Effectiveness of a 3D simulation tool to teach the designing of metal removable partial dentures: A mixed-method study

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ABSTRACT

Objective: Acquiring insights into the framework design of metal-based removable partial dentures (mRPD) is a current challenge in dental education. The aim of the present study was to explore the effectiveness of a novel 3D simulation tool to teach designing mRPD by investigating the learning gain and the acceptance and motivation toward the tool of dental students.

Methods: A 3D tool based on 74 clinical scenarios was developed for teaching the design of mRPD. Fifty-three third year dental students were randomly divided into two groups, with the experimental group (n=26) having access to the tool during one week while the control group (n=27) had no access. Quantitative analysis was based on a pre- and posttest in order to evaluate the learning gain, technology acceptance, and motivation towards using the tool. Moreover, qualitative data was collected by means of an interview and focus group to get additional insights into the quantitative results.

Results: Although the results showed a higher learning gain for students in the experimental condition, the study did not find a significant difference between both conditions based on quantitative results. However, during the focus groups, all students of the experimental group revealed that the 3D tool improved their understanding of mRPD biomechanics. Moreover, survey results revealed that students positively evaluated the perceived usefulness and ease of use of the tool and indicated to have the intention to use the tool in the future. Suggestions were made for a redesign (e.g. creating scenarios themselves) and further implementation of the tool (e.g. analyzing the scenarios in pairs or small groups).

Conclusion: First results of the evaluation of the new 3D tool for teaching the design framework of mRPD are promising. Further research based on the design-based research methodology is needed to investigate the effects of the redesign on motivation and learning gain.

Key words: dental education, educational technology, 3D simulation, motivation, learning gain, removable partial denture

INTRODUCTION

In 2009, 94% of the combined populations of England, Wales and Northern Ireland had at least one missing tooth. [1] Partial edentulism affects the majority of adults. The number of partially edentulous patients will continue to increase over the next 15 years. [2]

Besides implant-supported fixed restorations for replacing lost teeth, removable dentures are still widely used in clinical practice. Having a functional dentition, whether this is natural or prosthetic, is important for a good oral health-related quality of life. [3,4] Moreover, a removable dental prosthesis represents a valid and economic attractive alternative if treatment with oral implants is contra-indicated. [5,6] In case of partial edentulism, metal removable partial dentures (mRPD) can be applied by the incorporation into the denture of metal clasps and framework. However, despite their functional and aesthetic advantages, patient acceptance of removable dentures is relatively low. [7,8] This low acceptance may be due to poor framework design which is often caused by a lack of educational experience and limited training.[9-13] It has been found that many dentists do not analyse the study models or they transfer this responsibility to their technical staff who have not the ability to determine the best design and axis of insertion-removal for each mRPD patient. [14] Acquiring better insights in how to train framework design for dental prosthesis is a current challenge and a prerequisite for the formation of well-trained dentists.

Over the last 50 years, technology has become increasingly present in all areas of human society, including education.[15] The increased digitalisation can be seen as an opportunity to enhance flexibility in education and support a more (inter)active, collaborative and student-centred approach to learning and instruction. In the field of dentistry more particularly, digital tools create a lot of opportunities to facilitate the learning of complex clinical activities in a preclinical setting. [16-19] Hooper for example showed evidence that training with the help of clinical scenarios promotes deeper learning. [20] Some tools to teach the design of mRPD have been described in the literature and showed a students' preference for the integration of 3D visualization of virtual casts into the curriculum.[21-24] However, research on the effectiveness of these tools by means of qualitative and quantitative analysis is lacking within the field of dental education. There is a need to meet this gap by focusing on the effectiveness of the 3D simulation tool for teaching removable prosthesis regarding both cognitive and affective outcomes. Today, the dental educational staff of KU Leuven has developed a 3D simulation tool to train undergraduate students in designing mRPD, based on 74 clinical scenarios. Based on previous educational research on technology implementation beyond the domain of dental education, we decided to use the technology acceptance model to measure students' expectations and students' experiences with the new tool.[25,26] Additionally, the intrinsic motivation inventory (IMI) permits to measure the student's motivation while using a tool. [27] The IMI is based on the self-determination theory (SDT) claiming that to be motivated means to be moved to do something, and motivated people are energized and activated to complete a task. [27] Motivation is not considered to be a general trait, but assumed to be situated and changeable as a function of instructional activities that take place in education.[28] For that reason it is important to investigate students' motivation when developing and implementing innovative learning tools to get a better insight in how they interact with the tool and to provide guidelines for future (re)design and implementation.

The aim of the present study was to explore the effectiveness of a novel 3D tool to teach designing mRPD by investigating the learning gain, the acceptance, and motivation toward the tool of third year students at the dental Faculty of the KU Leuven. The effectiveness of the tool was studied using an experimental design in which half of the students had access to the tool (experimental group) while the other half did not (control group).

The following research questions (RQ) were formulated:

- RQ 1: Does the 3D simulation tool increase the learning gain? Based on previous research, this study hypothesizes that the use of a 3D tool can increase students' learning gain.[20]

- RQ 2: Does experience with the 3D simulation tool have a positive impact on the students' acceptance towards the new technology? Based on previous literature on educational technology in higher education, we hypothesize that after using the tool, students' perception of its usefulness, ease of use, and behavioral intention to use the 3D tool will be higher compared to the expectations before having experienced the tool. [25,26] This means that we expect that experiences will exceed expectations as was found in previous research.

- RQ 3: How motivated are students to use the 3D simulation tool and what are students' suggestions for improving the motivation to use the tool? As no prior research is found focusing particularly on this tool, no hypothesis can be put forth and this question will be answered more exploratively.

MATERIEL AND METHODS

Approval to conduct the study was obtained from the university's ethical review board (G-2021-4128-R2(MIN)). As visualized in Figure 1.A, the study was conducted one week after the theoretical lessons on mRDP had been finished, during a 3-week period, with third year dental students of KU Leuven as participants in the study. The final semester exam was conducted two weeks after the study.

2.1. Development of the 3D simulation tool

The dental educational staff of KU Leuven has developed, in collaboration with the BioMedical Technology Lab of KU Leuven, a 3D simulation tool to teach how to design a mRPD (Figure 1. B). The tool can be used to evaluate a number of framework outcomes. Based on the remaining teeth and the information provided by the patient regarding the importance of esthetics, oral hygiene, bite force level and possibly other relevant information, a mRPD design is suggested. The type of design, rigid or resilient, is indicated. Within each scenario, the student is asked to judge whether the proposed design is correct or not. If the student chooses the 'not correct' answer, he/she is asked for justification by selecting one out of three proposed reasons for failure. When evaluating the mRPD design, the student has access to the following interactive options:

- View of the design from different angles (top view, rear view, side view).
- Projection of the undercut zones (alternative: suprabulge and infrabulge area) on the abutment teeth.
- Adjustment of fulcrum lines
- Simulation of the movement of the prosthesis when applying a certain force (positive or negative, large or small) at a certain location (vestibular, central, or oral) on the major connector.

There are six learning levels with increasing difficulty. This means that students start practicing in level 1 and ends at level 6, which is the most difficult level.

2.2. Design and procedure of the study

At the start of the experiment, all students were equally divided into two groups. In the experimental group, students had full access to the 3D simulation tool for one week whereas the control group did not. Students of both groups were insisted to not study their course material during the experiment, more particularly during the week between the pre- and posttest in view of controlling for possible confounding variables impacting the evaluation of the tool. All students were asked to complete an individual pre-test, *i.e.* a knowledge test concerning mRPD design, as well as a survey probing the individual's expectations regarding using the tool. At the end of the experimental period, all students were asked to complete a post-test, similar to the pre-test but composed of other cases. Furthermore, participants of the experimental group were asked to complete a survey with questions related to their experience with and motivation while using the 3D tool. After the experiment, all students (also of the control group) had access to the tool. After the final semester exam which was three months after the experiment, two semi-structured focus groups were organized, one to which the participants belonging to the experimental group were invited and one to which participants belonging to the control group were invited. The main objective of the focus groups was to get additional insights into our quantitative results regarding the three research questions. This method is described as explanatory sequential design, wherein individual interviews and/or focus groups are used to explain the results obtained from quantitative surveys.[29]

2.3. Participants

Dental students enrolled in the third year of undergraduate training at KU Leuven were the student population within this study. In total, 90 students (65 female students (72%), 25 male students (28%), M_{age}= 22.5 ± 2.0 years) were invited to participate in the study after having followed the theoretical courses on removable oral appliances and more in particular mRPD design. Fifty-three students gave their informed consent to voluntary participate in the study (45 female students (85%), 8 male students (15%), M_{age}= 22.2 ± 1.7 years) (Table 1). When comparing the sample with the student population concerning gender, we noticed a slight overrepresentation of female students. The students were equally and randomly divided between experimental and control groups (Figure 1B). A drop-out of 10 students was reported due to not finishing the tests (n = 6) or not using the 3D tool during the experimental design (n=4). Although initially two focus groups were organized (one for students from the experimental condition and one for students from the control condition), it turned out that only one focus group took place due to the fact that only one student showed up for the focus group intended towards students from the control condition. This student was initially invited to participate in the control condition but decided not to participate in the experiment. She explained that she deliberately wanted to participate in the focus group to explain why she dropped-out and she wanted to share her opinion on the tool as she had used it in preparing for the exam (Table 2). As was planned for the focus group, we had a structured interview with that student about her experiences with tool as further explain in section 2.5. Six students (5 female students, 1 male students) attended the focus group intended for students from the experimental condition.

2.4. Variables included in the pre-and post-test

The online survey was developed using Qualtrics software. Learning gain was tested by a knowledge pre-test and post-test in which eight grouped questions with dilemma assignment type were addressed (See Appendix 1 & 2). The learning gain score was calculated by subtracting the knowledge score on the pre-test from the knowledge score on the post-test.

The students' expectations towards the new tool (measured at time of the pre-test, before experiencing the tool) and students' experiences with the new tool (measured at time of the post-test, after experiencing the tool) were investigated relying on the technology acceptance model including the following scales: perceived usefulness, perceived ease of use, and behavioral intention regarding the tool (Table 3). To measure the students' motivation while using the tool, the post-test survey made use of the intrinsic motivation inventory. The original instrument assesses participants' interest/enjoyment, perceived competence, effort, value/usefulness, experienced pressure and tension, perceived choice, and experience of involvement during a certain activity, thus yielding seven subscales. In the present study, only the scales experienced pressure and tension, perceived competence, effort, interest/enjoyment, and perceived choice were included (Table 3). For scoring the items of expectation, experience, and motivation, a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree) has been used. Internal consistencies were partially satisfactory for technology acceptance and motivation as indicated by Cronbach's alpha (Table 3).

Additional questions were addressed in the post-test measurement provided to the students of the experimental group in an attempt to capture how students used the tool regarding frequency and achieved level ("Did you use the tool?" "How often did you use it?" "How long did you use the tool?" "What learning level have you reached in the tool?"). The-students who indicated that they did not use the 3D tool, although they belonged to the experimental group, were excluded from the study (n = 4).

2.5. Focus groups

Two focus group were organized, one with the experimental group and one with the control group allowing the students to deeper discuss some topics, facilitated by two moderators (two co-authors of the study). Due to a lack of participation in the focus group intended for the control condition, the first focus group turned out to be a semi-structured interview. The interview and focus group were structured by means of a PowerPoint presentation (see Appendix 3). First students were asked about the expectations regarding the results of the study they were involved in, including perceived usefulness, the perceived ease of use and the behavioral intention to use the tool in the future, and their motivation while using the tool. Next, the results of the quantitative data were presented to the students. These two steps were followed by a discussion led by questions as 'Did you expect these results?' and 'Do you have possible explanations for this finding'. Students were also asked for suggestions for improvement regarding instructional design and implementation of the tool in the curriculum. The focus groups were organized virtually, using the video conferencing software Teams. The (focus group) interviews were recorded and transcribed afterwards.

2.6. Statistical analysis and qualitative analysis

In a first step, assumptions were checked to evaluate which tests could be used to test the research hypotheses. Data distribution was verified using the Shapiro-Wilk test. The results indicated that the data were not normally distributed meaning that non-parametric tests should be used. A preliminary analysis was required to confirm the homogeneity of the experimental and control groups. The unpaired data were analysed with the Mann-Whitney test.

In order to answer the first research question, the comparisons of knowledge score between pre- and post-test for the same group were analysed using the Wilcoxon signed rank test. The comparisons of knowledge score between 2 groups were subsequently analysed with Mann-Whitney test. The knowledge scores were compared with the neutral score (score 4 on the 1-to-7 scale) by one-sample Wilcoxon signed Rank test. The linear regression analysis examined the relationship between students' learning gain and their frequency and duration to use the tool, their final reached level within tool, and their motivation while using the tool. The linear regression analysis was conducted with learning gain as the dependent variable, and frequency and duration of using the tool, the achieved learning level, and motivation as the independent variables. To answer the second research question, the means of expectation towards the tool and experience regarding using the tool were compared using the Wilcoxon signed Rank test. The comparison of the mean of expectation and experience with neutral score (score 4 on the 1-to-7 scale) were analysed with one-sample Wilcoxon signed Rank test. Finally, for addressing the third research question, the motivation scores were compared with neutral score (4) by one-sample Wilcoxon signed Rank test. The extracted data were analysed with GraphPad Prism (GraphPad Software, San Diego, CA, USA) (α=.05).

As indicated earlier, qualitative data has been collected as part of the explanatory-sequential approach which is a sequential approach in which the qualitative data is used in the subsequent interpretation and clarification of the results from the quantitative data analysis. In this two-phase approach, the quantitative measures formed the structure in the qualitative analysis, meaning the main objective was not to find new themes based on the qualitative data, but to explain and give insight in the quantitative data and to obtain open suggestions from the students. Qualitative data of both the interview and the focus group were recorded and fully transcribed afterwards. Based on the transcriptions, content analysis was used to generate common experiences and valuable feedback regarding their experience of learning with the 3D tool and with specific attention to the three research questions.[30,31,32] As displayed in Table 2, next to information about the learning gain, the technology acceptance, and the motivation towards using the tool which were the main themes questioned in the survey, the qualitative approach also provided information - rather unexpectedly – about the reasons why students dropped (See 3.1). The qualitative results will be presented per research question, to give better insight in the quantitative results. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

RESULTS

3.1. Preliminary analysis of quantitative data

Regarding the quantitative data, in a first step, we investigated if both groups did significantly differ from each other before the intervention. Results showed that the knowledge pre-test score and the expectation score were not significantly different between experimental and control condition ($p > .05$) (Table 4).

3.2. RQ 1: Does the 3D simulation tool have a positive impact on students' learning gain?

The knowledge post-test scores were significantly higher than the knowledge pre-test scores for both conditions ($p < .05$) (Table 5) meaning that all students gained knowledge about framework design of mRPD. Although it was hypothesized that the 3D tool could positively affect conceptual understanding, no significant learning gain was found between the control and the experimental group ($p = .06$) (Figure 2.A). However, in the focus groups students expressed that the 3D tool helped them to better understand framework design of mRPD. At the end of the focus group, the quantitative results were presented. When students were asked about possible explanations for not finding a significant difference, students expressed that probably some students in the control group had studied their lessons before the post-test.

Students within the experimental group also indicated that they did not have the time to use the tool as much as they initially expected because they were preparing for their exams.

The linear regression analysis permitted to examine the relationship between learning gain and frequency and duration of using of tool, the achieved learning level, and the students' motivation scores. Only the achieved learning level in the tool has been found to be a significant predictor for the learning gain (F=5.73, β =0.55, $t(15) = 2.34$, $p < .05$) meaning that students who reached a higher learning level achieved a higher learning gain (Table 6). During the focus group discussion, one student explained that "the higher level you achieved, the better you understand it".

<u>3.3. RQ 2: Does experience with the 3D simulation tool have a positive impact on the students' acceptance towards the new tool?</u>

All mean scores for expectation and experience regarding using the 3D tool for both conditions were significantly higher from the neutral score ($p < .05$) meaning that students' expectations and experiences were positive (Figure 2.B-C). During the focus group discussion, students expressed that the tool is very useful to improve understanding of framework design of mRPD, to clarify the previous theoretical lessons, and to study specific clinical cases. In addition, three students explained that using the tool made them feel more confident than other students in designing the framework of mRPD on a patient in the clinic. Although it was hypothesized that the scores for technology acceptance would improve after technology use, it has been found that the mean scores for perceived usefulness and perceived ease of use significantly decreased after using the 3D tool ($p < 0.05$). The focus group discussion could partly explain this finding. Students revealed that, although they really liked the tool, there is room for improvement. Students expressed that they felt restricted concerning the clinical cases and the framework design of mRPD design solutions. They would like to be able to propose a clinical case or try other framework designs of mRPD by themselves. Concerning perceived ease of use, students found the tool more difficult to use than expected and students expressed that it took more time to use than they expected.

The mean score of behavioral intention was high (M=5.91±0.65) and did not significantly differ when comparing the scores before and after using the 3D tool ($p > 0.05$) (Table 7). In the focus group, some students suggested that the tool would be suitable for fourth year students when designing this type of prosthesis with patients. Additionally, students expressed that this tool could be used for graduate practitioners if they want to simulate and visualize their design choice regarding the framework of mRPD.

3.4. RQ 3 : How motivated are students to use the 3D simulation tool and what are students suggestions for improving the motivation towards using the tool?

The mean scores for perceived competence, perceived choice, and interest while using the tool were significantly higher than the neutral score ($p < .05$) (Figure 2.D). The mean score for pressure was significantly lower than the neutral score ($p < .05$). The students perceived themselves as competent. They showed interest and a desire to invest themselves in the learning activity. Even if students could use the tool without obligation and perceived no pressure, the semester exam period seemed too close to our study. The students revealed during the focus groups that they were nervous about this. When specifically asking the student about suggestions for improvement in the focus groups, students suggested using the tool in small groups in order to “discuss all design options". As already mentioned earlier, students also suggested simulating scenarios themselves. One student even expressed that it was “frustrated not being able to modify the clinical case designs”.

DISCUSSION

This study was conducted to determine the effectiveness of a new 3D simulation tool to teach the design of metal partial denture by investigating the learning gain, the acceptance and the motivation toward using the tool of third year students at the Faculty of Dental Surgery of the

KU Leuven. The tool under investigation in this study provides the students a three-dimensional representation of mRPD. In addition, the tool allows the students to interact and move the prosthesis according to the answers and design chosen by the student. To the best of our knowledge, no teaching tool for mRPD offered these functionalities.

In dentistry, learning complex clinical activities can be facilitated by digital tools and particularly by using clinical scenarios.[15-19] Although the descriptive results showed a higher learning gain for students in the experimental group (using the 3D tool) and qualitative results show great potential for improving conceptual understanding, our study did not find a significant difference between both groups. This means that the first hypothesis, stating that the use of 3D tool can increase students' learning gain could not be accepted. Students' experience and motivation to use the tool were positive which allowed to accept the second and third research hypotheses.

All students showed a learning gain regardless of their group. In order to limit bias, students were asked not to study the course material during the experiment. Despite this, some students studied the course material during the experiment. Students also mentioned during the focus group that the requirement of not studying the course material during the experiment was the reason to not participate in the study as this felt uncomfortable to "delay starting to study for the exam". In order to increase student compliance, it might be advisable for future studies to be carried out away from an exam period. Furthermore, the small sample size might have impeded finding a significant difference between both groups. Therefore, follow-up studies with larger sample sizes are needed. The factor of achieved level in the tool has been found to be a strong predictor of dental students' learning gain, explaining 31% of the variance in learning gain. Beyond the duration and frequency of use, working each level up to the highest seems to improve understanding of the mRPD desgin. These results are in line with the literature stating that the learning increases with the level of difficulty of the exercise.[33] Thus, it is therefore necessary to advise students to use this 3D tool until the last level.

The students' acceptance of using the tool was positive, although the perceived usefulness and perceived ease of use decreased after using the tool. Indeed, the tool has six learning levels of difficulty and students had access for only one week. In further studies the duration of the intervention should be increased allowing students to use the tool for a longer period. Liaw showed that the perceived usefulness and perceived satisfaction both contribute to the behavioral intention of students to use an e-learning tool.[34] Thus, the students' behavioral intention to use the tool in the future indicates that it could be made available to dentists.

The motivation of using the tool was positive for all students. Based on the self-determination theory (SDT), we know that autonomy, relatedness, and competence are the three basic needs to be motivated.[35] In line with this theory, improving choice to use the tool in your own way, would improve autonomy satisfaction and consequently also motivation for the tool. Using the tool in small groups could possibly increase the need for relatedness and consequently also improve the motivation.

CONCLUSION

This study investigated the impact of a new 3D tool on dental students. Exposure to the 3D tool in dental school could thus increase dentists' interest in designing metal partial dentures. However, due to the small sample size and limitations of the study, further studies are needed to establish the association between the 3D tool and learning gain.

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TABLES

Table 1: Number of participants for the pre- and post-test

	Number of participants	
	pre-test	post-test
Control group	27	24
Experimental group	26	15
Excluded		14
All students	*53*	*53*

Table 2: Excerpts derived from the focus groups.

Theme	Qualitative data
Reasons for drop-out / no participation	*"I know that several of my peers, including myself, did not want to participate in the study because the study design required us to not study the course material during the week of the experiment to not influence the experiment, but this felt counter-productive."* *"It felt uncomfortable to do the exercises, only based on what we had learnt in the course,. For me that does not work and this is the reason why I decided to not participate in the study. However, I used the tool in preparation of the exam and I have an opinion about the tool and this is why I wanted to participate in the focus group, to share my opinion."* *"In our program, we are used to study the course material after a lecture, so I indeed think that this is the reason why there was some drop-out"*.
Parameters influencing the learning gain and perceived usefulness	*"The 3D visualization and simulation makes the content much more concrete and more easy to understand."* *"I had the feeling that the fact that we could use the tool gave us (from the experimental condition) an advantage over the peers that did not yet have the change to use it (control condition). I felt I had a better understanding and I could help my friend who did not yet use the tool in explaining the prothesis."* *"The simulation visualizes the effect of our actions (e.g. active and passive anchor.)"* *"It was useful to view the mouth from different perspectives"* *"The tool really pushed me to think about the content by means of the different questions integrated in each of the cases."* *"It would be even more useful, if I would we able to test our own hypotheses."*

Technology acceptance: including perceived usefulness, perceived ease of use, and behavioral intention.	*"The tool is very easy to handle. I only had some problems during the login."* *"Indeed, it took some time to access the tool for the first time, including the password and login, but once we had access, it was very easy to use."* *"As the tool is still under development, the tool could only be used by twelve students simultaneously, during the experiment this was not a problem, but in preparation of the exam, the tool was often not available. Yet, this also means that the tool was popular to use."* *"I noticed that there were a lot of buttons in the learning environment and in the beginning I did not know the meaning of all these buttons, but after more experience it become more easy to use the tool."* *"I think the tool is especially useful in the educational context, less in the working context. However, if it would be possible in the future to manipulate the simulation yourself, I think it can be useful in our future working context, especially as nowadays, more and more dentists work in interdisciplinary teams and then, the tool could be used to discuss the effect of a certain decision regarding a specific patient."*
Parameters influencing the motivation	*"I prefer using the tool as an application of the theory, rather than using the tool without having the necessary conceptual understanding."* *"The cases should be more challenging when we should use them in group."* *"I look forward to the further development of the tool as I would really like to use the tool to build our patient, our case ourselves."*

Table 3: Survey assessing, expectation and experience, and motivation.

		Cronbach's alpha	
EXPECTATION & EXPERIENCE		Expectation	Experience
Perceived usefulness	- The 3D tool increases my understanding of the content - The 3D tool makes it easier to process the content - The 3D tool increases the quality of my learning process	0.832	0.797
Perceived ease to use	- The 3D tool is clear and easy to understand - The 3D tool does not require much mental energy - The 3D tool is flexible in use	0.623	-0.055
Behavioral intention	- If I had the chance, I would use the tool in the future - I would use the tool in the future if I had access to it	0.739	0.895
MOTIVATION: During the past activity, I felt …			
Perceived competence	- Proficient - Competent - Frustrated - Uncertain about my abilities - That my knowledge and skills were growing		-0.274
Experienced pressure and tension	- A certain pressure - Stressed - Nervous - Relaxed		0.462
Perceived choice	- Feeling that I could do the things that fit me		NA
Effort	- Focused - Effort - Difficulty keeping my attention on the task at hand		-1.342
Interest/enjoyment	- Interested - Fascinated - Bored - Cognitively aroused		0.517

Table 4: Pre-test scores for the variables knowledge score and expectation for control and experimental groups (n=37; mean and standard deviations are given).

Parameters	**Control**		**Experimental**		***p***
	M	*SD*	*M*	*SD*	
Knowledge score	4.58	1.64	4.07	1.79	0.5057
Perceived usefulness	6.22	0.48	6.09	0.62	0.5984
Perceived ease of use	5.76	0.77	5.38	0.74	0.0845
Behavioral Intention	5.90	0.75	6.20	0.70	0.2390

Significance levels are based on Mann Whitney test, with α=0.05.

Table 5: Learning gain for control and experimental conditions (n=37; mean and standard deviations are given).

Parameters	**Pre-test score**		**Post-test score**			**Learning gain**	
	M	*SD*	*M*	*SD*	***p***	*M*	*SD*
Control	4.58	1.64	5.26	2.09	0.0283 *	0.67	2.12
Experimental	4.07	1.79	6.13	1.85	0.0072 *	2.07	2.19
p			0.1871			0.0601	

*Significance levels are based on the Wilcoxon signed rank test and Mann Whitney test, * Indicates significance with $p < 0.05$.*

Table 6: Coefficient correlations between learning gain and frequency and duration using of the 3D tool, the level achieved, and motivation scores for the tool (n=15).

Learning gain as dependent variable	***R***	***R²***	***p***
Frequency of use	0.17	3%	0.4039
Duration of use	0.13	2%	0.2069
Level achieved	5.73	31%	0.0324*
Motivation for the tool			
Perceived Competence	0.14	2%	0.6424
Pressure/Tension	0.34	11%	0.2167
Perceived Choice	0.22	5%	0.4366
Effort/Importance/concentration	0.27	7%	0.3394
Interest/Enjoyment/value	0.08	1%	0.7661

*Significance levels are based on the simple linear regression analysis, * Indicates significance with p < 0.05.*

Table 7: Differences between expectation and experience of students regarding using the tool (n=15; mean and standard deviations are given).

Parameters	**Expectation**		**Experience**		***p***
	M	*SD*	*M*	*SD*	
Perceived usefulness	6.09	0.62	5.64	0.63	0.0182 *
Perceived ease of use	5.37	0.74	4.89	0.63	0.0457 *
Behavioral intention	6.27	0.70	5.91	0.65	0.1108

*Significance levels are based on Wilcoxon signed rank test, * Indicates significance with $p < 0.05$*

FIGURE LEGENDS

Figure 1: design of the study (A) and example of the 3D mRPD software (B).

Figure 2: Students' knowledge scores (A) for pre-test and post-test for both conditions. Students' expectation (B) and experience (C) regarding the perceived usefulness, perceived ease of use, and behavioral intention regarding using the 3D student tool. Students' motivation regarding the tool (D). * Indicates significance with $p < 0.05$, ** Indicates significance with $p < 0.001$.

APPENDICES

Appendix 1: pre-test survey.

Appendix 2: post-test survey for experimental group.

Appendix 3: power point presentation to semi-structure the focus group.