPK using scenario-based assessment. On the one hand, Study 2 has shown that scenarios are suitable to avoid self-assessment bias to a certain extent. On the other hand, the results of Study 3 suggest that learners' use of digital media may have the potential (although not yet in the desired direction) to be an important component of learners' digital skills. Accordingly, it would be interesting to use scenario-based self-assessment to explore situational classroom actions, such as teachers' TPK, in the future to get a holistic picture of teacher-initiated digital media use in the classroom and learners' related digital skills.

In summary, it can be emphasized that teachers' professional knowledge regarding TK and TPK is highly relevant for the successful use of digital media in the classroom, since teachers must be familiar with digital media and know how to implement their use. However, based on the findings of this dissertation, professional knowledge alone is not enough to have an impact on the digital skills of learners: it is also important that digital media are used in a profitable and learner-centered way in classroom instruction, which could be assessed in the future, for example, by applying scenario-based assessment to

situational classroom situations. Accordingly, it would be helpful with regard to further research and practical implications to specifically empower teachers' TK and TPK, and situational classroom instruction with a focus on initiating promising activities with digital media that positively impact learners' digital skills. One way to promote TK and TPK in the school environment would be to introduce professional learning communities or professional development strategies for teachers. Previous research has demonstrated that these approaches are promising for teachers' professional knowledge and thus, student achievement (Gräsel et al., 2006). For example, materials and strategies could be developed within the teachers' professional learning community to successfully use digital media in the classroom to initiate and facilitate learning processes (Eickelmann & Schulz-Zander, 2008). This could be achieved by examining both teachers' professional knowledge regarding TK and TPK, and situational instructional processes and then repeating Study 3 to obtain a more detailed impression of which factors at the teacher level are crucial for the successful use of digital media. In addition, factors such as digital media equipment or IT support at schools could be investigated as possible determinants of teachers' and learners' digital skills. This would provide insights into what conditions on the teacher level are necessary for digitally supported teaching and learning processes to enable teachers – in line with curriculum requirements – to teach digital skills to their students so that they can successfully participate in a digital society.

5.4 Limitations

Despite the promising results, some limitations must be noted. First, all three study samples included subjects from Bavaria almost exclusively. Accordingly, further studies should examine other German states and international samples to determine whether the results remain consistent. Another limitation was the relatively low response rate among teachers in Study 2 and Study 3 which could be a general reason for the non-

significant results. In addition, further research could investigate the extent to which teachers' digital skills influence their use of digital media in the classroom, which could be related to the non-significant results of Study 3. Furthermore, the non-significant results of Study 3 could be related to the fact that those teachers who have particularly high digital skills are more likely to use them in a teacher-centered way, e.g., for complex illustrations, which could explain why teachers' professional knowledge did not influence learners' digital skills. Future research could accordingly investigate whether certain levels of teachers' digital skills have a differential impact on learners' digital skills.

Regarding the measurement instruments, the TK test in Study 2 was developed for the study. Although the psychometric values were satisfactory, further use of the instrument in other studies is needed to confirm its psychometric quality. The measurement of teachers' TPK in Study 3 was conducted using Lachner et al.'s (2019) test instrument. Although Lachner et al. (2019) suggest a three-dimensional structure for assessing TPK, we analyzed the TPK scale with a one-dimensional structure using item response theory because our study results suggest a corresponding structure (see Study 3) and to cope with possible differences in difficulty levels. Therefore, the results related to TPK must be interpreted with caution.

6. Conclusion

This dissertation examined the digital skills of teachers and learners. Although learners' digital skills have been investigated in many international studies, we demonstrated that the COVID-19 pandemic impacts learners' digital media use, so a refocusing of previous research findings is required. While research on learners' digital skills is already well advanced apart from the findings of the COVID-19 pandemic, comparatively little research has been conducted on teachers' digital skills, although teachers are responsible to foster learners' digital skills due to curricula requirements.

Teachers' digital skills have been assessed insufficiently so far, because in a large body of research self-assessment instruments were used, which can be understood very heterogeneously by participants. Study 2 has contributed to this by investigating how context-specificity in self-assessment can help increase the validity of self-assessment instruments by approximating the results of an objective assessment. Based on the findings of this dissertation, the fledgling discipline of teachers' digital skills research would benefit from learning more about the status quo with scenario-based self-assessment providing a promising alternative to regular self-assessment for less complex digital skills.

Finally, Study 3 examined both teachers' and learners' digital skills. Contrary to expectations, Study 3 showed that teachers' professional knowledge of TK and TPK did not significantly influence learners' digital skills. Nonetheless, the results of this study showed the potential to give greater consideration to student-centred learning activities with digital media in relation to digital skills in the future. Accordingly, student use of digital media in the classroom appears to be a promising starting point for conducting further research on teacher and learner digital skills and equipping learners with the skills they need to participate successfully in the digital society.

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APPENDICES

APPENDIX A – Students Questionnaire on Technology Usage Study 1

Material is available upon request due to restrictions.

Further and detailed information can be found here:

Lohr, A., Sailer, M., Schultz-Pernice, F., Vejvoda, J., Murböck, J., Heitzmann, N., Giap, S., & Fischer, F. (2021). Digitale Bildung an bayerischen Schulen vor und während der Corona-Pandemie. vbw. https://www.vbw-bayern.de/vbw/Themen-und-Services/Bildung/Vorschule-Schule/Publikation-Digitale-Bildung-an-bayerischen-Schulen-vor-und-w%C3%A4hrend-der-Corona-Pandemie.jsp

APPENDIX B – Teacher TK Questionnaire (Study 2)

Material is available upon request due to ongoing studies at the time of printing.

Further and detailed information can be found here:

Kastorff, T., Sailer, M., Vejvoda, J., Schultz-Pernice, F., Hartmann, V., Hertl, A., Berger, S., & Stegmann, K. (2022). Context-specificity to reduce bias in self-assessments: Comparing teachers' scenario-based self-assessment and objective assessment of technological knowledge, *Journal of Research on Technology in Education*. Advance online publication. https://doi.org/10.1080/15391523.2022.2062498

APPENDIX C – Teachers TK scenario-based assessment (Study 2)

Material is available upon request due to restrictions.

Further and detailed information can be found here:

Sailer, M., Stadler, M., Schultz-Pernice, F., Franke, U., Schöffmann, C., Paniotova, V., Husagic, L., & Fischer, F. (2021). Technology-related teaching skills and attitudes: Validation of a scenario-based self-assessment instrument for teachers. *Computers in Human Behavior*, 115(2), 106625. https://doi.org/10.1016/j.chb.2020.106625

APPENDIX D -Teachers TK Questionnaire (Study 3)

Material is available upon request due to restrictions.

Further and detailed information can be found here:

Senkbeil, M., & Ihme, J. M. (2015). NEPS Technical Report for Computer Literacy: Scaling results of Starting Cohort 6–Adults (NEPS Working Paper No. 61). Bamberg: Leibniz Institute for Educational Trajectories, National Educational Panel Study. https://www.neps-data.de/Portals/0/Working%20Papers/WP_LXI.pdf

APPENDIX D -Teachers TPK Questionnaire (Study 3)

Material is available upon request due to restrictions.

Further and detailed information can be found here:

Lachner, A., Backfisch, I., & Stürmer, K. (2019). A test-based approach of modeling and measuring technological pedagogical knowledge. *Computers & Education*, 142(1), 103645. https://doi.org/10.1016/j.compedu.2019.103645

APPENDIX E – Students ICT literacy Questionnaire

Material is available upon request due to restrictions.

Further and detailed information can be found here:

Senkbeil, M., Ihme, J. M., & Wittwer, J. (2013). The Test of Technological and Information Literacy (TILT) in the National Educational Panel Study: Development, empirical testing, and evidence for validity. *Journal for Educational Research Online, 5*, 139–161. https://doi.org/10.25656/01:8428

APPENDIX F Information for Participants Declaration of Consent

F.1 Study 1

Material is available upon request due to restrictions.

Further and detailed information can be found here:

Lohr, A., Sailer, M., Schultz-Pernice, F., Vejvoda, J., Murböck, J., Heitzmann, N., Giap, S., & Fischer, F. (2021). Digitale Bildung an bayerischen Schulen vor und während der Corona-Pandemie. vbw. https://www.vbw-bayern.de/vbw/Themen-und-Services/Bildung/Vorschule-Schule/Publikation-Digitale-Bildung-an-bayerischen-Schulen-vor-und-w%C3%A4hrend-der-Corona-Pandemie.jsp

F.2 Sudy 2

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN | IN.K19+

Sehr geehrte Teilnehmende,

das folgende Selbsteinschätzungsinstrument sowie der medieninformatische Wissenstest wurden im Rahmen der Qualitätsoffensive Lehrerbildung von einer Forschungsgruppe am Lehrstuhl für Empirische Pädagogik und Pädagogische Psychologie der Ludwig-Maximilians-Universität München in einer Kooperation von Forscher*innen und Lehrkräften entwickelt.

Vorgehensweise

Im Folgenden werden Ihnen zunächst ein paar einleitende Fragen gestellt.

Im Anschluss daran beginnt die Selbsteinschätzung: Hier werden Ihnen verschiedene Szenarien und Antwortmöglichkeiten gezeigt, die sich auf diese Szenarien beziehen. Lassen Sie sich bitte nicht davon verwirren, dass manche der Szenarien sich nur geringfügig voneinander zu unterscheiden scheinen: Lesen Sie diese einfach aufmerksam durch und beantworten Sie, soweit möglich, alle gestellten Fragen. Sollten Sie mit einigen der Szenarien nichts anzufangen wissen, denken Sie bitte an möglichst ähnliche Situationen.

Im Anschluss folgt der medieninformatische Wissenstest. Beim medieninformatischen Wissenstest können jeweils 1-4 Antworten richtig sein. Hierfür erhalten Sie im Laufe der Befragung noch weitere Informationen.

Die Bearbeitung des Fragebogens nimmt circa 20 Minuten in Anspruch. Sie können die Befragung jederzeit ohne Angabe von Gründen abbrechen.

Vielen Dank für Ihr Interesse !

Bei Rückfragen wenden Sie sich jederzeit an Tamara Kastorff, M. Ed. (tamara.kastorff@psy.lmu.de)

Das Projekt Lehrerbildung@LMU wird im Rahmen der gemeinsamen „Qualitätsoffensive Lehrerbildung" von Bund und Ländern aus Mitteln des Bundesministeriums für Bildung und Forschung gefördert.

Lehrerbildung@LMU

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

Hinweise zum Datenschutz

Ihre Antworten in dieser Studie werden streng vertraulich behandelt und nur für Forschungszwecke verwendet. Sowohl in der Erfassung wie auch in der Auswertung Ihrer Daten wahren wir Ihre Anonymität.

Wir erheben ausschließlich die Daten, die Sie uns angeben. Es werden keine IP-Adressen gespeichert. Die erhobenen Daten werden SSL-verschlüsselt und in einem BSI-zertifizierten Rechenzentrum sicher verwahrt. Die Daten werden höchstens zehn Jahre lang gespeichert und nach Ablauf der Frist automatisch gelöscht.

Jegliche Informationen, die es ermöglichen könnten, Sie zu identifizieren, werden direkt nach der Erhebung der Daten von Ihren Antworten getrennt. Darüber hinaus sind die Rohdaten vollständig anonymisiert, das heißt Ihre Antworten werden nicht mit personenbezogenen Daten verknüpft, sondern mit einem numerischen Code. Demografische Angaben werden demnach getrennt von Ihren Fragebogen-Antworten gespeichert und gelöscht, sobald sie nicht mehr benötigt werden.
Vor einer Veröffentlichung der Ergebnisse oder im Falle eines Austausches im Rahmen von Open-Science-Prozessen werden die Daten so aufbereitet, dass allein mit den veröffentlichten bzw. ausgetauschten Daten ein Rückschluss auf Ihre Person nicht mehr möglich ist. Entsprechend ist nach der Aufbereitung Ihrer Daten auch keine gezielte Löschung Ihres persönlichen Datensatzes möglich, da wir diesen nicht zuordnen können.

Nur Personen, die mit der Erhebung verbunden sind, haben Zugriff auf die erhobenen Daten.

Auskunft über Ihre Rechte

Gemäß Art. 13 II b der Datenschutzgrundverordnung haben Sie das Recht auf:
Auskunft (Art 15 DSGVO)
Widerspruch (Art. 21 DSGVO)
Datenübertragbarkeit (Art 20 DSGVO)
Löschung (Art 17 DSGVO)
Einschränkung der Verarbeitung (Art 18 DSGVO)
Berichtigung (Art 16 DSGVO)

Ihre Teilnahme ist freiwillig und Sie können den Fragebogen jederzeit ohne Konsequenzen und ohne Angabe von Gründen abbrechen.

Weiterhin haben Sie das Recht, Beschwerde bei der zuständigen Aufsichtsbehörde einzulegen:
Bayerische Landesbeauftragte für den Datenschutz
Prof. Dr. Petri
Postfach 22 12 19, 80502 München 089 212672-0
poststelle@datenschutz-bayern.de

Wenn Sie Fragen zum Selbsteinschätzungsinstrument oder zum Datenschutz haben, wenden Sie sich bitte an die betreuenden Wissenschaftler*innen:

Direkte Kontaktperson:

Tamara Kastorff, M. Ed.

weitere involvierte WissenschaftlerInnen:

Dr. Michael Sailer
Dr. Florian Schultz-Pernice
Johanna Vejvoda, M.A.

Sie haben auch die Möglichkeit, sich an den behördlichen Datenschutzbeauftragten der Ludwig-Maximilians-Universität München zu wenden:
Dr. jur. Rolf Gemmeke
Geschwister-Scholl-Platz 1
D- 80539 München
Tel.: +49 (0) 89 2180 - 2414

Bitte beachten Sie:
Wenn Sie den Internet Explorer benutzen, stehen Ihnen die automatischen Rückmeldungen des Selbsteinschätzungsinstrumentes leider nicht in vollem Umfang zur Verfügung, da der Explorer von Microsoft nicht mehr weiterentwickelt wird und daher bestimmte Funktionen nicht unterstützt. Wir empfehlen in diesem Fall auf einen anderen Browser auszuweichen!

- Einverständniserklärung:

  Ich habe die Hinweise zum Datenschutz gelesen und verstanden und willige in die Speicherung und Verarbeitung meiner Daten ein. Mir ist bewusst, dass meine Teilnahme an der Studie völlig freiwillig ist und dass ich meine Zustimmung / Teilnahme jederzeit ohne Konsequenzen und ohne Angabe von Gründen widerrufen kann.

F.3 Study 3

Einwilligungserklärung zur Teilnahme an der DigitUS-Studie

2. Einwilligungserklärung für

Lehrkräfte

- Bitte an der Schule bei der Schulleitung aufbewahren -

Ich (Name der Lehrkraft in Druckschrift)

---

bin *schriftlich* über die Studie zum *DigitUS*-Projekt und den Versuchsablauf aufgeklärt worden. Ich willige freiwillig in die Erhebung und Verarbeitung meiner personenbezogenen Daten ein. Ich bin ausreichend informiert worden und hatte die Möglichkeit, Fragen zu stellen. Über die Folgen eines Widerrufs der datenschutzrechtlichen Einwilligung bin ich aufgeklärt worden. Die schriftliche Aufklärung und Einwilligung habe ich erhalten. Sofern ich Fragen zu dieser vorgesehenen Studie hatte, wurden sie von der Versuchsleitung vollständig und zu meiner Zufriedenheit beantwortet.

Mit der beschriebenen Erhebung und Verarbeitung der Daten bin ich einverstanden. Die Aufzeichnung und Erhebung der Daten erfolgen im DigitUS-Projekt unter Verwendung eines generierten Tokens ohne Angabe meines Namens. Auf Grundlage meiner persönlichen Angaben wird ein einwegverschlüsselter Token generiert, ohne dass meine persönlichen Daten dabei gespeichert werden. Ich erhalte ein Informationsblatt mit meinem Token, mit dem ich ggf. mein Widerrufsrecht gemäß DSGVO wahrnehmen kann. Meine Daten werden nach den in der Teilnehmerinformation beschrieben Fristen anonymisiert. Damit ist es niemandem mehr möglich, die erhobenen Daten mit meinem Namen in Verbindung zu bringen.

Mein Einverständnis zur Aufbewahrung bzw. Speicherung meiner Daten kann ich jederzeit widerrufen, ohne dass mir daraus Nachteile entstehen. Ich kann jederzeit eine Löschung all meiner Daten verlangen, sofern diese noch nicht anonymisiert wurden.

Ich bin einverstanden, dass meine vollständig anonymisierten Fragebogen- und onlinebasierten Daten zu Forschungszwecken weiterverwendet werden können. Dazu werden sie über eine Internet-Datenbank öffentlich zugänglich gemacht.

Ich hatte genügend Zeit für eine Entscheidung und bin bereit, an der o.g. Studie teilzunehmen. Ich weiß, dass die Teilnahme an der Studie freiwillig ist und ich die Teilnahme jederzeit ohne Angaben von Gründen beenden kann. Dadurch entstehen keinerlei negative Konsequenzen.

Eine Ausfertigung der Teilnehmerinformation über die Untersuchung und eine Ausfertigung der Einwilligungserklärung habe ich erhalten. Die Teilnehmerinformation ist Teil dieser Einwilligungserklärung.

Ort, Datum & Unterschrift Lehrkraft	Name Lehrkraft in Druckschrift
Ort, Datum & Unterschrift Versuchsleitung	Name Versuchsleitung in Druckschrift

Die unterschriebene Einwilligungserklärung geben Sie bitte bei Ihrer Schulleitung zum dortigen Verbleib ab. Nach einem Jahr wird Ihre Einwilligungserklärung von der Schulleitung vernichtet.

F.3.1. Study 3

Einwilligungserklärung zur Teilnahme an der DigitUS-Studie

2. Einwilligungserklärung für

Schüler*innen

- Zum Verbleib an der Schule -

Ich (Name d. Schüler*in in Druckschrift)

---

bin *schriftlich* über die Studie zum *DigitUS*-Projekt und den Versuchsablauf aufgeklärt worden. Ich willige freiwillig in die Erhebung und Verarbeitung meiner personenbezogenen Daten ein. Ich bin ausreichend informiert worden und hatte die Möglichkeit Fragen zu stellen. Über die Folgen eines Widerrufs der datenschutzrechtlichen Einwilligung bin ich aufgeklärt worden. Die schriftliche Aufklärung und Einwilligung habe ich erhalten. Sofern ich Fragen zu dieser vorgesehenen Studie hatte, wurden sie von der Versuchsleitung vollständig und zu meiner Zufriedenheit beantwortet.

Mit der beschriebenen Erhebung und Verarbeitung der Daten bin ich einverstanden. Die Aufzeichnung und Erhebung der Daten erfolgen im DigitUS-Projekt unter Verwendung eines generierten Tokens ohne Angabe meines Namens. Auf Grundlage meiner persönlichen Angaben wird ein einwegverschlüsselter Token generiert, ohne dass meine persönlichen Daten dabei gespeichert werden. Ich erhalte ein Informationsblatt mit meinem Token, mit dem ich ggf. mein Widerrufsrecht gemäß DSGVO wahrnehmen kann. Meine Daten werden nach den in der Teilnehmerinformation beschrieben Fristen anonymisiert. Damit ist es niemandem mehr möglich, die erhobenen Daten mit meinem Namen in Verbindung zu bringen.

Mein Einverständnis zur Aufbewahrung bzw. Speicherung meiner Daten kann ich jederzeit widerrufen, ohne dass mir daraus Nachteile entstehen. Ich kann jederzeit eine Löschung all meiner Daten verlangen, sofern diese noch nicht anonymisiert wurden.
Ich bin einverstanden, dass meine vollständig anonymisierten Fragebogendaten zu Forschungszwecken weiterverwendet werden können. Dazu werden sie über eine Internet-Datenbank öffentlich zugänglich gemacht.

Ich hatte genügend Zeit für eine Entscheidung und bin bereit, an der o.g. Studie teilzunehmen. Ich weiß, dass die Teilnahme an der Studie freiwillig ist und ich die Teilnahme jederzeit ohne Angaben von Gründen beenden kann. Dadurch entstehen keinerlei negative Konsequenzen.

Eine Ausfertigung der Teilnehmerinformation über die Untersuchung und eine Ausfertigung der Einwilligungserklärung habe ich erhalten. Die Teilnehmerinformation ist Teil dieser Einwilligungserklärung.

Ort, Datum & Unterschrift Schüler*in	Name Schüler*in in Druckschrift
Ort, Datum & Unterschrift Versuchsleitung	Name Versuchsleitung in Druckschrift

Die unterschriebene Einwilligungserklärung wird von der Schule zum dortigen Verbleib eingesammelt. Nach einem Jahr wird Ihre Einwilligungserklärung von der Schulleitung vernichtet.