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How to Cluster Students Based on Their Digital Competence for Learning?

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Abstract: Finding the most relevant and effective teaching and learning methods is one of the core challenges in education. As the educational community is valuing personalized learning, student clustering for better outcomes is relevant. Therefore, the aim of the current study is to identify student clusters according to their level of digital competence for learning. 268 students (grades 3–8) from four schools in Estonia participated in the study and completed a test for assessing their digital competence for learning in ten dimensions. Four student clusters were identified using hierarchical cluster analysis: programmers, creators, casual users and beginners. The clusters were determined mainly by operational and programming skills. As all the students had rather positive attitudes towards using digital devices for learning, the levels of skills and knowledge ranged from very low to high. The results might be useful in designing long-term studies for monitoring the development of digital competence for learning throughout primary and lower secondary school. Furthermore, it is evidently clear from the findings that students do need tailored support in order to improve their digital competence for learning.

Keywords: digital competence for learning, cluster analysis, primary education, secondary education

1. Introduction

The importance of using digital devices, environments and materials in learning cannot be overrated. As the society moves towards digitalization, being an active member of it means having skills and knowledge to use digital devices. Therefore, schools have an important responsibility of making sure that children are ready to face the challenges of our more-and-more digital world. Furthermore, due to the COVID-19 outbreak, which started in 2020, students' ability to use digital devices for learning is now more relevant than ever. As we demanded more from our students than mere information seeking and document writing, students' skills were really put to test. Many students found the lockdown challenging due to their low level of digital skills (Carretero Gómez, 2021). Moreover, extra attention had to be paid to following the rules and communicating in the digital classroom. At the same time, as students were alone with their devices, they needed more knowledge regarding how to protect themselves in the digital world.

The digital skills needed for being an active society member are described in the Digital Competence Framework for Citizens (Vuorikari, Kluzer & Punie, 2022), which is describing five competence areas: information and data literacy, communication and collaboration, digital content creation, safety and problem solving. Digital competence itself is a set of knowledge, skills and attitudes that are required when using information and communication technology to perform tasks (Ferrari, 2012). Since the DigComp framework is describing the competence for citizens, it is a reasonable guideline for schools, because the role of schools is to help children to become active citizens.

Based on the DigComp framework, Estonian data from the EU Kids Online study and the Estonian Digital Competence test results, Pedaste, Kalmus and Vainonen (2021) defined the dimensions of the digital competence for learning, which serves as the basis for the digital competence assessment test created and validated by Kallas and Pedaste (2022). However, while we now could obtain the knowledge of students' skill level on different skills, attitudes and knowledge related to the digital competence for learning, clear guidelines on how to teach children based on this knowledge still remain a necessity for practitioners. As in education we steer towards teaching students as individuals (person-oriented approach, where individuals are seen as an organized whole; Bergman & Lundh, 2015), it would be ideal to personalize learning paths for each learner. However, as education often suffers from teacher-student ratios which are far from optimal and teaching each student completely separately is nearly impossible in practice, classifying students based on their abilities could be the solution for more personalized learning. Classifying students' profiles through clustering gives us information about how the student groups are formed in light of the digital competence for learning and therefore provides practitioners with the option of also creating interventions for further digital competence development. Therefore, the goal of the current study is to determine the students' profiles based on their digital competence for learning.

2. Previous research on student profiling

It has previously been observed that students do differ according to their abilities and clustering is helpful in determining various student groups based on their traits. As the use of technology in schools and among young people in general is widespread, there are attempts to cluster them according to the use of technology in general and also more specifically in learning. Van den Beemt, Akkerman and Simons (2011) were looking into young people's (aged 10–23) media activities with the goal of obtaining valuable information about using media in learning. As a result, they proposed distinguishing four student profiles according to their type and frequency of media usage: *traditionalists*, *gamers*, *networkers* and *producers*. Pedaste and colleagues (2017) were clustering students who were using mobile devices for the purposes of learning science and mathematics. The authors concluded that five general groups and eleven subgroups could be distinguished according to the nature of their use of mobile devices. The two main clusters were *users* (further categorized as *digital natives* (use technology for different activities in learning), *communicating information students* (use social media in learning more than others), *information students* (share actively links to materials relevant in learning), *creation students* (often develop and adapt learning materials)) and *non-users*. Scherer, Rohatgi and Hatlevik (2017) analyzed the Norwegian ICILS 2013 dataset and found evidence of two profiles that described students' use of information and communication technologies (ICT) at school and outside of it. The profiles differed on the extent to which the students used ICT outside of school and for leisure-related activities – less consistent users with low frequency and advanced users, whose frequency and variety of ICT use was high.

These studies illustrate that attempts have been made to find connections between students' technology usage and skills, and behind it is a need for proposing more effective learning and teaching strategies. However, previous studies also indicate the need for more research in the area, as there is still a lack of knowledge regarding what kind of support students need for improving their digital competence for learning. In addition, this need might have significantly changed during the COVID-19 pandemic, which initiated rapid developments in education for using digital technologies.

3. Methods

3.1 Data collection

The data were collected in September 2021 with the digital competence assessment test called Digitest, which can be used to measure primary (from grade three) and lower secondary school children's digital competence in ten dimensions. The test (see https://survey.ut.ee/index.php/697392?lang=en) has been validated in Estonia by Kallas and Pedaste (2022). The ten dimensions of digital competence are assessed with 37 test items: social aspects (value of peers' use of digital tools; motivation to do what others expect; perception of others' support when using digital tools; 2 items), perceived control (students could decide whether to use digital devices; believing in one's own ability to use digital devices; 5 items), behavioral attitudes (anxiety towards using digital tools; belief in the value and simplicity of digital tools; 5 items), behavioral intention (students prefer digital devices or environments to other ways of doing things; 3 items), creation of digital materials/content (knowledge and skills required to create digital texts or visual materials; 4 items), programming digital content (knowledge and skills required for programming; 3 items), communicating in the digital world (knowledge and skills required for secure online communication in the digital world; 3 items), performing operations with digital tools (technical knowledge and skills acquired by using digital devices to solve problems; 4 items), protecting themselves and others in the digital world (the respondent's ability to protect themselves and others from the threats in the digital world; 4 items) and following the rules in the digital world (the law-abiding nature of the respondent in the digital world; 4 items). The test was assessing skills and knowledge with different types of multiple-choice and open-ended questions. In the case of some tasks students had to perform practical assignments. Students' attitudes were assessed with statements on a six-point Likert type agreement scale.

The test was completed in an electronic environment where there was no option of moving back to the previous question. However, it was possible to skip questions which respondents perceived to be too difficult. There was no time limit for completing the test, but as the test was taken during the students' regular classes, the length of the lesson (45 minutes) was usually taken as a time frame for completion. The average time of completing the test was 46 minutes (SD = 11.8, range from 13 to 77). Taking the test was voluntary, students did not get a grade or any other benefit. The schools got feedback about their students' digital competence at class level.

3.2 Participants

The test was completed by 426 students from four Estonian schools. The age of the students was 9–15 (16 students from the 3rd grade, 112 from the 4th grade, 56 from the 5th grade, 87 from the 6th grade and 155 from the 8th grade). Of the students, 224 were males and 202 were females. As the items about attitudes towards digital devices and environments for learning were at the end of the test, the data about attitudes was incomplete. In order to have a more trustworthy analysis of student clusters, the students with missing data about attitudes were removed from the analysis. The final sample consisted of 268 students (137 males and 131 females).

3.3 Data analysis

In order to determine which student clusters could be distinguished based on their level of digital competence, hierarchical cluster analysis was carried out using the Ward method. A dendrogram was created for selecting a meaningful number of clusters. Cluster membership was saved and ANOVA analysis was used to find the differences between the clusters. Eta squared was calculated for determining the most weighty dimensions of each cluster.

4. Results

From hierarchical cluster analysis, four meaningful student clusters concerning digital competence for learning could be established (Figure 1). All the students have positive or average attitudes towards using digital devices and environments for learning. The skills and knowledge give a more varied picture, as high-, medium- and low-performing students could be distinguished between. The differences between the clusters are mainly in the dimensions of skills and knowledge (Table 1). All the differences are significant, except for the attitude dimension of social acceptance. Students' membership in the cluster is determined mainly by the level of their operational and programming skills.

High-performing and highly motivated students are profiled as *programmers*. The programmers have higher skills and knowledge levels in all the dimensions. What distinguishes them from all the other students is mainly their knowledge and skills in the programming. The second cluster is called *creators*. Creators exhibit high knowledge of creating digital materials and, at the same time, above-average operational and communication skills. Both programmers and creators have more positive attitudes than the rest of the students. The third cluster is labelled *casual users*, who have a low level of operational skills but an average level of knowledge and skills of creating materials and communication in the digital world. Casual users exhibit an average level of attitudes towards using digital devices in learning. The fourth cluster is called *beginners* due to their low level of operational skills and weaker performance in all the other dimensions describing skills and knowledge. Beginners have an average attitude level.

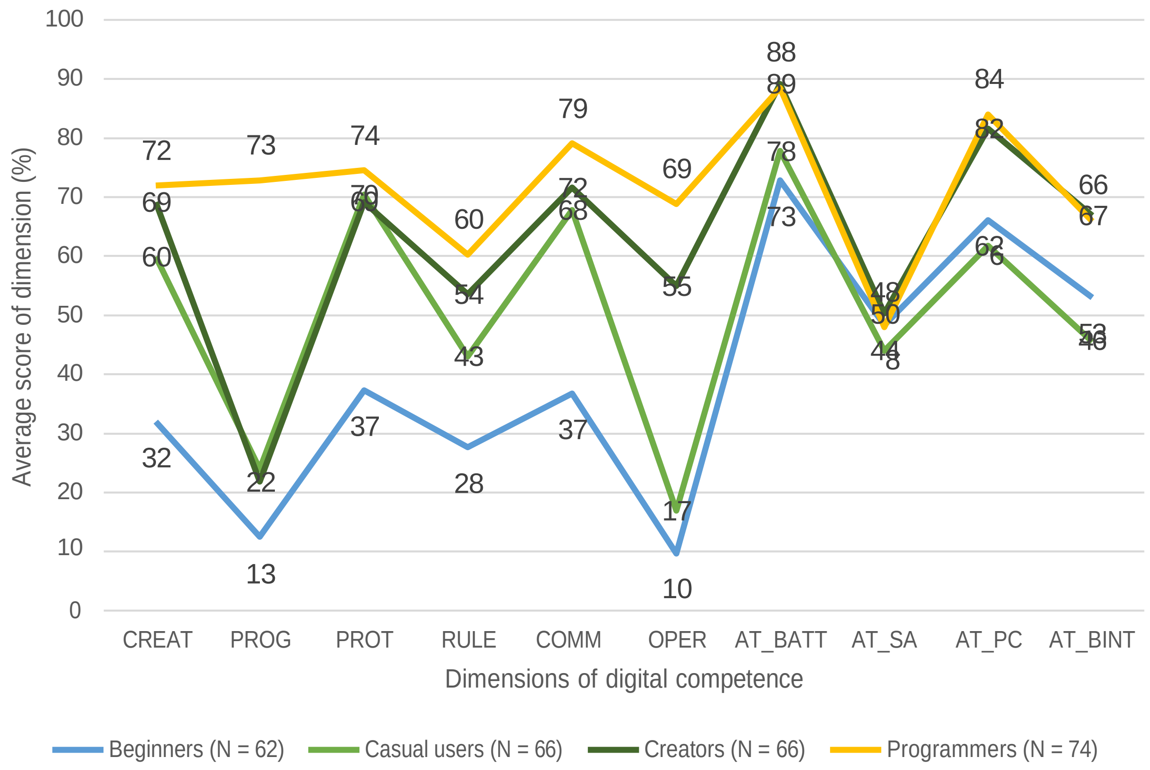

Figure 1. Student clusters based on their level of digital competence (CREAT – creating digital materials, PROG – programming digital content, PROT – protecting oneself and others in the digital world, RULE – following the rules in the digital world, COMM – communicating in the digital world, OPER – performing operations with digital tools, AT_BATT – behavioral attitudes, AT_PC – perceived control, AT_SA – social aspects, AT_BINT – behavioral intention)

Table 1. *ANOVA results comparing the dimensions of digital competence for learning across identified clusters and their importance in defining the student clusters*

Dimension of digital competence for learning	F	p	ε^2
CREAT	73.187	<.01	0.454
PROG	155.649	<.01	0.639
PROT	63.767	<.01	0.420
RULE	51.838	<.01	0.371
COMM	69.511	<.01	0.441
OPER	177.550	<.01	0.669
AT_BATT	14.870	<.01	0.145
AT_SA	0.973	>.05	0.011
AT_PC	26.288	<.01	0.230
AT_BINT	19.261	<.01	0.180

5. Discussion

This study aimed to identify user profiles, i.e. clusters of students based on their digital competence for learning. Four clusters were identified using hierarchical cluster analysis: programmers, creators, casual users and beginners. The programmers exhibit high scores in all the dimensions of digital competence, meaning that they have a sound set of skills for learning with digital devices in different learning environments. The biggest difference between programmers and creators lies in their programming skills. Casual users have mostly average scores in the dimensions of digital competence. What sets them apart from creators is their low level of operational skills and slightly lower level of attitudes. Casual users have the knowledge of creating materials, protecting their and other people's creative work and following the rules in the digital world, but shortcomings in operational skills may inhibit them from learning as efficiently as they could. The lowest-performing students can be labelled beginners. They have moderate attitudes towards using digital devices and environments for learning; however, they seem to have less skills and knowledge to actually perform well.

Our findings bear some similarities with the previous studies. Scherer et al. (2017) observed two very distinguishable clusters of advanced ICT users and beginners, and these clusters are evident in the current study as well. Scherer et al. (2017) suggested the clustering according to frequency of technology use, which could also be a factor in this study. However, our study sheds a bit more light on the qualitative differences in the clusters. Similar to Pedaste et al. (2017), we also found more clusters which slightly differ from one another by distinctive factors. However, Pedaste's study was conducted in a narrower context of using only mobile devices for learning science and mathematics.

Approximately a quarter of the respondents (27%) in the current study belong to the programmers' cluster. These findings are somewhat surprising given the fact that other research shows that the number of students who have a well-developed set of digital skills is usually lower. In a study by Van den Beemt et al. (2010), the *creator* cluster representatives had more skills than others and only 6% of all the participants belonged to this group. Pedaste et al. (2017) also determined that only 5% of students in their study belonged to the *net generation* (also called *digital natives*) group. These somewhat different results compared to study by Pedaste and others (2017) could be explained by the latter study's higher number of clusters, which could mean that the *net generation* cluster only includes the highest-achieving students. Van den Beemt and colleagues (2010) were looking more into media production, which is a somewhat narrower skill than creating digital materials and different from programming, which could be the reason why the percentages of highest-achievers are not comparable. However, the changes might also be explained by the effect of the COVID-19 pandemic. For example, Rannastu-Avalos and Siiman (2020) indicated in their study conducted just five weeks into the pandemic that one of the teachers' challenges was establishing cognitive, social and teaching presence with young teenagers. Now, more than two years later the teachers might have found ways to support that and it might have had an effect on the learners. This explanation is also supported by Lepp, Aaviku, Leijen, Pedaste and Saks (2021), who found that during the COVID-19 pandemic teachers started to focus more on maintaining students' social interaction and supporting student motivation, valuing learners' well-being, socialization and motivation over subject matter competences. Digital competence might also have been viewed as one of the general competences, receiving more attention in the new situation. The study by Gerard, Wiley, Debarger, Bichler, Bradford and Linn (2021) even demonstrated how teachers had developed several strategies to support students' self-regulated learning in online settings in the context of the COVID-19 pandemic. Therefore, it is expected that students' digital competence has improved more than before the pandemic-related school closures when distance education was applied at a very limited level.

The current study brought forward differences between the student clusters, which could help us to create specifically tailored learning paths and interventions to enhance children's digital competence for learning. For example, programmers could benefit from more complex learning tasks, as their skills and knowledge related to the digital competence for learning are on a higher level. Creators could be further supported in completing more complex operational tasks, and they could benefit from tasks designed for learning programming as a way to create content. Casual users would profit from further support in improving their operational skills for learning, as they struggled with tasks which are quite basic for learning. Like creators, casual users would also benefit from knowing the basic programming concepts. Furthermore, as casual users have the lowest overall attitude scores, teacher initiatives for improving their attitudes towards digital devices for learning may prove beneficial. Beginners could be supported in becoming programmers, as the programmers have the best overall results in the test. Therefore, beginners would profit from learning more technical skills (operational and programming), since these are the areas they are evidently struggling in.

With regard to the research methods, some limitations of the study need to be acknowledged. As the study was based on a limited number of respondents only in Estonia, the number of identified clusters may either increase or decrease with a larger international sample. Furthermore, as there was an open call to participate in the study, which took place in a time where COVID-19 had an impact on the functioning of schools, only the most motivated and digitally active schools might have responded and therefore, the picture of the clusters might be somewhat distorted. In conclusion, this study could be repeated with a larger sample both in Estonia and internationally in order to get more accurate results.

6. Conclusions

This study showed that different student profiles, i.e. clusters determined by their level of digital competence exist, thus pointing out the need for personalizing learning with digital devices and environments. Moreover, although young people are considered to be more digitally competent, we still need to teach them the digital skills for learning purposefully, as the clusters show that there are significant differences in the levels of some skills. The findings of the current study point to the need for further research on how to support different student clusters in order for them to have higher-level digital competences for learning; also, the findings could provide a basis for understanding student learning throughout primary and lower secondary school. We also believe that having the knowledge of different student clusters based on their skill levels offers the teachers more information about designing their learning paths, and, for researchers, it is a great basis for intervention development.

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