Technology-Enhanced Learning: Correlates of Acceptance of Assistive Technology in Collaborative Working Setting

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Abstract. Considering stagnant interest in science, technology, engineering and math (STEM), on the one side, and an increasing dropout rates in computer science at different levels of the university education due to difficult and complex learning contents, on the other side, appropriate technology solutions which support learners are very promising. In this study we examine a digital learning assistant in the form of tangible objects interacting with a multi-touch tabletop. This learning tool is meant to support students in the way they learn complex material. In an experimental setting, participants working in groups had the task to acquire novel learning content (i.e., regular expressions) and, using the assistive technology, to assign the correct expressions to their predefined terms. Results revealed that the users' psychological factors and performance factors which result from the interaction with the learning tool are significantly connected with the correlates of acceptance and affect, therefore, the later adoption of such technology. The positive overall assessments show a high attachment for, and willingness to, use such technology. However, user diversity has to be considered in the design and further development. Knowledge gained discloses expedient hints for technology-enhanced learning that can support and accompany the education at different levels, i.e., in schools, vocational training, and university education.

Keywords: Tangible user interfaces · Learning assisting technology · Technology acceptance · User diversity

1 Introduction

In recent years, due to the ongoing digitalization, learning and working environments have decisively changed [1]. The majority of knowledge-based, professional fields increasingly use digital tools and processes, requiring more and more basic computer science skills. This represents a high demand for professional computer scientists. In

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addition, education in the fields of science, technology, engineering and mathematics (STEM) are facing crucial challenges resulting from a ubiquitous use of, and need for, different kinds of technology.

Instead, reality unfortunately does not look very promising in this respect. Especially among the undergraduate computer science students, the university education is tremendously afflicted with high dropout rates [2]. But also, high numbers of graduates who are willing to enter STEM courses of study leave these fields or changes to non-STEM fields, leading to high attrition rates as well [3]. The complex and frequently very abstract subject matter of these study programs is difficult for learners to grasp. Accordingly, students often perceive the study programs as being too complicated to comprehend [4].

In this study we present a digital learning assistant – a learning tool that is meant to support students in the way they learn complex material – and examine its acceptance in association with different user factors.

1.1 Related Work

The Role of Technology in Education. Since the beginning of the 20th century, the introduction of technological assistance for teaching has been promoted and propagated but has also been discussed intensively. The desire to use new technologies to compensate for the weaknesses of the education system has not yet been fulfilled by any technology alone. The weaknesses of the education system worldwide are the average from teacher to pupil, the lack of promotion of individual learning speed, and the low influence on the motivation and attention of the pupils. The most important goal is the associated increase in general learning success.

Edison formulated his wish and belief in the success of new technologies back in 1922: "*I believe that the motion picture is destined to revolutionize our educational system, and that in a few years it will supplant largely, if not entirely, the use of textbooks in our schools*" [5] (p. 9). Nowadays books are just as much material in class as they were 100 years ago. Even the approach of electronic textbooks has not yet been able to replace this. Thus, this quote also reflects the central criticism of the use of technology in teaching: The use of technology alone does not improve learning success – regardless of the use of tablets, smartphones, laptops, interactive whiteboards, multi touch tables and augmented (AR) or virtual reality (VR) devices.

Many meta-studies show a positive influence on learning success when using technologies with medium or small effect size, country and culture independent (e.g., [6–11]. However, a purely technology-based comparison and evaluation is not permissible, since didactic design is at least as important a separating variable. General statements about learning success using a technology are at best dubious and at worst wrong without considering the entire didactic design.

We aim to integrate technology into the learning process, where conventional methods have weaknesses that can be compensated by technology. One example is the individual fostering of learners in group learning scenarios. Our research direction is therefore based on the one hand on the pedagogical principles [12, 13] and on the other hand on the theories and models of how multimedia content can be used with technologies in a target-group oriented way [14, 15]. The learning evaluation is based on the work of Bloom's taxonomy [16] and Krathwohl modifications [17].

User-Centered Technology Acceptance. The pace of technological advances coupled with a growing shortage of skilled workers, especially in STEM disciplines, cause a need for action and enables, at the same time, to reshape the education systems. Indeed, introducing new technologies is not an easy task: Not only that the intended device or system has to operate technically flawlessly, but also the product design must be optimally adapted to the requirements of the end user, who has to accept the technology accordingly, so that it can be implemented in the corresponding areas of life. Thus, in the end technology acceptance is the key criterion for a successful adoption in the long run.

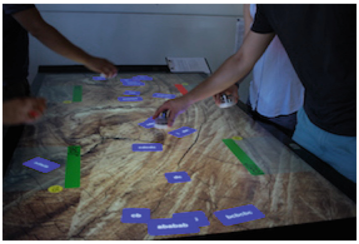
Technology acceptance has been discussed in the literature intensively in different application fields. Originally, this topic revolved around job-related information and communication technologies that were used to increase productivity and work effectiveness. On the other side, lack of acceptance has been identified as a significant impediment to the successful implementation and adoption of new information systems [18, 19].

In the first place, this research has been strongly influenced by the theory of diffusion of innovation proposed by Rogers [20] that was focusing on the process of adoption of novel technology devices or products among the users. Ever since, several empirical models have been developed to understand key factors of technology acceptance. One of the most prominent, empirically repeatedly validated models in different fields of application is the Technology Acceptance Model (TAM) [21] and its further development the Unified Theory of Acceptance and Use of Technology (UTAUT) [22, 23], which constitute the theoretical framework for this study. According to TAM, perceived ease of use and perceived usefulness are the key components of the technology acceptance. In this model, attitude of the user serves as a key mediating aspect between beliefs and usage intentions [24]. However, since diversity of the users and performance expectancy have been proven to play an important role in the intention to use and the actual behavior, we additionally refer to the comprehensive UTAUT-model when examining these aspects in the present study.

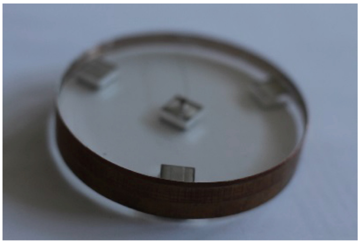
1.2 Assistive Technology for Learning: Tangibles on Multi-touch Tabletops

For the purposes of the study, a digital learning assistant was used which was meant to assist students in learning new subject matter. The learning tool consists of a multi-touch tabletop – a large display mounted as a table – which allows its users to stand around it and collaboratively interact with presented digital items. The information displayed on the tabletop can be manipulated, using tangible user interfaces (TUI). Figure 1 depicts the learning tool as it was used in the study.

A learning application was developed to teach the students pattern recognition with regular expressions (regex) in a collaborative setup on such multi-touch display, supporting meaningful interaction with and without tangibles. The application based on an



a) A multi-touch tabletop for collaborative working



b) Tangible as a user interface

Fig. 1. Assistive technology for learning as used in the study: (a) a multi-touch tabletop for displaying the digital information, (b) tangible object as an input and feedback device.

instructional approach and consisted of three modes, which are described in more detail in Sect. 3.1.

1.3 Objectives of the Research

In an experimental study, participants worked in groups of four persons and their task was to assign correct expressions to their predefined terms and, therefore, collect as many points as possible. The participants worked yet individually in the learning mode, but then collaboratively in the actual experimental trial. Prior to the interaction with the tangibles on multi-touch tabletop, participants filled in the first part of a quantitative survey, which collected demographic data and information about different user factors (e.g., attitudes toward technology use). Directly after the interaction, a second part of the survey was pursued, which evaluated the learning and the teamwork success, and the correlates of acceptance of the given technology (e.g., ease of use, intention to use). Finally, participants discussed within their groups ethical, legal and social implications (ELSI) of the learning tool for the university education.

Three main objectives were addressed in this study: First, we examine the correlative relations between the user factors, like cognitive, attitudinal, and performance factors, and factors associated with technology acceptance, such as perceived ease of use, intention to use the assistive technology and (collaboratively achieved) learning success. Second, we investigate how user diversity, which referred to participants' gender and their level of education, affects the learning success and the acceptance of the learning tool. And third, we reveal the most powerful predictors for the acceptance of the technology among the considered research variables.

2 Method

In order to examine whether collaboratively working students can learn new subject matter (i.e., regular expressions), and to understand how they evaluate and accept the learning assistant device in the context of this purpose, an experimental user study was conducted. Focus of the study was to let participants use the assisting tool for a learning task and, thereby, assess their performance and acceptance in terms of the technology.

The experiment was conducted at the InfoSphere – Student Laboratory for Computer Science at the RWTH Aachen University – in a laboratory environment. Participants were recruited partly directly from the university, and partly from the immediate social network of the authors.

In this section, firstly, used materials are described, followed by the presentation of the experimental procedure and the research approach. Description of the sample closes the method section.

2.1 Materials

Hardware Design. The learning application, which was especially conceived for our experimental purposes, was installed on an 84″ Microsoft Surface Hub. This multi-touch display is able to detect up to 100 touch points on a 220 × 117 cm display with a resolution of 3840 × 2160 pixels. The display was brought in a horizontal position on a metal frame with wheels, bringing the surface to a height of 87 cm, suitable for most adult learners. Figure 1 depicts the hardware.

Another aspect researched in this setting is the learning effect of tangibles. One strength of tangibles is to reduce the distance between the data and the way they are manipulated. Thus, tasks with a spatial representation can be solved more quickly [25]. Furthermore, the manual manipulation of toys while reading a story helps children to understand the content of the story. This approach also helps in Number Board Games to understand orders of magnitude. In addition, learners achieve better learning success when they work with haptic, visual and auditory content and feedback than with just one of these types [26].

In our setting, we use tangibles as haptic devices that are recognized by the capacitive touch screen. The tangibles offer bidirectional communication, opening another personal feedback channel by lighting up, buzzing and vibrating on interaction.

Software Design. As the task was to learn basics of regular expressions, the learning application was primary conceived for testing of the learning assistive tool in an experimental setting.

Regular expressions can be didactically reduced due to a differently complex representation. The length of the words and the iterative introduction of the different operators make it easy to design tasks of increasing degrees of difficulty.

The application consisted of three modes: one demo-mode, one learning mode and a collaborative mode. Participants were provided with direct feedback after each interaction (i.e., moving a matching word to a predefined regular expression): A green background of the regular expression and a slow 360° rotation of the word were chosen for a correct assignment, and a red background and a short twitch of the word in case of a wrong assignment of the regular expression.

During the interaction with the learning tool, in each user's personal zone appears a regular expression (e.g., a|b, c|cd*), which has to be matched with correct expressions presented in the middle of the tabletop display. There, different distractors and character sequences pop up next to the target items which have to be matched to the correct regular expressions. Each participant has a different target expression and the task is to find and match as many correct items as possible. A correct match (confirmed with green) brings two additional points, which are added up for the whole group. In case of a wrong matching, the expression returns to the central part of the tabletop, for feedback the upper bar of the personal area flushes in red, and the user – and so the group – loses one point.

2.2 Experimental Procedure

Participants were tested in groups of four persons and the experimental setting was divided in several steps:

First, participants were introduced into the general topic and motivation of the research, and they were informed about the general aim as well as the course of the study. At this point, formal framework conditions were also clarified, i.e., that their data was being recorded in order to measure performance and, therefore, the learning success. Moreover, participants were informed that their interaction with the assistive technology would be recorded on video, not exposing their faces in frame, but only their hands.

Second, previous to interaction with the learning tool, participants completed a first part of an online survey (pre-survey), filling in information about their demographic characteristics (i.e., age, gender, level of education), attitudes towards technology, as well as prior knowledge of regular expressions. After finishing this part, number connection test [27], which provided information about participants' perceptional speed was pursued.

In the third part of the experiment participants interacted with the digital learning assistant. The task was to assign the correct expressions to their predefined terms, collecting as many points as possible in the designated time (90–120 s). The task difficulty increased thereby from one experimental trial to another. Before the actual interaction started, learners got an introduction to regular expressions and a manual, where the experimenter explained the basic regex-operations with examples. Once the theoretical part was done and the emerging questions answered, the experimenter demonstrated the way the digital learning tool works, showing how to place the recognized regular expression to the individual target space. After this, participants started a learning session, where they could test the technology by themselves in order to better understand the application and the idea of regular expressions. Participants interacted with the learning application in two rounds, each 90 s; afterwards, they still had time and possibility to ask questions, when required. In the final, experimental trial, participants absolved two collaborative gaming sessions, each 120 s.

After the interaction with the multi-touch display, a post-experimental questionnaire followed. This part of the questionnaire allowed evaluation of the system usage and feedback modalities, and enabled to gather information about perceived learning success and acceptance.

Finally, participants discussed ethical, legal and social aspects connected to such a collaborative technology-enhanced learning. The time for the completion of the whole operational sequence never exceeded 90 min and averaged around 70 min.

2.3 Research Approach

The research variables used in this study focus on different user factors related to acceptance criteria, which are considered factors leading to a long-term adoption of assistive learning technologies – as such presented above – in the education. Figure 2 summarizes the research design used for the purposes of this study.

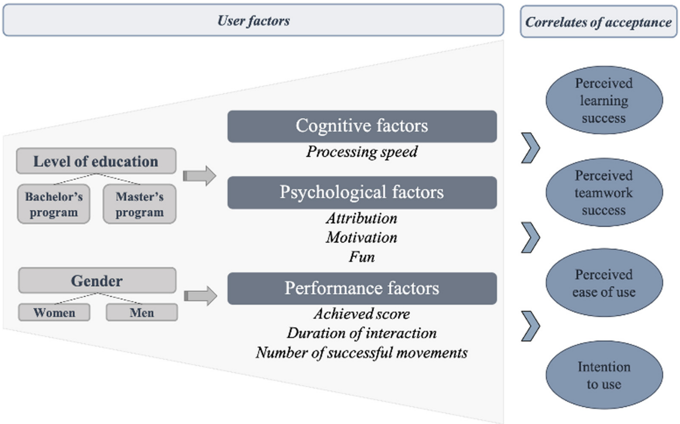


Fig. 2. Research design used in the present study.

Based on the concept of the user-centered design (e.g., [28, 29]), we included gender (females vs. males) and level of education (students of bachelor's program vs. master's program) as variables referring to the user diversity among the potential users of learning assisting technologies. Using these as *independent variables*, we examine if criteria of acceptance significantly differ between the particular user groups. Moreover, factors referring to cognitive (i.e., processing speed, according to Oswald and Roth [27]) and psychological aspects of participants (i.e., attribution in dealing with technology, according to Beier [30], motivation and fun[1]) as well as their resulting interaction performance (i.e., achieved score, duration of interaction and the number of successful movements) were considered in the subsequent analyses to get an overview of the correlative relationships and find out which of these are the best predictors for acceptance.

Finally, as *dependent research variables* acceptance criteria were used:

- Perceived learning and teamwork success: self-evaluations to be assessed on 6-point scales reaching form 1 (= 'not successful at all') to 6 (= 'absolutely successful');
- Perceived ease of use (PEoU): a score of 7 items (e.g., "It was easy for me to perform the necessary actions.") to be assessed on a 6-point Likert scale reaching

[1] Self-developed items for motivation (e.g., "I was inspired to do the job as best I could") and fun (e.g., "Interacting with the game was fun.") to be assessed on 6-point (dis)agreement scales.

form 1 (= 'I do not agree at all') to 6 (= 'I absolutely agree'); Cronbach's alpha = .84;

- Intention to use (ItU; "I would like to use such game environment more often for education purposes") to be assessed on a 6-point agreement scale.

2.4 Sample Description

In total N = 45 persons participated in the study and they were randomly assigned to the respective experimental groups (three to four persons each session). All participants were novices as regards the use of the learning tool and for most of them (89%) the concept of regular expressions was a novelty. The sample consisted of 49% females and 51% males, of which 56% reported to currently study in the master's program and 22% in bachelor's program; 22% of them were not (any longer) in their studies.

Overall, participants reached a relatively high average score in attributions of self-confidence in dealing with technology (*M* = 74.3 out of maximum 100, *SD* = 19.7). In addition, in the sample achieved mean values in motivation (*M* = 81.8/100, *SD* = 14.5) and fun (*M* = 82.5/100, *SD* = 13.5) indicate a favorable attitude towards the used technology and a vital prerequisite for a successful adoption on the long run.

Participants were recruited directly from the university and from the immediate social network of the authors. The participation in the experimental study was voluntary and attendees were not compensated for participating.

3 Results

Results presented in this section were analyzed, using bivariate correlations, *t*-tests and multiple linear regression analyses. Pearson's product-moment correlation coefficients (ρ) were calculated for continuous variables and for dichotomous variables Spearman's rank correlation coefficients (r_s) were used. For descriptive analyses, means (*M*) and standard deviations (*SD*) are reported. The level of statistical significance was set to 5% and two-tailed tests were used for the statistical analyses.

In this section we, firstly, provide an analysis of correlative relationships between the user factors and acceptance criteria for the learning tool. Secondly, we examine the influence of gender and education level on the evaluations of interaction with the assistive technology and the perceived learning success. And thirdly, we determine the best predictors for the acceptance of the used technology.

3.1 Interrelations Between User Factors and Acceptance Factors

To provide an overview of the associations between the research variables, in the first step we perform a correlation analysis for the previously described user factors and aspects referring to acceptance of the assistive technology. Figure 3 summarizes the resulting coefficients between these factors.

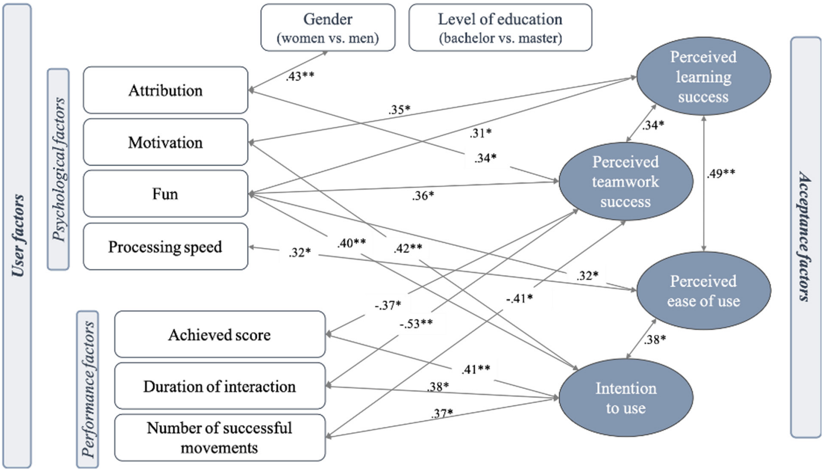


Fig. 3. Correlative relationships between user factors and acceptance factors (N = 45; gender coding: men = 1, women = 2; $**p \leq .01$, $*p \leq .05$).

The results of the bivariate correlation analysis show that user factors are moderately related to the factors of acceptance. Especially psychological factors are significantly correlated with aspects that promote accepted use of digital learning assistant. Fun, for example, seems to be a key user factor which is positively linked with all acceptance variables: It correlates significantly with the learning success ($\rho = .31$, $p = .038$) and teamwork success ($\rho = .36$, $p = .030$), and it is associated with the perceived ease of ($\rho = .32$, $p = .018$) and the intention to use the learning tool ($\rho = .40$, $p = .006$). The latter acceptance factor is also positively linked to the user's motivation ($\rho = .42$, $p = .004$), which is also positively related to the individual learning success ($\rho = .35$, $p = .019$). High processing speed makes user perceive the technology as easier to use ($\rho = .32$, $p = .030$) and higher means in attributed self-confidence in dealing with technology are moderately correlated with better teamwork success ($\rho = .34$, $p = .023$).

Moreover, performance aspects are positively connected with acceptance, indicating that a higher intention to use the assistive learning technology in the future goes along with reaching high scores ($\rho = .41$, $p = .010$), longer durations of interaction ($\rho = .38$, $p = .017$), and higher number of successful movements ($\rho = .37$, $p = .019$). On the contrary, higher average results in the performance factors correlate negatively with the teamwork success, which indicates that subjectively perceived high performance is not necessarily interpreted as a team success.

The bivariate correlation analysis shows that psychological and performance-related user factors are significantly related to the acceptance criteria.

3.2 Impact of User Diversity on Accepted Technology-Enhanced Learning

In the next step, we examined the influence of the user diversity factors gender and level of education on variables, referring to the acceptance (i.e., PEoU, ItU, perceived learning and teamwork success) and evaluations of the interaction with the learning technology.

Aspects of Acceptance. Using independent-samples t-test, firstly differences between the *gender groups* were examined, considering the acceptance criteria used in this study. The analyses revealed no statistically relevant differences between males and females when it comes to assessments of the perceived ease of use [$t(43) = -0.26$, *n.s.*] and the intention to use the device [$t(43) = -0.51$, *n.s.*]. Regarding perceived learning success [$t(43) = -0.27$, *n.s.*] and teamwork success [$t(42) = -1.74$, *n.s.*], the opinions between the gender groups did not differ either.

Further, we tested whether the criteria of acceptance are influenced by the *level of education*, comparing opinions of students in bachelor's vs. master's program. The analyses disclosed statistically significant differences for the perceived ease of use of the technology [$t(33) = 2.08$, $p < 0.05$] with bachelor students ($M = 77.9$, $SD = 8.2$) reaching considerably lower means than master students ($M = 85.4$, $SD = 12.6$). The main effect of the level of education on the PEoU is depicted in Fig. 4.

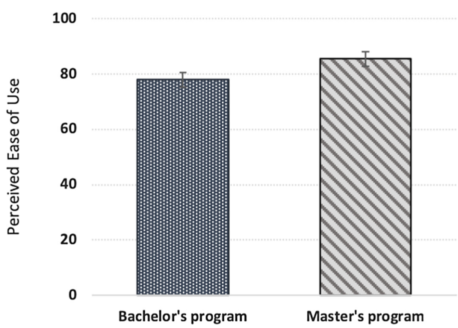


Fig. 4. Main effect of the level of education on the acceptance criterium perceived ease of use (PEoU; n = 35).

On the contrary, differences in the education groups are absent for the intention to use the tool [$t(33) = -1.91$, *n.s.*] as well as with regard to the perceptions of learning [$t(33) = 0.14$, *n.s.*] and teamwork success [$t(32) = 0.25$, *n.s.*]. Overall, the reached means consistently show a quite high acceptance of the technology.

Evaluation of the Interaction. In addition to the acceptance-related criteria, after the interaction with the learning tool participants assessed it by means of semantic differential – a method according to Osgood [31]. To derive the attitude towards the technology participants assessed series of bipolar pairs of adjectives, defined by verbal opposites (e.g., useful – useless) on a seven-steps scale. We examined whether there are meaningful differences between the gender- and education-related groups.

The resulting means for males and females are depicted in Fig. 5. Overall, the evaluations indicate a high attachment for learning with tangibles on multi-touch tabletops, as the average values distinctly lie on the positive side of the scale. *T*-Tests, which were run for examination of statistically relevant differences between men's and women's opinions, revealed significant difference solely referring to perceptions of the technology being exciting vs. boring [$t(43) = 2.01$, $p < 0.05$]. Thereby, male participants assessed the digital assistive technology as considerably more exciting than their female counterparts.

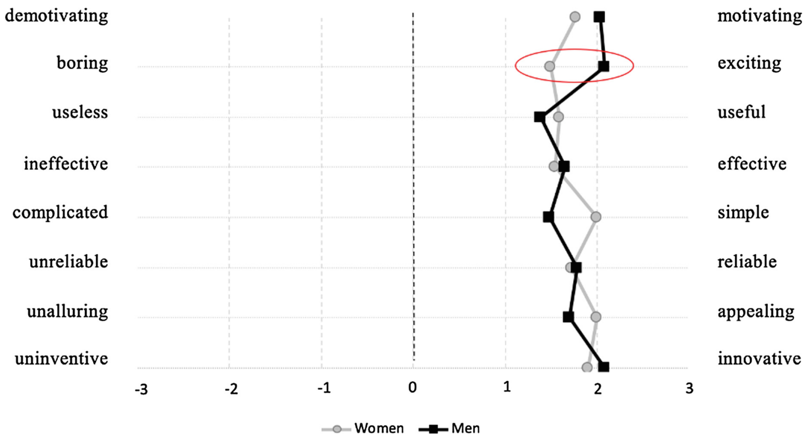


Fig. 5. Evaluations of the interaction with the learning assistant, considering gender groups (statistically significant difference is circled red; n = 45). (Color figure online)

In addition, assessments of interaction with the learning technology were examined for both education groups: The opinions of bachelor's vs. master's program students were compared and tested for differences. Statistical analysis revealed significant differences between the groups in terms of the perceived (in-)effectivity [$t(33) = -2.45$, $p < 0.05$] and enthusiasm vs. boredom [$t(33) = -2.92$, $p < 0.01$]. As can be seen from Fig. 6, students in bachelor's program reached basically lower means than students in master's program.

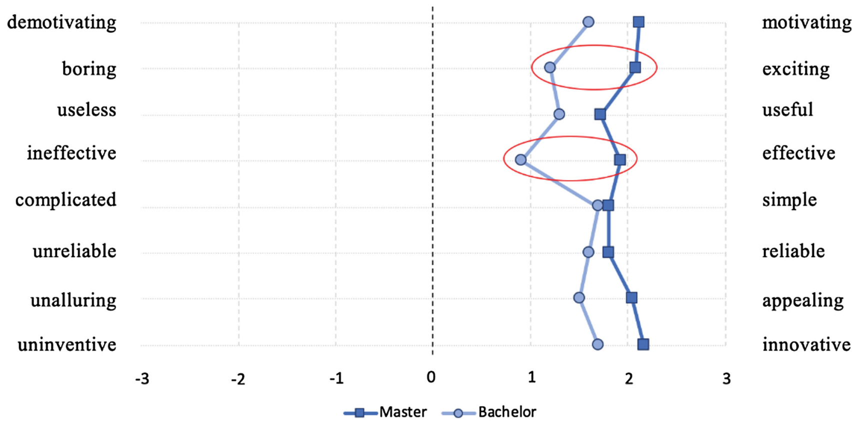


Fig. 6. Evaluations of the interaction with the learning assistant, considering different levels of education (statistically significant differences are circled red; n = 35). (Color figure online)

3.3 Best Predictors for Acceptance

In the final step of the statistical analyses, we search for the best predicting variables for acceptance and collaborative learning success when using the digital learning assistant. For this purpose, stepwise multiple regression analyses were performed.

In our calculations, the acceptance criteria were added as dependent variables in the analysis and the user factors, including psychological and performance aspects, as independent variables. From the regression analyses resulted statistical models as summarized in Table 1.

Table 1. Statistical models resulting from multiple regression analyses for acceptance and collaborative learning success when using assistive learning technology (N = 45; $**p \leq .01$, $**p \leq .05$; VIF = variance inflation factor)

Acceptance correlates	*Predictors*	R^2	*ß*	*t*	*VIF*	*ANOVA*
Perceived learning success	Motivation	30.2%	.50	3.44**	1.1	$F(2, 38) = 7.8$, $p = .002$
	Duration of interaction		−.42	−2.89**	1.1	
Perceived teamwork success	Fun	49.5%	.48	3.90**	1.05	$F(2, 37) = 17.1$, $p \leq .001$
	Duration of interaction		−.63	−5.14**	1.05	
Intention to use	Motivation	29.5%	.37	2.56*	1.09	$F(2, 38) = 7.5$, $p = .002$
	Achieved score		.30	2.05*	1.09	
Perceived ease of use	Processing speed	11.2%	.33	2.16*	1.0	$F(1, 38) = 4.7$, $p = .037$

Perceived Learning Success. From the upper part of Table 1 it is evident that the prediction model for perceived learning success [$F(2, 38) = 7.8$, $p = .002$] entered two out of nine possible predictors and accounted for over 30 percent of the variance. The user factor motivation received the strongest weight in the model ($\beta = .50$), followed by the performance factors referring to the duration of interaction with the assistive technology ($\beta = -.42$). For this model, thus, motivation [$t(36) = 3.44$, $p = 0.002$] and duration of interaction [$t(36) = -2.89$, $p = 0.007$] are the significant predictors for the perceived learning success.

Perceived Teamwork Success. The regression model for perceived teamwork success is statistically significant [$F(2, 37) = 17.1$, $p \leq .001$] and explains almost 50% ($R^2 = .495$) of the variance. Among the predictors entered in the model, the duration of interaction with the tool reaches the largest beta coefficient of −, making the strongest unique contribution to explain the perceptions of teamwork success, which is followed by the also strong contribution of fun ($\beta = .48$).

Intention to Use. For the intention to use the examined assistive technology, again, two variables were included into the regression model [$F(2, 38) = 7.5$, $p = .002$] which accounted for almost 30% ($R^2 = .295$) of the variance. Motivation ($\beta = .37$) and the achieved score ($\beta = .30$) reached the strongest contributions to explain the intended use of tangibles on multi-touch tabletops in the future.

Perceived Ease of Use. Finally, for the perceived ease of use the regression model contained only one out of nine possible predictors. The model reaches statistical significance [$F(1, 38) = 4.7$, $p = .037$] and explains overall only 11.2% of the variance ($R^2 = .112$). Processing speed was the only predictor (beta coefficient = .33; $t(37) = 2.16$, p = .037) that was included into the model, making the unique contribution to explain PEoU.

For all presented regression models, VIF values are all well below the value of 10 and the tolerance statistics lie all well above 0.2. These results allow to conclude that there is no collinearity within the present data.

4 Discussion

In the presented study we experimentally examined how students manage to acquire novel study matter (i.e., regular expressions), using a learning assisting technology in the form of tangibles on multi-touch tabletop. The aim was to take a closer look at the associations between factors brought by the potential users in dependence on their perceptions of accepted and successful technology-enhanced collaboration for learning purposes. In the discussion section, we firstly focus on the most relevant findings of our study and bring them in the broader context of education. Secondly, we consider the limitations of the study and discuss further research directions.

4.1 Acceptance of Assistive Technology in Collaborative Learning

Results presented in this study are insightful and indicate that the users' psychological and factors resulting from the interaction with the learning tool – we called these performance factors – are significantly connected with the correlates of acceptance. The moderate correlations show that especially fun and motivation play an important role for an accepted use of the assisting technology. Moreover, better performance positively affects the user's intention to use the technology, which is an acknowledged criterium for acceptance and successful adoption in the future. Based on this knowledge, assisting technologies that use serious games, which already have been repeatedly showed to be useful in different areas of application (for overview see e.g., [32, 33]), should be considered a meaningful learning support for learners and teachers, and be increasingly integrated into educative settings.

The overall assessments after interaction with the learning assistant were (very) positive, showing a high attachment for, and willingness to, use such a technology. The opinions were quite consistent among the queried persons. However, the resulting differences in the particular gender and education groups for enthusiasm/excitement and boredom, on the one hand, and for (in-)effectivity of the technology, on the other hand, suggest that one part of the potential users either not yet perceives the added value of the assistive technology or represents potential user profiles among the learners, who simply decline the use. This valuable result shows that there are clear limits of this technology in education. This finding is additionally underpinned by the negative correlations resulting between performance and perceptions of teamwork success, which indicate that higher performance not necessarily leads to a perception of teamwork success but rather suggests in that case that a well-performed task does not necessarily require a collaboration.

Moreover, the performed regression analyses showed that the examined user factors solely partly contribute to explanation of the variance of acceptance. From the psychological user characteristics, especially motivation and fun to use the assistive learning tool seem to play a relevant role for the long-term adoption of the technology in education. Among the performance data, the duration of interaction turns out to be a reliable indicator for perceptions of learning and teamwork success. The negative orientation of the resulting beta coefficients suggests thereby that perceptions of success are associated with a short duration of interaction. In other words: the shorter the interaction time, the greater the perceived learning success. This outcome can be either explained by the fact that the today's students expect, or are used to, fast and efficient technology solutions. On the other side, interpreting the outcomes some caution is required, because the results can be artifact-related and only refer to the content examined in the presented experiment.

Summarizing, the technology as described here is promising. Creating and ongoing development of a well-functioning, accepted, and didactically meaningful learning technology that serves learners as an assistant can lead to a significant change of learning motivation and learning success also for the difficult subject matters, like these required in the STEM study programs. This study demonstrates that students exhibit positive mind-sets towards such a technology-enhanced learning and show overall welcoming reactions in interacting with it. These are optimal conditions for long-term adoption of such learning aids in education. Thus, even though the learning tool cannot serve for all potential learners, for example these who are in wheelchair or are somehow disabled in their movements, or those who simply do not want to work with it, it represents an option for the clear majority, who is willing to be supported by this technology in their learning process.

4.2 Limitations and Future Research

Despite providing relevant insights, it is also important to note limitations of the study, which should be addressed in future research.

The first limitation relates to necessary caution in the interpretation of the results. The outcomes are based on an examination of a first prototype of the assistive learning technology, which in many respects might not yet be mature, especially in the didactical sense. Further research is needed in parallel with a further development of the learning tool in order to validate the findings.

Another limitation refers to the methodological approach: One shortcoming is a relatively small sample size and a not perfectly distributed proportions of bachelor and master students in the educative groups. Strictly speaking, the number of persons considered in the statistical analyses in this regard, reaches the threshold of possible proportion of comparable group sizes. The unequal group sizes can increase the risk of type II error. Thus, this issue should be better considered in future research.

Further, in the current study we examined the learning success for all participants and did not include a control group nor consider other learning methods for comparison of the effectivity. Next studies should conceive such competitive settings in order to validate a didactically useful learning assistance.

Future research and the subsequent in-depth developmental activities of the assistive technology should ensure that the present requirements of the potential users are accordingly considered without compromising the didactically necessary principles. This means a further integration of the stakeholders in the design and optimization processes.

5 Conclusion

Assistive technology for learning affords a great potential for the learners of today. Sophisticated learning assistants, which optimally convey contents for the learners through various feedback modalities, and are didactically sound and well-elaborated, can offer great advantages, especially for complex learning material that is difficult to grasp.

The present study makes its contribution to the development of such cleverly designed technology. Results evidence that individual characteristics considerably influence the users' perceptions of the learning tool and, therefore, affect the interaction, perceived success and acceptance. In addition, this study provides insightful information about the existing willingness to use assistive technology for learning purposes.

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