Evaluation of Learning Motivation within an Adaptive e-Learning Platform for Engineering Science

Mathias Bauer[1], Jacqueline Schuldt[2] and Heidi Krömker[3]
Media Production Group, Technische Universität Ilmenau, Gustav-Kirchhoff-Str. 1, Ilmenau, Germany

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Abstract: Learning motivation represents an important determinant for a successful learning process. Especially in the context of self-regulated learning with e-learning systems learning blocks or learning breaks occur increasingly when motivation is dropping. Creating appropriate learning experiences that respond to learners' needs is important to maintain learning motivation. This supports continuous usage of e-learning systems at universities. Adaptive e-learning systems are a possibility to react profoundly to individual needs of the learners before or during the learning process. Therefore, an e-learning platform for micro- and nano-technologies was transformed into an adaptive learning system to foster learning motivation at the Technische Universität Ilmenau within a multi-level development process. Results showed that the e-learning platform was well accepted but a significant benefit of the adaptive version compared to the non-adaptive version could not be identified.

1 INTRODUCTION

Motivated learning is the prerequisite for a deep processing of learning content and a long retention performance (Bauer et al., 2018a) as well as the basis for joy of learning and persistent interest (Schiefele, 2009). Social aspects, personal histories, experiences and circumstances may influence the motivation of learners. Disturbances of learning motivation can lead to superficial learning processes or even to learning blocks. Therefore, an e-learning platform for micro- and nanotechnologies was transformed into an adaptive learning system that adjusts its user navigation according to the current motivation of the learner. Motivational user data is acquired through self-reports within the platform. A multi-level development and evaluation process was set up from 2017 to 2019 to answer the research question whether learning motivation can be fostered with techniques of adaptive navigation support. The focus of this paper is on the evaluation of the final adaptive system version. The progress of the current motivation was measured during a laboratory study with 64 participants in early 2019 and an extract of the results will be presented in the following paper. Research questions of the study were: (a) Can a change of the learning motivation be measured during an e-learning session? (b) Does the instructional design has an influence on the learning motivation? (c) How does learning motivation affect the learning results?

2 THEORETICAL FRAMEWORK

The study heavily relies on the depiction of learning motivation in a self-regulated e-learning session. Therefore, a suitable motivation model has to be defined and operationalised. Also, basics of adaptive e-learning will be described.

[1] https://www.tu-ilmenau.de/en/media-production-group/staff/bauer-mathias/
[2] https://www.tu-ilmenau.de/en/media-production-group/staff/schuldt-jacqueline/
[3] https://www.tu-ilmenau.de/en/media-production-group/staff/kroemker-heidi/

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2.1 Learning Motivation in Self-regulated Learning Contexts

According to Rheinberg motivation is defined as the "activating orientation of the current day-to-day living towards a positively assessed target state" (Rheinberg & Vollmeyer, 2012). Consequently, motivation should be able to explain the direction, persistence and intensity of behavior.

The research focus is on motivation in learning contexts, especially on self-regulated learning in e-learning. Intentional learning activities under one´s own guidance, without direct tutor-instructions or -control are called "self-regulated learning" (Rheinberg et al., 2000). Therefore, the cognitive-motivational process-model of self-regulated learning was used as a framework for describing the effects of the interrelation between person and situation factors on the learning outcomes. As indicated in figure 1 the framework starts with the antecedents of the current learning motivation that result indirectly in learning outcomes for a specific learning task and learning episode via mediating variables during learning (Rheinberg et al., 2000).

Besides demographic variables and prerequisite domain-knowledge, motivational factors like self-efficacy (Bandura, 1977) can be considered.

2.2 Adaptive e-Learning

Adaptive systems come in different varieties depending on the frequency of adaptations and the initiating force for these changes (Ennouamani, 2017). Leutner (2011) distinguishes macro- and microlevel adaptation. There are adaptable systems that allow the user to adjust defined system-components, such as the user interface.

Macrolevel adaptation allows changes by the system with a low frequency (Leutner, 2011). That means the system changes only once or only at the beginning of a session. In learning systems that could be a test on the previously learned topics.

Microlevel adaptation goes one step further by changing the system constantly depending on a continuous stream of information from the user. The system is monitoring the user and depending on her state may initiate changes. Microlevel adaptation was the basis for the development of the adaptive system described in this paper. Paramythis et al. (2010) describe the adaptation process for microlevel adaptive systems in five steps. The basis for any adaptation is the collection of user data. This could be usage data or any other kind of measurement. Next, the system needs to interpret the data. In this case, the e-learning platform has to decide whether the learner is motivated or not. Depending on this information the system must make a decision on applying an adaptation or not. Through the adaptation technique the user interface changes and the user becomes aware of the adaptation. This may again lead to changes in the user states and initiates the process anew.

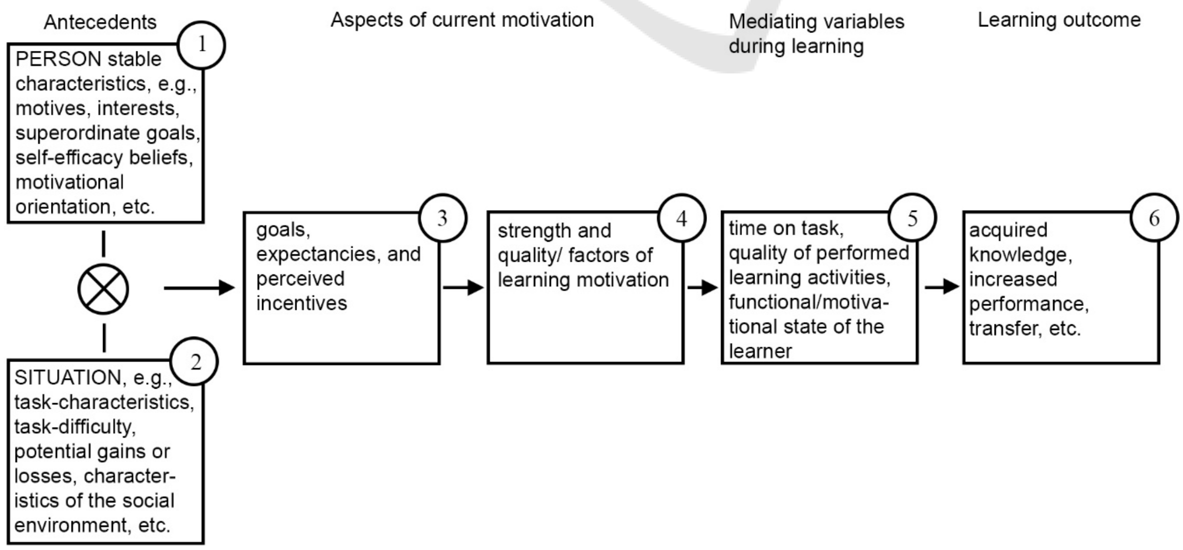

Figure 1: Cognitive-motivational process-model of self-regulated learning (in accordance to Rheinberg et al., 2000).

Situational factors can address the instructional design of e-learning environments and should foster the current learning motivation. An established model for the derivation of design recommendations is Keller´s ARCS-model (Keller, 2010). The four major components attention (A), relevance (R), confidence (C) and satisfaction (S) provide the conceptual framework for the use of motivationally fostering actions (Zander & Heidig, 2018). The mediating variables can for example be the learner´s emotional functional state. This is especially of interest since there are conceptual similarities between motivation and emotion. Considering Rheinberg´s definition of motivation it is obvious that positive activation, as part of a circumplex model of affect (Schallberger, 2005), is also a core component of motivation (Rheinberg, 2010).

The operationalised framework depicts learning motivation as a process variable. Direct effects of learning motivation on learning outcomes are not automatically to be expected, but mediated through variables like the emotional functional state. Especially, complex tasks demand a preferably direct acquisition of motivation and its indicators, because learning outcomes in this case are dependent on many factors. Such "live" acquisition of motivational data can be achieved through self-reports in the form of experience sampling approaches (Engeser, 2005).

The adaptation of the described e-learning platform relies on adaptive navigation support. Basically, adaptation techniques can be divided into two large groups: adaptive presentation on the one hand and adaptive navigation support on the other hand. While adaptive presentation techniques such as stretch text or dimming change the content itself, adaptive navigation support changes the way the learner is guided through the learning material. A comprehensive overview of adaptation techniques is given by Knutov et al. (2009). Two major techniques for adaptive navigation support are for example direct guidance and link annotation that were also tested within the multi-level research design that is described in the following section.

3 RESEARCH DESIGN

3.1 Evaluation Process

Figure 2 shows a simplified version of the overall research design for developing and evaluating the adaptive e-learning platform NanoTecLearn (NTL). In the first stage the motivation of learners was evaluated in a laboratory study with the non-adaptive basic-version. Also, possible adaptation techniques were derived with the aid of techniques of user-centred development, especially in the form of focus groups with learners and experts for usability, e-learning didactics and e-learning technology (Bauer et al., 2018b).

The second stage was then the implementation of three adaptive versions of the learning platform – specifically link annotation, direct guidance and a pedagogical agent. These versions were compared to the non-adaptive version in the form of an experimental laboratory study. Therefore, a formative and summative evaluation of the system with learners was carried out. For in depth results see (Bauer et al., 2019a; Bauer et al., 2019b).

The current paper focusses on the last stage of the process, the user evaluation with the final version of the adaptive system. Within figure 2 this is represented as no. 4: Survey of learning motivation with platform-version V2, the optimized adaptive NTL Platform.

3.2 Description of the Adaptive e-Learning Platform

The e-learning platform that served as a case study for the evaluation process was the NanoTecLearn platform that was developed as a non-adaptive knowledge and learning platform in a research project from 2014-2017 at the Technische Universität Ilmenau. The platform describes different phenomena in the area of micro- and nanotechnologies. It offers three access points to the knowledge. The first point is classical text and images or videos. Most knowledge is represented in this way. Figure 3 gives a brief overview of the theory-section based on the chapter "Wechselwirkungen an Grenzflächen". Texts, a table and an embedded learning video are displayed within this figure.

Furthermore, the platform allows learners to view and interact with different images of samples. Figure 4 shows a microscope image that is part of the learning platform. Viewing and interpreting images from different kinds of microscopes are important skills for this field of application. Since microscopes are a limited resource, actual time with these tools is limited during training. NanoTecLearn offers a simple but powerful substitute for this. Lastly, formulas and physical laws describe the phenomena. Therefore, the platform includes interactive formulas like the Young-Wenzel-Equation shown in figure 5. Learners can change different parameters within a formula and view the implications in graphical representations. This way, they can gain a better

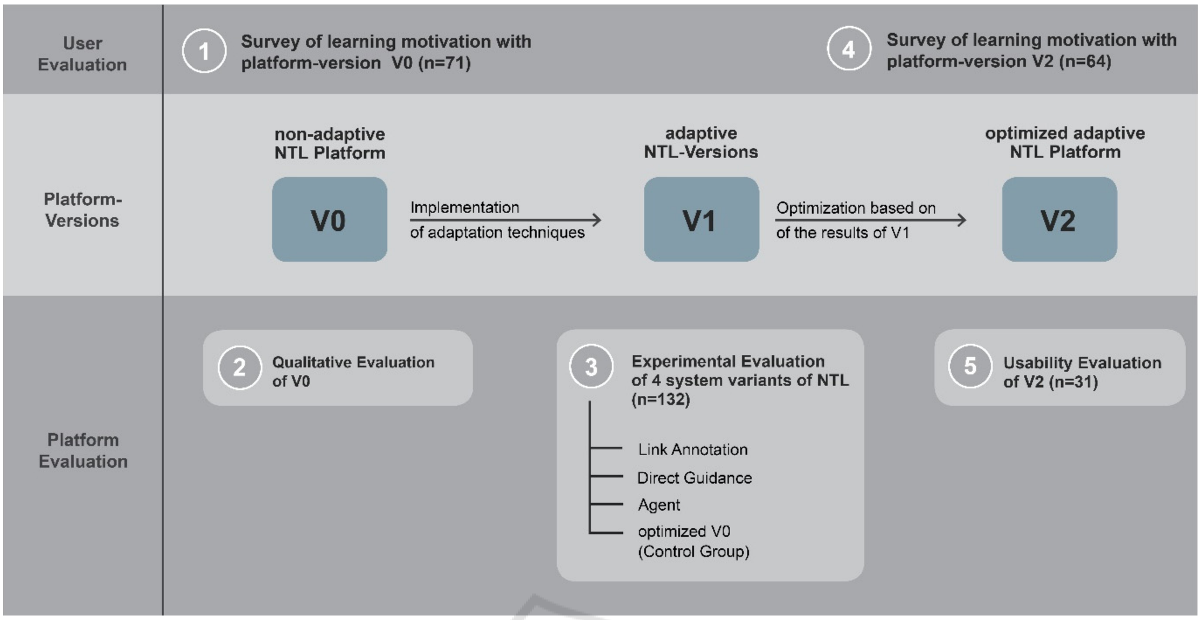

Figure 2: Procedure model for the further development and evaluation of the e-learning platform.

understanding of the formulas. The content of each chapter is divided into six parts, which can be seen on the left side of figure 3. First, there is a short introduction into the topic of the chapter called orientation, which is followed by a longer theoretical section that introduces the main themes of the chapter. Next is a part on practical implications and scenarios called application. After that learners can interact with formulas, samples or 3D-models of microscopes and other tools in the interaction-section. Lastly, the main points of knowledge are summarised and follow-up questions are asked. The chapter closes with a repetition of the given contents. This also includes interactive quizzes and questions for testing the own domain-knowledge. The different chapters of NanoTecLearn can be accessed via the navigation bar at the bottom of figure 5.

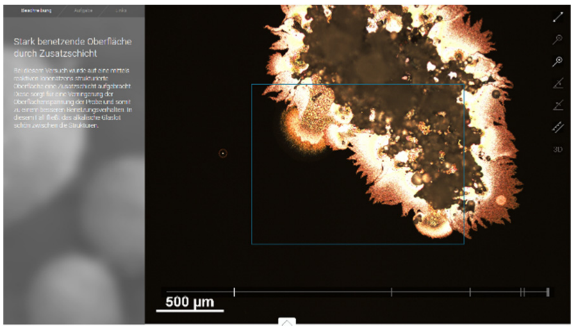

Figure 3: Screenshot of the theory-section of the chapter on “Wechselwirkungen an Grenzflächen”.

Figure 4: Screenshot of an interactive sample “Strongly wetting surface through additional layer”.

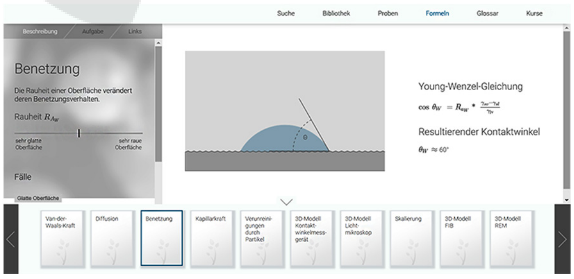

Figure 5: Screenshot of an interactive formula “Young-Wenzel-Equation”.

The evaluation of the adaptive versions described before resulted in the implementation of a final adaptive version of the platform that relied mainly on the link annotation technique and some aspects of the direct guidance technique.

Basically, link annotation is a recommendation technique that highlights appropriate subsequent sections of a chapter based on the motivation based self-reports that have to be filled at the end of every section. The direct guidance leads the user through relevant content. Besides the visual clue in the form of a subtle highlighting there is also a verbal coding naming the recommended section. Being a recommendation system the user is free to choose whether to follow these hints. Completely ignoring the hints, it would thus be possible to experience a totally self-regulated learning as in the non-adaptive version. This was one specifically named requirement during the conception-phase that learners want to have full control over their learning process.

The motivation based self-report mechanism of the platform relies on two elicited parameters of current motivation, being situation-specific interest and confidence or competency expectation (Vollmeyer & Rheinberg, 2003). The mechanism included two items, one for each parameter, and a three-point scale telling the system whether the user is still interested or confident or not or whether the state remains unchanged. Recommendations that should foster the learning motivation are only given if there is a decrease in one of the two parameters. Otherwise, the user will be guided hierarchically through the chapter. For every chapter and section there is a decision-table in the backend for suitable subsequent contents that might increase the learning motivation. This was also conceptualised throughout the already mentioned focus groups.

4 RESULTS

4.1 Study Design

The laboratory study was conducted in January 2019 and consisted of a sample of 64 students of the Technische Universität Ilmenau. The study design and included survey instruments were based on Rheinberg´s motivation model that was described in section 2.1. Figure 6 shows the operationalised framework. Elicited person variables were demographic and study related variables as well as domain specific knowledge and self-efficacy beliefs. Situation variables were the motivationally aspects of the instructional design according to Keller´s already mentioned ARCS model. The four factors of the model were measured with the aid of the Instructional Materials Motivation Survey (IMMS) (Keller, 2010). The current motivation was conceptualised according to Rheinberg on the basis of four factors and measured with the belonging survey called FAM (Rheinberg et al., 2001). As a mediating variable served the emotional functional state that was measured with a short survey for eliciting positive and negative arousal as well as valence called PANAVA-KS (Schallberger, 2005).

There were four measurements of the emotional state throughout the e-learning session – one directly after the first section, the second one after the theory-section, the third one after the first interaction with the samples and the last one after the interactive

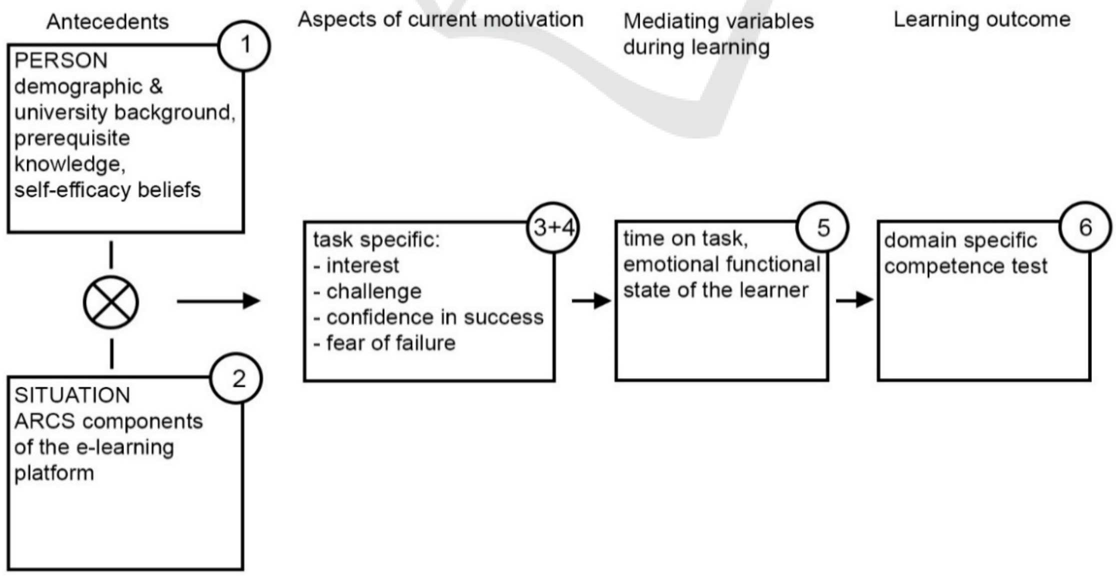

Figure 6: Operationalised framework for learning motivation and its effects on self-regulated learning (in accordance to Rheinberg et al., 2000).

formula. During the study, the students had to work through one predefined chapter of the platform called "Wechselwirkungen an Grenzflächen" (interactions at boundary layers). Also, the individual user paths through the learning material and the self-reports of motivation within the platform was gathered with the aid of log files. After completing the chapter there was a test to record the learning results.

The experiment took about 50-60 minutes. Every participant worked on two screens, one depicting NanoTecLearn and one depicting the survey to prevent users from overlooking relevant parts of the instruction. The study was conducted in a computer lab and a maximum of six students could be tested simultaneously. The participation was also rewarded with a remuneration of 20 Euros.

4.2 Data Analysis and Results

4.2.1 Description of the Sample

The sample consisted of 39 male and 25 female students that were between 19 and 35 years old (M=24.31, SD=3.80). With a number of 38, the majority of students were matriculated in Bachelor study programs. The content of the platform aimed at students of engineering sciences but the study was also open to students without prior knowledge. Nevertheless, the test of the prior knowledge that came with six achievable points showed an overall medium domain-specific knowledge (M=3.97, SD=1.10).

4.2.2 Description of the Process of Learning Motivation with Log File Analysis

Research Question (a): Can a Change of Learning Motivation be Measured During on e-Learning Session?

Figure 7 shows the process of the learning motivation measured via the self-report mechanism of the platform during the e-learning session. Table 1 additionally defines the encoding of the parts of the chapter and specifies the means of the motivation rating. Every chapter of the platform had an assigned number. For the relevant chapter of the study this number was 34.

The visualisation of the process shows that there was a decrease in learning motivation during the text-heavy parts like theory and application. The interactive parts of the platform like the samples and formulas were able to increase the motivation noticeable. Compared to the prototypical implementations that were tested in an experimental laboratory study before (Bauer et al., 2019b) the repetition could enhance the motivation even more. This may indicate that the improvements regarding the insertion of interactive tests and quizzes could lead to a better learning motivation.

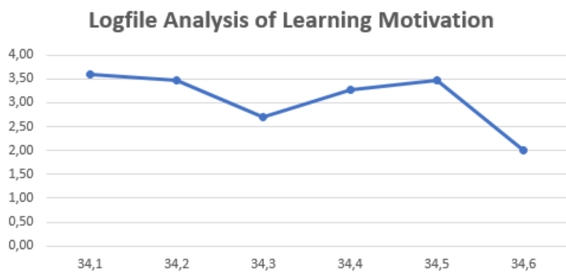

Figure 7: Process of learning motivation measured via the self-report mechanism during the e-learning session.

In sum over all participants the system made 284 suggestions of suitable subsequent sections on the basis of the self-report based adaptive navigation support. 217 of these suggestions were followed by the users which means that around three-fourths of the system-based suggestions were likely seen as useful. In comparison, for the Link Annotation approach of the previous study, only 65% of the suggestions were followed (Bauer et al., 2019b).

Table 1: Encoding of the sections of the chapter and means of the motivation rating.

Section of the chapter	Encoding	Mean of the motivation rating
Orientation	34.1	3.59
Theory	34.2	3.47
Application	34.3	2.71
Interaction	34.4	3.26
Repetition	34.5	3.46
References	34.6	2.00

4.2.3 Analysis of the Elicitation of the Instructional Design

Research Question (b): Does the Instructional Design has an Influence on the Learning Motivation?

To investigate this research question, correlation and regression analyses were conducted for the instruments measuring current motivation (FAM) and the instructional design (IMMS).

Statistically significant results could be found for situational interest and relevance (r=0.365, p=0.001), situational interest and confidence (r=0.289, p=0.010) and situational interest and satisfaction (r=0.338, p=0.003).

The factor of situational interest thus is positively correlated with three out of the four examined factors of the instructional design, which means that higher values of situational interest probably will lead to a more positive judgement of the instructional design. For the factor challenge and the instructional design no significant correlations could be found. The factor confidence in success reveals statistically significant positive correlations with the factors relevance ($r=0.251$, $p=0.023$), confidence ($r=0.403$, $p<0.001$) and satisfaction ($r=0.212$, $p=0.046$) of the instructional design. The factor fear of failure only showed a statistically significant positive correlation for relevance ($r=0.259$, $p=0.019$). The positive direction of this correlation was unexpected since the conceptually opposed concept of confidence in success also showed a positive correlation. This may be due to the common distinction between these two approaches as key motives of achievement motivation (hope for success vs. fear of failure) (Schiefele & Schaffner, 2015).

For examining the influence of the instructional design on the learning motivation multiple linear regression analyses were conducted.

For the factor situational interest, the model showed a moderate explained variance (Cohen, 1988) with an adjusted $R^2=0.155$. The factor situational interest is predicted statistically significant by the instructional design, $F(4,59)=3.882$, $p=0.007$. Therein, relevance was the only significant predictor ($\beta=0.271$, $p=0.036$). For confidence in success the model showed also a moderate explained variance with an adjusted $R^2=0.196$. The factor confidence in success is predicted statistically significant by the instructional design, $F(4,59)=4.840$, $p=0.002$. There were two significant predictors within the model, confidence and attention. Confidence had the strongest influence ($\beta=-0.460$, $p=0.001$). Attention also predicted the motivation factor significantly ($\beta=-0.265$, $p=0.038$) although the direction of the coefficient was surprising as it indicates that an increase of attention would lead to less confidence in success.

For the factors challenge and fear of failure no statistically significant influences could be found within the models.

4.2.4 Analysis of the Mediation-effect of Current Motivation Mediated through Emotional State on the Test-results

Research Question (c): How Does the Learning Motivation Affect the Learning Results?

The already described process model of Rheinberg et al. (2000) postulates an indirect influence of the current motivation on the learning results. Therefore, a mediation analysis was conducted, relying on the mediation model displayed in figure 8. The measures of the emotional states two, three and four were used since these served as the mediators in the first study with the non-adaptive version of the platform (Bauer et al., 2018c). Measure one was excluded since it was not part of the actual learning session during the first study and instead was measured before the orientation as a baseline.

Before conducting the mediation analysis, the descriptive statistics of the parts of the analysis are examined. Overall, the students showed a moderate situational interest ($M=4.38$, $SD=0.82$) and confidence in success ($M=4.58$, $SD=1.02$). The learning material was rated challenging ($M=5.32$, $SD=0.72$) but there was no distinct fear of failure ($M=3.20$, $SD=1.15$).

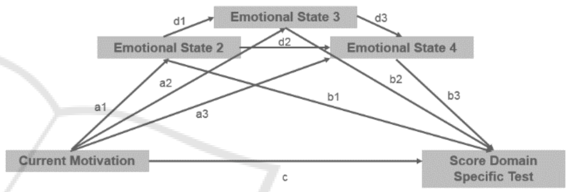

Figure 8: Mediation model of current motivation, emotional state and test results.

The overall ratings of the emotional state of the measures showed a moderate positive arousal ($M_{ES2}=4.23$, $SD_{ES2}=0.93$; $M_{ES3}=4.23$, $SD_{ES3}=0.97$, $M_{ES4}=4.37$, $SD_{ES4}=0.89$) a minor negative arousal ($M_{ES2}=2.81$, $SD_{ES2}=1.01$; $M_{ES3}=2.75$, $SD_{ES3}=1.01$; $M_{ES4}=2.64$, $SD_{ES4}=1.01$) and rather positive valence ($M_{ES2}=4.90$, $SD_{ES2}=1.01$; $M_{ES3}=4.99$, $SD_{ES3}=1.13$, $M_{ES4}=5.27$, $SD_{ES4}=0.96$).

Both instruments come with a 7-point-likert scale with values from one to seven.

Also, before the mediation analysis an ANOVA for repeated measurements was conducted. For the three included measures two, three and four no significant differences could be found. With a Greenhouse-Geisser correction the mean positive arousal levels for all four measures showed a statistically significant difference between measures, $F(2.32, 78.97)=5.14$, $p=0.006$, partial $\eta^2=0.131$. Statistically significant differences were found between measures one and two ($p=0.025$) and between measures one and three ($p=0.002$). In both cases there was a significant decrease in the positive arousal; that means during the text-heavy sections of the platform the positive arousal decreases, which could also be shown for the process of learning motivation (research question A).

For the actual mediation no significant paths from current motivation over the emotional state-measures to the score of the domain specific test could be found which is in contrast to the findings of the study with the non-adaptive platform. There, for example the assumption of the model worked perfectly for the situational interest of current motivation and the positive arousal of the three measures.

In the current study, there were statistically significant paths from the three mediators to the test results for the models of valence and each of the four factors of the current motivation (the path d1→d3→b3 of the model). In no account there were significant paths between the motivation factors and the emotional state (the “a”-paths of the model) which was in contrast to the study with the non-adaptive platform as mentioned before. What remained the same for both studies was the non-significant path c in any combination of factors. Current motivation therefore does not seem to be a significant predictor of the test results. This suggests that the model assumption of an indirect effect might be true but maybe emotional state in this study was not the appropriate mediator in contrast to the study with the non-adaptive platform.

4.3 Limitations of the Study

The data acquisition of the emotional states during the e-learning session was a much bigger challenge compared to the study with the non-adaptive platform were the students had to go through the material stepwise from orientation to repetition. Because of the recommended following sections each learning path could differ from one another. Therefore, the emotional state was captured via pop-up windows that were attached to the end of the relevant sections orientation, theory, samples and formulas. Unfortunately, the pop-ups were not displayed correctly for every participant, which led to data losses (measure two had 20 missing data sets, measure three and four had 13 and 15 missing data sets).

The domain specific test during the study with the non-adaptive platform was paper and pencil-based. The test at the end of the current study was directly implemented in the online-survey and thus contained some other task-types like drag and drop. The test seemed to have a much higher level of difficulty since the average score (M=1.64, SD=1.13) was quite low compared to the moderate score of the test of the prior knowledge. For a maximum of six points this result is not acceptable. The average score of the test of the study with the non-adaptive platform was distinctly higher (M=4.23, SD=1.21).

Another limitation is that more students from non-engineering science programs participated in this study compared to the first one, which also could be an explanation for the worse test results. The sample size itself was rather small and was also determined by the research economic framework conditions. A major challenge was that the platform could not be integrated into a specific lecture since the samples of the addressed study programs that get in contact with micro- and nanotechnologies are too small for meaningful results.

5 CONCLUSIONS

In summary, the existence of the platform itself was seen as a motivational factor and added value for many of the participants. This was clearly shown in the commentary sections at the end of the survey. Many students stated that they wished to have this or a similar platform for their study-relevant contents to support their self-regulated learning as an addition to the actual lectures.

However, the implementation of adaptive navigation support does not seem to support the students in a way that it is truly fostering learning motivation. Compared to the results of the study conducted with the non-adaptive version of the platform the results actually deteriorated as for example the score of the domain specific test could not be predicted by current motivation and emotional state anymore. Therefore, it should carefully be considered whether the additional effort of conceptualizing and implementing adaptive components on top of the already time- and effort-consuming implementation of a learning platform is reasonable.

Possible alternatives may be the integration of short learning videos, interactive tests or gamification elements, which also were named to foster learning motivation in the commentary sections of the current study. Furthermore, direct guidance facilitates the entry into complex topics, especially when previous knowledge is low.

Future studies in this field should try to implement working with e-learning platforms into “real” study-settings during one semester with an actual exam. Since many lectures are relevant for a variety of study programs it could also be possible to shift the adaptation from adaptive navigation support to adaptive presentation like study-specific contents and case-studies. Also, other potential mediators affecting current motivation and learning results should be examined like flow, concentration, time on task or alike.

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