An Initial Evaluation of Metacognitive Scaffolding for Experiential Training Simulators

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Abstract. This paper elaborates on the evaluation of a Metacognitive Scaffolding Service (MSS), which has been integrated into an already existing and mature medical training simulator. The MSS is envisioned to facilitate self-regulated learning (SRL) through thinking prompts and appropriate learning hints enhancing the use of metacognitive strategies. The MSS is developed in the European ImREAL (Immersive Reflective Experience-based Adaptive Learning) project that aims to augment simulated learning environments throughout services that are decoupled from the simulation itself. Results comparing a baseline evaluation of the 'pure' simulator (*N*=131) and a first user trial including the MSS (*N*=143) are presented. The findings indicate a positive effect on learning motivation and perceived performance with consistently good usability. The MSS and simulator are perceived as an entity by medical students involved in the study. Further steps of development are discussed and outlined.

Keywords: self-regulated learning, metacognitive scaffolding, training simulator, augmentation.

1 Introduction

Self-regulated learning (SRL) and especially metacognition, is currently a prominent topic in technology-enhanced learning (TEL) research. Many studies provide evidence of the effectiveness of SRL in combination with metacognitive scaffolding (cf. [1, 2]). Self-regulated learning refers to learning experiences that are directed by the learner and describes the ways in which individuals regulate their own cognitive and metacognitive processes in educational settings (e.g. [3, 4]). An important aspect

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of self-regulated learning is therefore the learners' use of different cognitive and metacognitive strategies, in order to control and direct their learning [5]. These strategies include cognitive learning strategies, self-regulatory strategies to control cognition (i.e. metacognitive strategies) and resource management strategies. Self-regulated learning also involves motivational processes and motivational beliefs [4]. It has been shown that good self-regulated learners perform better and are more motivated to learn [6] than weak self-regulated learners. TEL environments provide opportunities to support and facilitate metacognitive skills, but most learners need additional help and guidance [7] to perform well in such environments.

In the EU project, ImREAL[1] (Immersive Reflective Experience-based Adaptive Learning), intelligent services are being developed to augment and improve experiential simulated learning environments – including one to scaffold metacognitive processes. The development of the scaffolding service focuses on the salient and timely support of learners in their metacognitive processes and self-regulated learning in the context of a simulation environment. Herein we report a concrete study examining the medical training simulator provided by EmpowerTheUser[2] augmented with the ImREAL Metacognitive Scaffolding Service (MSS). The service will provide prompts and suggestions adapted to a learner's needs and traits of metacognition and aiming at enhancing motivation towards the learning activity in the simulation. While the aspect of supporting metacognition needs to be integrated in the learning process, the according service will be technically decoupled from the specific learning system itself. Overall, the research presented investigates the effectiveness and appropriateness of the service and the scaffolding it provides. To allow a more detailed examination of the issues, we address four sub questions:

1. **Is self-regulated learning supported?** For the evaluation and analysis of self-regulated learning we distinguish between the *general learning approach* (i.e. application of cognitive, metacognitive strategies), and the *metacognitive and specific learning processes in the simulation* (i.e. cognitive, metacognitive strategies or actions within simulator context); thereby, learning and metacognitive scaffolding in the simulation may optimally, and on a long-term basis, influence the general learning approach of a learner. That means learning in the simulation in combination with metacognitive scaffolding may optimally influence the general learning approach. If this approach is successful it may have also an influence on SRL on a long-term basis.
2. **Does the simulator augmentation through the service lead to better *learning performance*?** The learning performance refers to the *(objective or subjective/perceived) learners' knowledge/competence acquisition and performance* in the learning situation and to the *transfer* of acquired *knowledge* to other situations.
3. **Does the simulator augmentation through the service increase *motivation*?** The aspect of motivation addresses the motivation to learn, i.e. the structures and processes explaining learning actions and the effects of learning [8].

[1] `http://www.imreal-project.eu`
[2] `http://www.empowertheuser.ie`

4. **Is the service *well integrated* in the simulation and learning experience?** This refers to the question whether the scaffolding interventions provided during the simulation via the MSS are perceived by learners as appropriate and useful – in terms of their content, context and timing.

In order to answer these evaluation questions the paper is organized in the following structure. Section 2 gives an overview of the MSS and outlines related work. Section 3 presents the simulator and its normal usage. Section 3 gives an overview of the MSS and outlines related work. In section 4 the experimental design of the study is introduced and section 5 includes the according results. These results are discussed in section 5. Section 6 provides a conclusion and an outlook to further research.

2 Metacognitive Scaffolding – Background and Technology

Scaffolding is an important part of the educational process, supporting learners in their acquisition of knowledge and developing their learning skills. Scaffolding has been a major topic of research since the pioneering work of Vygotsky (e.g. 1978 [9]) and the key work of Bruner, Wood and colleagues (cf. [10]). Bruner [11] identified several aspects which should be considered when providing feedback to students such as form and timing.

Work on the use of scaffolding with the help of computer-based learning environments has been extensive (cf. [12]). Originally, the emphasis was on cognitive scaffolding which has many forms (cf. [13]). In the last ten years there has been a move towards research in metacognitive scaffolding (e.g. [14–17]) as well as in the use of metacognitive scaffolding in adaptive learning environments (e.g. [18–21]).

Other forms of scaffolding have also been explored both in educational and technology enhanced learning contexts – such as affective scaffolding and conative scaffolding. Van de Pol et al. [14] sought to develop a framework for the analysis of different forms of scaffolding. In the technology enhanced learning community, Porayska-Pomsta and Pain [22] explored affective and cognitive scaffolding through a form of face theory (the affective scaffolding also included an element of motivational scaffolding). Aist et al. [23] examined the notion of emotional scaffolding and found different kinds of emotional scaffolding had an effect on children's persistence using a reading tutoring system.

There are different forms of metacognitive scaffolding. Molenaar et al. [2] investigated the distinction between structuring and problematizing forms of metacognitive scaffolding and found that problematizing scaffolding seemed to have a significant effect on learning the required content. They used Orientation, Planning, Monitoring, Evaluation and Reflection as subcategories of metacognitive scaffolding.

Sharma and Hannafin [24] reviewed the area of scaffolding in terms of the implications for technology enhanced learning systems. They point out the need to balance metacognitive and “procedural” scaffolds since only receiving one kind can lead to difficulties – with only procedural scaffolding students take a piecemeal approach, and with only metacognitive scaffolding students tend to fail to complete their work. They also argue for systems that are sensitive to the needs of individuals.

Boyer et al. [25] examined the balance between motivational and cognitive scaffolding through tutorial dialogue and found evidence that cognitive scaffolding supported learning gains while motivational scaffolding supported increase in self-efficacy.

The aim of the ImREAL project is to bring simulators closer to the ‘real world’. As part of training for a diagnostic interview, in the ‘Real World’ a mentor sits at back observing and providing occasional input / interventions as necessary. The MSS has been developed to integrate into the simulator learning experience as an analogue of a mentor, sitting alongside the simulator to provide scaffolding. The ETU simulator supports meta-comprehension and open reflection via note taking.

For this trial metacognitive scaffolding was provided using calls to a RESTful [26] service developed as part of the ImREAL project. The service utilises technology initially developed for the ETTHOS model [27] and presents Items from the Metacognitive Awareness Inventory [28] according to an underlying cognitive activity model, matched to Factors in the MAI. In this way the importance of the tasks being undertaken by the learner is clear scaffolding is developed in order to match a learners’ cognitive activity to metacognitive support.

The scaffolding service supplements the pre-existing ETU note-taking tool, both of which are illustrated in Figure 1 below. The text of the thinking prompt item is phrased in order to elicit a yes/no response. If additional context / rephrasing has been added by the instructional experts that is displayed before the open text response area. A link that activates an explanatory text occurs underneath the text input area, as well as a “Like button” which can be selected and the submit action.

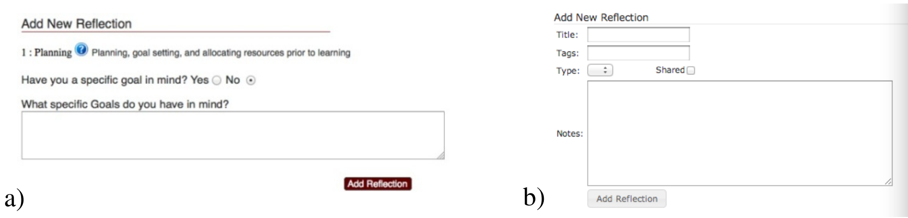

Fig. 1. a) MSS Interface b) ETU Note-taking tool

3 Overview of Simulator and Normal Usage

For this research the ETU Talent Development Platform was used, with training for medical interview situations. The user plays the role of a clinical therapist and selects interview questions from a variety of possible options to ask the patient. When a question is selected a video is presented that shows the verbal interaction of the therapist with the patient (close up of the patient, voice of the therapist) and the verbal and non-verbal reaction of the patient (close up of the patient). Starting the simulation, users can choose between two types of scenarios (Depression and Mania), which offer the same types of subcategories: Introduction and negotiating the agenda, eliciting information, outlining a management plan and closing the interview.

After a scenario is chosen, the user may simulate the interview as long as they prefer or until the interview is "naturally" finished. Furthermore, the users could have as many runs of the simulation as they want and could choose a different scenario in the following attempts. When going through the simulator the student obtain scores. The simulator performance scores are a measure of the students' potential to perform effectively in a real interview. In this study we focused only on the Depression interview scenario. A screenshot of a typical interaction within the ETU system is show below in Figure 2.

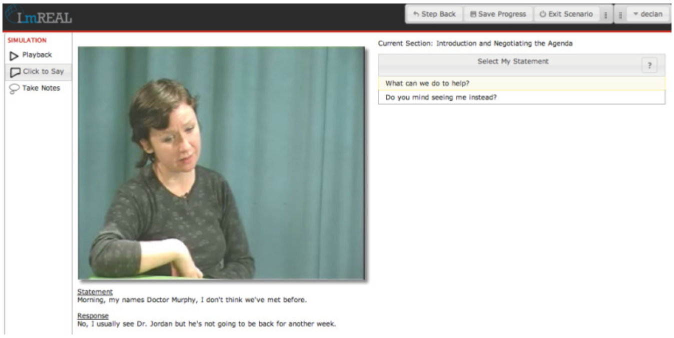

Fig. 2. Screen shot of the EmpowerTheUser Simulator. The scenario of diagnosing a patient with clinical depression is just beginning.

4 Experimental Design

4.1 Cohort

143 medical students participated in the study and performed the simulation as part of their second year (2011/2012) medical training at Trinity College, Dublin (TCD). They were on average approximately 22 years old (40% male vs. 60% female, 80% Irish). In addition, these results are compared, as far as they have been assessed at both time points, to a baseline evaluation based on using the simulator without ImREAL services. In the baseline evaluation, 131 TCD medical students from the previous year group (2010/2011) participated (cross-section design).

4.2 Measurement Instrument

ETU Simulator. Within the simulation learning performance is assessed by tracking scores for each of the 4 subsections, as well as dialogue scores and notes are recorded that were written in a note pad for reflections.

Questionnaire on Self-Regulated Learning. Self-regulated learning skills were measured by the *Questionnaire for Self-Regulated Learning* (*QSRL*; [29]). The QSRL consists of 54 items, which belong to six main scales (Memorizing / Elaboration / Organization / Planning / Self-monitoring / Time management) and three subscales (Achievement Motivation / Internal attribution / Effort). In the online version of the questionnaire, respondents indicate their agreement to an item by moving a slider on an analogue scale between the positions “strongly disagree” to “strongly agree”. The possible score range is 0-100 in each case, with higher values indicating a better result.

Survey Questions on Use of ETU, Experience in Performing Clinical Interviews and Relevance of the ETU Simulator. In order to control possible influences of prior experience with the respective simulated learning environment or real world medical interviews, their experiences were assessed through three survey questions. The following survey question assessed the relevance of the simulator with answer options ranging from “not relevant at all” to “very relevant”.

Thinking Prompts. Triggers that made calls to the MSS were inserted into the practice phase of the simulator but not available during ‘live/scored usage’. The triggers were created using the ETU authoring platform and made a call to the MSS requesting a prompt of a particular Factor (Planning, Information Management, Comprehension, Debugging or Evaluation). As explained above, each Factor consisted of a number of Items or *Thinking Prompts.* An item was not redisplayed once a reflection had been entered with it.

Motivation. Motivation was assessed with four survey questions referring to learning more about clinical interviews, improve own interview skills, performing a good interview during the simulation and applying what has been learned in a real interview.

Workload. Measures of workload were assessed by six subscales of the NASA-TX [30, 31] with a score range of 0-100. In this case higher values indicate a higher workload. An overall workload score was calculated based on the subscales by computing a mean of all item contributions. In contrast to the original NASA-TLX, students did not mark their answers to an analogue scale, but entered digits between 0-100 into a text field.

Usability and Service Specific Integration. The Short Usability Scale (SUS, [32]) consists of ten items with answer options of a five-point-Likert-scale ranging from “strongly disagree” to “strongly agree”. The raw data were computed to an overall SUS score. The overall SUS score ranged from 0-100 with higher values indicating higher usability. Additionally to the SUS questions, three service specific usability questions were administered regarding the relation of the prompts to the rest of the simulation and obvious differences. The answer options were the same as for the SUS.

Learning Experience with MSS. Learning experience with MSS was measured by 10 questions referring to helpfulness and appropriateness of the MSS thinking prompts within the simulator with answer options on a 5-point-Likert-scale ranging from “not at all” to “very much”. In addition, a free text comment field was provided.

Procedure. The baseline evaluation, using the pure simulator, was conducted in mid-February and beginning of March of 2011; the first user trial was carried out in Dublin from mid-February until the beginning of March of 2012. The TCD medical students used the ETU medical training simulator.

Data collection was carried out during the simulation (e.g. ETU scores, MSS data) and after learning with the ETU simulator (questionnaire data). At first the students worked on the simulation for as long as they wanted and could choose between two scenarios: Mania or Depression. After they were finished they were directed to the online questionnaires. In this stage they filled in the survey questions on relevance and on motivation, NASA-TLX, SUS, questions on prompts, learning experience and the QSRL.

After working on the simulation in the TCD course students still had access to the ETU simulator via the internet for approximately two weeks. It was not mandatory to use the simulation in the medical course at TCD or to participate in the evaluation.

5 Experimental Results

PAWS Statistics, version 18.0 [33] and Microsoft Excel (2010) were used for statistical analyses and graphical presentations. If not explicitly mentioned, statistical requirements for inference statistical analyses and procedures were fulfilled. For all analyses the alpha level was α=.05. Due to an unbalanced number of participants in the samples in regard to comparisons of the first user trial and baseline evaluation appropriate pre-tests have been performed and the according values are presented.

This section focuses mainly on the first user trial evaluation based on using the ETU simulator with the integrated MSS ImREAL services.

5.1 Log-Data

ETU Simulator – Descriptive Data. All students of the first user trial reported that they have never used the ETU medical training simulator before. Nonetheless, they were quite experienced in conducting clinical interviews, since 97% reported to have already performed at least one, but only 15 % had experienced interviewing a psychiatric patient.

A comparison of the first user trial and the baseline evaluation showed that duration time in minutes (M_{base}=17.89, SD_{base}=11.15; M_{1UT}=15.45, SD_{1UT} =6.81) and scored points (M_{base}=31.34, SD_{base}=6.33; M_{1UT}=27.61, SD_{1UT} =5.91) in the simulation decreased from baseline evaluation to the first user trial (duration time: $t_{211,49}$=2.17, p=.031; score: t_{272}=5.10, p<.001). These results show that students spent on average less time in the simulator and reached lower scores. This is rather surprising, because, students of the baseline cohort and first user trial cohort were similarly experienced whereas the participants of the first user trial worked with the additional MSS. In this case longer duration time was expected for the cohort of the first user trial.

Metacognitive Scaffolding Service (MSS) Comments. 10 comments have been collected by MSS learning experience questionnaire free text comment field. The participants provided interesting comments, which however referred more to the simulator than to the MSS. This implies that the MSS seems to be perceived as well integrated in the simulation, because students do not seem to differentiate between the additional service and the simulation itself. The participants pointed to sometimes inappropriate prompts in combination with the simulator in situations, especially, when only one answering option was available in the dialogue with the patient and they were asked to think about their strategy. Nevertheless, one learner recorded that "*I am learning a lot actually, it is amazing how much you can miss just by asking a question in a slightly different way! I keep going back a step and looked through the other options to see where the scenario goes. Usually I've picked the most suitable one, but not always. Sometimes I am surprised about how much I would have missed!!*".

Prompts Analysis. Five different types of prompts were presented according to the five MAI phases described in section 3. In total 2001 prompts (Planning: 469, Information Management: 752, Monitoring: 425, Debugging: 301 and Reflection: 54) were shown to 50 students. The other students ignored the up-popping prompts. Every student who used the practice facility in the simulator was presented with a pop-up suggesting they reflected. Clicking on that pop-up would move the simulation to the MSS screen (Figure 2a). The relative frequency of the prompts was compared to the expected frequency based on the probability of available prompts for each phase. The results indicate that the learners were scaffolded more often in the second phase "Information Management" and were less scaffolded in the reflection phase as could have been expected ($\chi^2_{(4,0.95)}$= 314.55, p<.001, Figure 3). On the one hand, learners seem to need more assistance in effectively processing information by hints to use more organizational, elaborative, summarizing or selective learning strategies. On the other hand they are rather confident in the reflection phase and wave the offer of scaffolds.

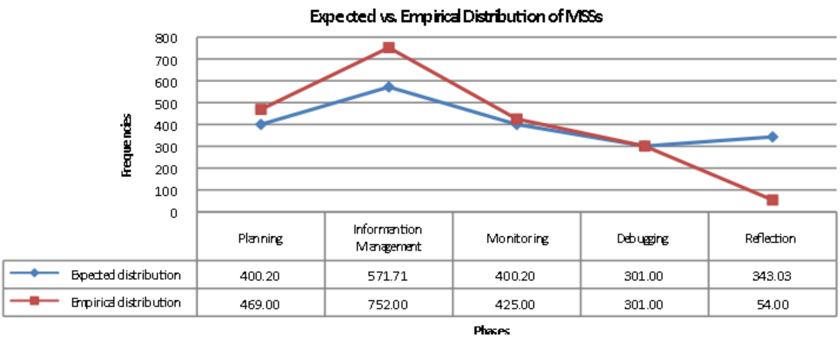

Fig. 3. Comparison of the expected and empirical distribution of metacognitive scaffolds for the five phases of Schraw's Metacognitive Awareness Inventory

5.2 Questionnaire Data

QSRL. The quantitative results of the MSS are a little surprising, because students estimated the use of cognitive learning strategies, especially elaboration strategies, relatively high. In general, all SRL scores are located above the center point of the score range and indicate positive results for all cognitive and metacognitive strategies. However, a stronger use of elaboration strategies is reported (t_{20} = 3.34, p=.003) in the first user trial. It needs to be explicitly stated that this is not an unfavorable result as such as elaboration strategies are strategies of deeper learning [34], which should be further supported by scaffolding services.

A comparison to the baseline study shows no significant increase in any of the usage of reported learning strategies.

Motivation. 38 participants filled in the motivation questions. The results show that the scores were on a high motivation level around 3.16-3.49 on a 4-point-Likert rating scale. This implies that the students were very motivated to learn about the clinical interview during the simulation, to improve their interview skills, perform a good interview during the simulation and to apply what they have just learnt in the simulation in a real world clinical interview context. Furthermore, a comparison of the overall motivation scores assessed immediately after the simulation of the first user trail and immediately after the baseline evaluation reveals significant higher motivation scores for the MSS trial (M=3.35, SD=.4.14) compared to the baseline (M=2.48, SD=.73; $t_{118.47}$=-8.64, p<.001).

Workload. A moderate overall workload could be observed. It has to be noted at this stage that for a learning environment it should not be aimed at reducing the workload to a minimum; rather, the challenge should be at an appropriate, medium level of challenge – in an optimal case adapted to the individual learner. Participants reported the highest, but still moderately pronounced, load for effort. This subscale refers to the mental and physical resources that had to be mobilized to accomplish the task. Consequently, the result for effort can be relegated rather to mental than physical demand. Yet the simulation is a complex program that supports and requires active learning processes; a reduction of mental demand is somewhat challenging, but could possibly be realized by improving the MSS and addressing the challenge to reduce repetitions and provide only appropriate scaffolds. Furthermore, the second highest score was observed for performance (see Figure 4), showing that the students felt they successfully accomplished what they were supposed to do. Performance scores (referring to subjective/perceived learning outcome) even increased for the first user trial (M=54.83, SD=17.90) compared to the baseline evaluation (M=43.00, SD=23.68) significantly (t_{109}=-2.63, p=.01). A t-test for independent groups remains insignificant comparing overall workload scores for the first user trial (M=44.19, SD=10.86) and baseline evaluation (M=44.81, SD=12.011; $t_{75.52}$=.27, ns.).

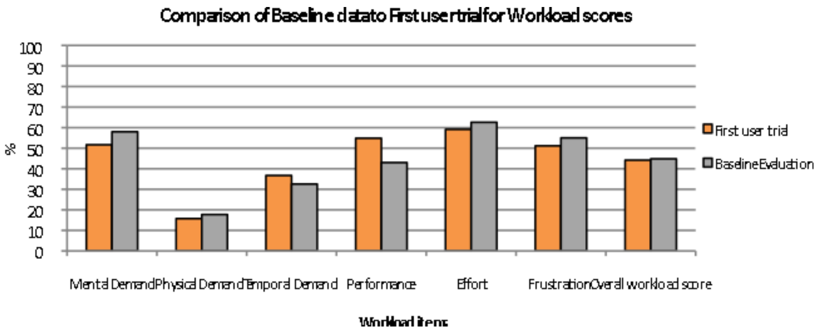

Fig. 4. Comparison of Baseline and first user trial data for workload

Usability and Service Specific Integration. No differences could be observed between the rather high usability overall scores for the first user trial (*M*=62.50, *SD*=17.90) and the baseline evaluation (*M*=62.80, *SD*=16.08; $F_{57.90}$=.90, ns.).

With respect to service specific integration with the ETU medical training and MSS prompts the majority of the students ratings were positive with 21 out of 33 stating they felt supported during their learning process by the MSS and that the service was well integrated in the system (*M*=3.26, *SD*=.40).

Learning Experience with MSS. The learning experience with the MSS was relatively positive. More than 63% of the participants perceived the MSS learning experience overall as very much helpful and appropriate. The high score for the individual items were all above the center point of the scale, which underlies this encouraging impression.

6 Discussion

In this paper we examined the effectiveness and appropriateness of the MSS. Results of the first user trial have been reported, involving the ETU medical training simulator augmented with the MSS. These results have been compared to a baseline evaluation where the 'pure' simulator was administered without any additional ImREAL services. Addressing the evaluation questions stated in the introduction section:

Is Self-Regulated Learning Supported? Even though self-regulated learning and metacognitive scaffolding are closely connected, because the SRL process heavily relies on applying cognitive and especially metacognitive learning strategies and techniques, no changes in SRL profile could be observed comparing the first user trial to the baseline data. This is because influencing self-regulated learning aspects is rather a long-term process [35]. This result might also be explained by having a look at the usage frequency of the simulator. The students were confronted with the simulation only in the TCD course and no one had used the simulation before.

Furthermore, duration time of working with the simulator, which was on average less than half an hour, might not be too short to change a rather stable learning approach.

For future studies the application of a longitudinal-evaluation-design could be suggested instead of a cross-section evaluation, to better meet the requirements of a longer-term process. In addition, teachers' or supervisors' judgments on SRL performance could be included to assess their observations on potential changes in learners' daily learning behavior. However, the last point might be difficult to realize in an university setting with more than 140 students in a course.

In general, all SRL self-reports were positive, indicating a higher use of elaboration strategies compared to memorizing strategies. Elaboration strategies represent strategies of deeper learning [34]. Nevertheless, fostering memorizing/rehearsal strategies might be taken up as an idea for improving the MSS. Assuming that the participants in the evaluation trials constitute a representative sample of ETU simulator users, ImREAL could start from this result and aim at improving users' rehearsal strategies through the provision of appropriate scaffolding. Of course, this strategy type should not be the only one to be supported. Rehearsal strategies help the learner to select and remember important information, but may not represent very deep levels of cognitive processing [34]. As a result, ImREAL services should especially try to further support elaboration as well as organizational strategies. In the ImREAL pedagogical framework learning [36] is seen as a cyclic process of three phases: forethought, learning and reflection. These individual phases are already represented in the ETU system, but not covered comprehensively. As described above, medical students do not tend to use the ETU simulator very often and if they do they undertake the interview scenario only for a short period of time. Therefore, reflection and coverage of the SRL phases should be further extended and supported by the ImREAL MSS.

Does the Simulator Augmentation through the Service Lead to Better Learning Performance? Results concerning the learning performance draw a clear picture. The actual objective data collected by the ETU simulator demonstrates that overall scores decreased from the baseline evaluation to the first user trial. Accordingly also self-reports on performance decreased. A decrease in self-report scores is expected, if actual performance is lower and may have been influenced by the MSS encouraging learners to think about their learning process and therefore make an accurate estimation of their performance. Accurate self-estimation might be seen as a factor to regulate the own learning approach. One reason why overall scores decreased could be the fact that the students spend less time working with the simulator. This is due to a change in the curriculum

Does the Simulator Augmentation through the Service Increase Motivation? Motivation scores increased from the baseline evaluation to the first user trial.

In addition to the consideration of motivation as a state characteristic, motivational beliefs (motivational traits in terms of being more stable and outlasting than state motivation) can be further influenced by positive sounding scaffolds and hints to optimize learning. If students see the prompts as support of their learning approach a positive attitude to the whole learning process can be expected and could explain the current result, because these motivational beliefs are factors influencing the initial motivation of the learner [37].

Is the Service Well Integrated in the Simulation and Learning Experience? Results on usability of the whole system (simulator + MSS) and service specific integration provide evidence that the MSS is well integrated in the simulation and leads to real augmentation. This is not only demonstrated by the positive scores on the service specific integration questions, but also by user comments, which were overall quite positive. Such positive results may be attributed to the MSS operating in an appropriately timely and salient manner, with the pop-up triggers appearing at apposite times created by the instructional design experts. Also the RESTful interface allows calls to be made to an ETU simulator-specific interface for the MSS, ensuring there are no obvious presentational and interactional differences between the hosting simulator and the MSS.

7 Conclusions and Outlook

The results above demonstrate a clear advantage in providing a MSS to augment an experiential training simulator, leading to more engaged, motivated learners without overly burdening them or interrupting the flow of their learning experience. With respect to the actual learning performance no positive effect could be identified. This would be desirable to investigate in more detail in future studies. These further studies should optimally be realized in a longitudinal-evaluation-design, as well as an assessment of real-world performance on medical interviews (i.e. learning transfer).

The collecting and monitoring of the development of motivation throughout both evaluation runs is important, because in the next version of the ImREAL MSS there will be a strong focus on extending it by ‘affective scaffolding’. As a result, the data from the first user trial evaluation (with metacognitive scaffolding ‘only’) will serve as benchmark for a comparison with evaluation outcomes for the affective metacognitive scaffolding, thus allowing to investigate the additional benefit of the affective part.

The MSS will be integrated within additional experiential simulators to investigate the service’s capabilities for generalization and integration within different systems and usage cases and to further evaluate its effect on learning experience.

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