# A typology of adolescents' technology use before and during the COVID-19 pandemic: A latent profile analysis

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## 1. Introduction

With the ongoing digitization of society and education, adolescents' technology use is attracting much interest in educational research (e.g., Bundsgaard & Gerick 2017; Davis & Eynon, 2013; Hu et al., 2018; Petko et al., 2017). Educational research interest is based on the fact that purposeful use of technology (e.g., for study-related purposes) is positively related to adolescents' academic achievement (Juuti et al., 2022; Senkbeil, 2017). However, with the onset of the COVID-19 pandemic, schools were physically closed and global curfews were imposed. As a result, adolescents had to rely solely on technology such as devices, software, and the Internet to maintain their social lives and education (Eghtesadi, 2020; Goh & Sandars, 2020), which may have permanently changed the way adolescents use technology. Previous research has already shown that there are different types of technology users (e.g., Brandzaeg 2010, Senkbeil 2017). In addition, findings showed that adolescents socioeconomic status plays a role in technology use. Accordingly, adolescents from families with a high socioeconomic status are more likely to use technologies for sophisticated study-related purposes, while adolescents with a lower socioeconomic status are more likely to use technologies for less sophisticated purposes such as social communication (Senkbeil, 2017), which may also be related to the availability of technologies in the household (OECD, 2019).

Consequently, the COVID-19 pandemic may particularly place adolescents from educationally disadvantaged families in an unfavourable position to keep up with digitization, which has been accelerated by the COVID-19 pandemic (Thorn & Vincent-Lancrin,

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2021), as adolescents whose parents have lower levels of education may not be able to participate in online courses during physical school closures due to a lack of financial resources and thus technological equipment at home (Van Lancker & Zachary, 2020). The sample of the studies presented in this article are adolescents from Bavaria, a region of Germany. The state of Bavaria, one of the 16 German states, consists of both rural and urban areas. Bavaria is already well advanced in terms of digitization in schools, with digital learning initiatives and basic technical equipment in schools (Sailer et al., 2021). In Bavaria, as in many other German states, a state of emergency was declared in spring 2020 and all schools were closed. After this initial phase of school closures, certain cohorts of school types, particularly graduating classes, transitioned to a "mixed school mode" at the end of the spring, and additional groups of students gradually returned to schools beginning in the summer of 2020 (Lohr et al., 2021).

To shed light on the impact of the COVID-19 pandemic on adolescent technology use, this study used Latent Profile Analysis (LPA) to examine the extent to which technology use changed before and during the COVID-19 pandemic, based on two studies for Bavaria, a region of Germany. Second, personal factors such as adolescents' gender and their parents' education were associated with profiles based on adolescents' technology use. The results of this study expand the international field of research on the typology of adolescents' technology use and provide evidence of the impact of the COVID-19 pandemic on the typology of adolescents' technology use.

### *1.1. Typology of adolescents' technology use*

How adolescents use technology has been studied for several years (e.g., Bakardjieva, 2005) and has recently attracted considerable research interest given the ongoing digitization of schools and society (Fraillon et al., 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 regarding adolescents' technology use. 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 diverse 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 diversity 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 the Standing Conference of the Ministers of Education and Cultural Affairs (conference of federal ministers (KMK), 2016), the *Advanced Users* and *Instrumental Users user types* would be considered user types with strong digital skills because they use technology in multiple ways, 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.

### *1.2. Personal factors in relation to adolescents' technology use*

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 et al., 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 et al., 2021).

### *1.3. 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 (Frallion 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 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 et al., 2021, Beaunoyer et al., 2020, Thorn & Vincent-Lancrin, 2021).

In summary, the COVID-19 pandemic had a major impact on education and adolescents' use of technology was an indispensable part of sustaining the education system during the physical school closures in many countries in 2020. Consequently, it may be plausible that adolescents were encouraged to use technology for study-related and instrumental purposes during the 2020 school closures due to the COVID-19 pandemic. According to common competency models (e.g., KMK, 2016, Krumsvik, 2011), such study-related and instrumental technology use is beneficial for adolescents' digital skills. In contrast, however, less privileged adolescents may have been particularly at risk of falling behind in school due to the COVID-19 pandemic because, for example, low-education parents were unable to support remote teaching and learning or raise the financial capital necessary to provide the appropriate type of technology at home. In summary, it is useful to ask to what extent adolescents' technology use changed during the COVID-19 pandemic and the 2020 physical school closures, and to what extent adolescents' personal factors played a role in determining their technology use during the COVID-19 pandemic. The current study therefore aimed to gain further valuable insights into the extent to which the COVID-19 pandemic influenced teaching and learning processes in order to develop appropriate, targeted interventions.

### *1.4. Research questions*

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 (Study 1) 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 et al., 2017; Kim et al., 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 differed adolescent technology use before the COVID-19 pandemic in 2019 and physical school closures caused by the COVID-19 pandemic in 2020 (Study 1 & 2)?

RQ 2. 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 3. 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 4. 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 5. 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)?

## 2. Materials and method

### 2.1. Sample and research design

In two cross-sectional studies, we examined two independent samples of Bavarian adolescents (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% identified themselves female ($n = 343$), none of the subjects identified themselves as divers. 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 German 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% identified themselves as female ($n = 353$). None of the subjects identified themselves as divers. 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

### 2.2. 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., 2021). Subjects were randomly selected and stratified by district and school type based on available official statistical data. 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, and indicated themselves as female, male or divers and the type of school they attend. The interview concluded with questions about the interviewee's technology use, (e.g., "how often do you use Technology to collaborate with others?" see also Table 1, for full version of the instrument see [Blinded FOR REVIEW]). 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. Subjects were informed that they could end the interview at any time without negative consequences. The interviews were conducted by GMS Dr. Jung GmbH.

### 2.3. Measurement of variables

#### 2.3.1. Adolescents' technology use

Adolescents' technology use was assessed with six self-estimation items following the suggestions made by KMK (2016; see also Sailer et al., 2021 for more information). The self-estimation items referred to how often adolescents use technologies, such as computers, software, and the Internet, at home and during leisure time. 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).

**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 | .60 | 2.00 | 4.00 | 3.70 | .68 | 1.00 | 4.00 |
| Research via technology | 3.45 | .79 | 1.00 | 4.00 | 3.20 | 1.14 | 0.00 | 4.00 |
| Communication via technology | 3.84 | .44 | 2.00 | 4.00 | 3.79 | .47 | 1.00 | 4.00 |
| Collaboration via technology | 3.03 | .07 | 1.00 | 4.00 | 3.44 | .81 | 0.00 | 4.00 |
| Production of content via technology | 1.89 | .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 |

#### 2.3.2. 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 et al., 2019). Further, students were asked about their *gender* and the *type of school* they were attending.

### 2.4. 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 et al., 2018). We identified the optimal number of profiles using the following 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 et al., 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 et al., 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).

## 3. Results

### 3.1. RQ1: comparing adolescents' technology use before (Study 1) and during the COVID-19 pandemic (Study 2)

Table 1 shows the overall mean to what extent adolescents technology use for different purpose (e.g., research via technology) before they are classified into latent profiles. To examine the extent to which adolescent technology use differs before (Study 1) and during (Study 2) the COVID-19 pandemic, multivariate analysis of variance (MANOVA) was conducted to compare the responses of participants in Study 1 and Study 2 (see Table 1 for mean values). There was a significant effect of belonging either in Study 1 (prior to the COVID-19 Pandemic) or in Study 2 (during the COVID-19 Pandemic) on adolescents technology use $F(6, 1050) = 77.00$, $p < 0.001$). Furthermore, separate univariate analysis of variance (ANOVA) on adolescents technology use revealed that adolescents used technology statistically more often during the COVID-19 pandemic for research via technology $F(1,1237) = 37.54$, $p < 0.001$, Collaboration via technology $F(1,1230) = 64.47$, $p < 0.001$, Produce content via technology $F(1,1231) = 72.27$, $p < 0.001$, and study-related purposes $F(1,1247) = 40.1$, $p < 0.001$. However, results revealed that adolescents in Study 2 (during the COVID-19 Pandemic) did not use technology statistically generally more often $F(1,1249) = 0.43$, $p = .51$ for communication via technology $F(1,1240) = 2.97$, $p = .08$.

### 3.2. RQ2: Profiles identified before to the COVID-19 pandemic (Study 1)

To answer RQ 2, 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 Fig. 1. Descriptive statistics for the latent profiles identified in Study 1 are summarized in Table 3.

*Profile 1 – socializers*

The adolescents in Profile 1 *Socializers* ($n = 110$) stated that they used technology mostly for *communication via technology* ($M =$

**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.

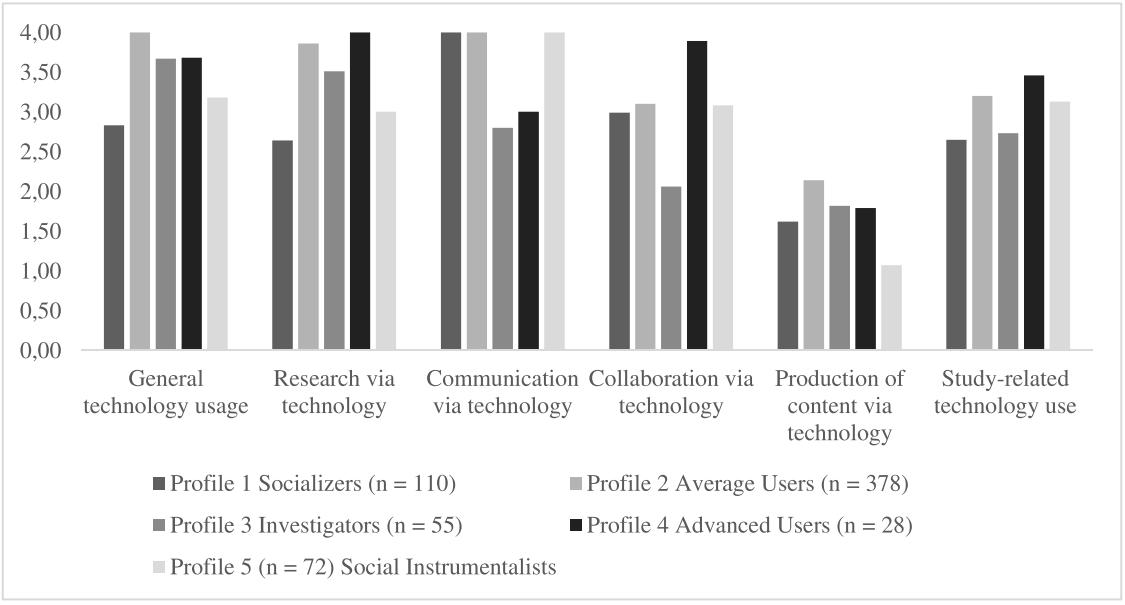


**Fig. 1.** Five-profile Solution for Adolescents' Technology use Prior the COVID-19 Pandemic. *Note.* Mean scores for adolescents' technology use before the COVID-19 pandemic ranged from 0 (*never*) to 4 (*very often*).

**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 |

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.

### 3.3. RQ3: personal factors in relation to the profiles identified prior to the COVID-19 pandemic (Study 1)

To address RQ 3, 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.

### 3.4. RQ 4: profiles identified during to the COVID-19 pandemic (Study 2)

To address RQ 4, 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. Fig. 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.

*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

**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.

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

**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.

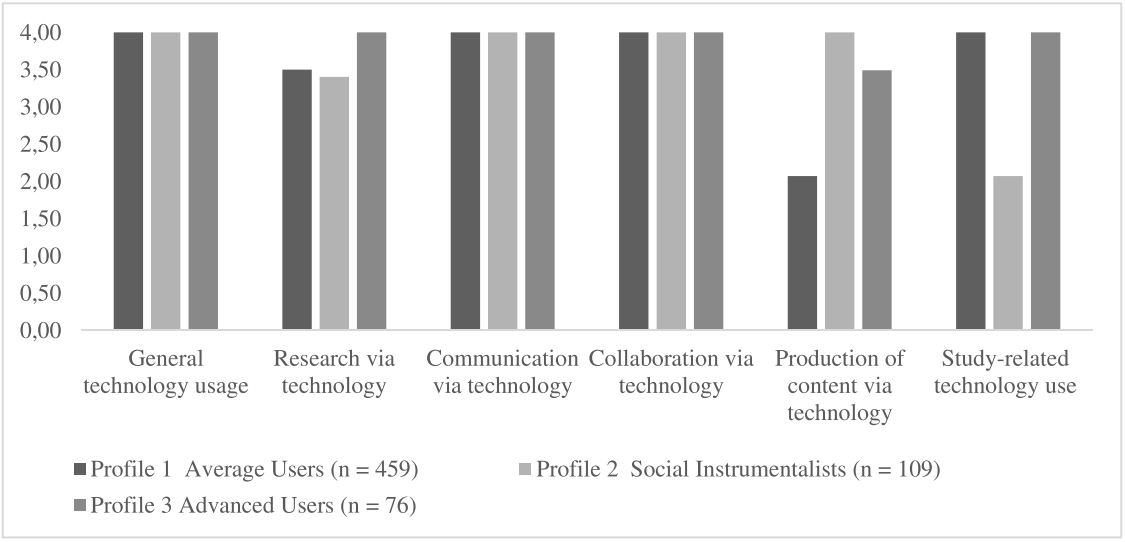


**Fig. 2.** Three-profile Solution for Adolescents' Technology during the COVID-19 Pandemic. *Note.* Mean scores for adolescents' technology use before the COVID-19 pandemic ranged from 0 (*never*) to 4 (*very often*).

**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 |

technology $M = 4.00$). Accordingly, the adolescents in Profile 1 were classified as *Average Users*.

*Profile 2 – social instrumentalists*

Adolescents in Profile 2 (n = 109) 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 (n = 76) 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.*

### *3.5. RQ5: personal factors in relation to the profiles identified during the COVID-19 pandemic (Study 2)*

To address RQ 5, 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.

## 4. Discussion

In this paper, we used latent profile analysis to examine adolescents' technology use in two independent samples of Bavarian adolescents (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).

### *4.1. Profiles of adolescents' technology use before and during the COVID-19 pandemic*

RQ1 showed that adolescent technology use increased significantly during the COVID-19 pandemic in terms of frequency for almost all types of use. Accordingly, it was worthwhile to further analyze adolescents' patterns of response to technology use before and during the COVID-19 pandemic to more accurately determine how technology use changed in order to draw conclusions about adolescents' digital skills. With respect to RQ2, 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* or Profile 1 *Socializers*. Fewer adolescents were present in the profiles characterized as *Social Instrumentalists, Investigators*, or *Advanced Users*. The identified profiles show diversity 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. By contrast, adolescents in the *Investigators* and *Advanced Users* profiles reported using technology less for social communication, but primarily for instrumental purposes, such as *research via technology*. Accordingly, the results are in line with previous research as adolescents are divergent 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

**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 parents educational level as predictor.

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 Social Instrumentalists*, and *Advanced Users*. Thus, two of the profiles from Study 1 (i.e., *Investigators* and *Socializers*) could no longer be identified in Study 2. However, although the identified profiles were similar to Study 1, the responses differed differed in terms of mean scores: For example, adolescents in the *Average Users* profile in Study 2 had higher 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, 2018). The increase in the use of technology for instrumental purposes suggests that adolescents' overall digital skills increased during the COVID-19 pandemic, which is important for adolescents to successfully participate in society and later professional life (Fraillon et al., 2020).

### *4.2. 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 & Meinck, 2016; Senkbeil, 2017). For example, authors have shown that male adolescents are more likely to use technology for social communication (Alkan & Meinck, 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 et al., 2021). Interestingly, the result could not be replicated during the COVID-19 pandemic in Study 2: school type was no longer a significant predictor. While research on the COVID-19 pandemic is still pending, the results can be interpreted to mean that all adolescents from all school types were equally affected by the COVID-19 pandemic and had to rely on technology, which minimized differences in technology use based on school type. However, the result must be interpreted cautiously as no causality can be assumed.

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 et al., 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, 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). Political developments also need to be taken into account, such as the fact that funding was available in Germany at the time through the so called *Digitalpakt Schule* (KMK, 2021) to support technical equipment in schools, which adolescents may have been able to borrow from home during school closures. However, further research is needed on the exact impact of the COVID-19 pandemic on adolescents' technology use, especially given that parental education levels continue to play a key role in adolescents' technology use.

However, 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.

### 4.3. 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 randomly selected 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 et al. 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 randomly selected 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 et al. 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.

The present paper included two randomly selected samples for Bavaria, both before and during the COVID-19 pandemic. Although this study only sampled adolescents Bavarian adolescents, it is reasonable to assume that the results of this study can be generalized to countries that are similarly positioned to Germany in terms of their economies and the digital divide and prerequisites within schools (for an overview, see Cruz-Jesus et al. 2016). Germany is also close to the OECD average in technology use according to the recent ICILS study (Fraillon et al., 2020), suggesting that the study of German adolescents' technology use is also applicable internationally, although limitations must of course be taken into account. Further the COVID-19 pandemic affected multiple countries to a similar extent between March and September 2020 (Bormann et al., 2021), which also supports the generalizability especially regarding the results of the second study (during the COVID-19 pandemic).

Accordingly, many countries have declared a state of emergency and physically closed schools, prompting many adolescents in many countries to turn to technology to participate in social and learning processes. However, it is of interest that the global pandemic from March to September 2020 was a state of emergency. Whether our findings regarding adolescent technology are valid after the COVID-19 pandemic will need to be clarified in further studies.

### 4.4. 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 divergent 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 et al. 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. We suggest that it would be useful to collect data with the same instruments as used in this study at a later stage to determine whether the change in adolescents' technology use has continued and whether previous findings need to be revised based on this change.

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## CRediT authorship contribution statement

**Tamara Kastorff:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Michael Sailer:** Funding acquisition, Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Supervision. **Karsten Stegmann:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Supervision.

## Declaration of Competing Interest

None.

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