Social Robots and Gamification for technology supported learning:

An empirical study on engagement and motivation

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Abstract

Enhancing learning scenarios with social robots, as well as gamification elements, has been shown to positively influence motivation, engagement, or even both. However, they have not been combined in a learning environment. For this contribution, we created a learning environment for students in higher education and implemented additions (social robot and gamification) based on guidelines for gamification in learning scenarios, and research on pedagogical agents. Using a 2x2 design for systematic investigation of gamification elements and social robots, we tested the impact of our learning environment on motivation and engagement across four conditions: with a social robot, gamification elements, both or neither. We found no significant increase in engagement or motivation when adding gamification elements or the social robot. Quite contrary to our expectations, we found an interaction effect when combining both additions, showing lower engagement. Based on our results and former research, we discuss possible reasons for this finding and potential improvements for future research.

Keywords: interactive learning environments; adult learning; lifelong learning

1. Introduction

Self-directed learning is increasingly relevant within today's society. This is reflected in a trend to digitalize learning, resulting in an ever growing supply of technology supported learning, especially in the areas of data science, programming and web-design (Allen & Seaman, 2013; Goodman, Melkers, & Pallais, 2019; Rodriguez, 2012). These courses can convey self-selected useful skills, facilitate personal growth and might support career advancement. However, self-directed learning requires the learner to motivate themselves to complete the courses, and to engage with the learning material. Both are crucial since engagement (Rodgers, 2008) as well as motivation (Law, Lee, & Yu, 2010) are predictors for successful learning. To increase engagement and motivation in self-directed learning scenarios, different approaches were used in the past, including the addition of gamification or robotic tutors.

In this contribution, we combine social robots and gamification for the first time in an interactive learning experience. To this end, we describe the implementation of both aspects in a learning environment in plug-and-play functionality. In a controlled study, we investigate their effects on motivation and engagement, in relationship to an existing university course. Thereby, the addition of a social robot and gamification are tested in isolation, as well as in combination.

2. Related Work and Theoretical Background

For our endeavor, we need to take an interdisciplinary approach, combining knowledge from various areas of motivational psychology, learning, entertainment and computer-science. In the following subsections, we introduce the theoretical background and related implementations, necessary for our approach.

2.1. Motivation and Engagement

Motivation

Motivation, especially intrinsic motivation, can be considered as one of the most relevant concepts in learning (Vallerand et al., 1992), due to its positive relationship to learning success (Law et al., 2010) as well as related constructs such as academic performance (Froiland & Worrell, 2016). Most recent models suggest a multidimensional structure of motivation in three distinct aspects, namely intrinsic, extrinsic and amotivation. Intrinsic motivation describes the motivation to engage with a task because the execution of the task in itself is pleasurable. Extrinsic motivation describes the motivation to execute the task because external factors, such as some kind of reward, are desirable for the person. For academic motivation intrinsic and extrinsic motivation can be divided into different subscales such as intrinsic motivation regarding knowledge, accomplishment and stimulation (Vallerand et al., 1992). Alternatively Deci and Ryan (2011) present motivation as a spectrum from completely intrinsic to completely extrinsic. Both approaches also take note of amotivation, which is considered as distinct from the spectrum. Even though measures and subscales are not identical, both approaches are based on self-determination theory (Deci & Ryan, 2011; Vallerand et al., 1992). Self-determination theory is based on the idea that motivation of humans is connected to the basic psychological needs for competence, autonomy and relatedness. In more detail, the theory predicts that social contexts which support the fulfillment of these three needs, can maintain or even enhance intrinsic motivation, and support internalization and integration of extrinsic motivation (Deci & Ryan, 2011).

Due to the relevance of motivation in learning it is not only of interest to measure intrinsic motivation in educational settings, but rather to enhance it. However, in general, intrinsic motivation is relatively stable over time (Ryan & Deci, 2000; Vallerand et al., 1992), but long term changes may occur under specific circumstances for example based on changes in perceived competence (e.g., Tsigilis & Theodosiou, 2003).

Engagement

A very common approach to define engagement is to describe it as the quality of user experience on several levels for an interaction with a digital system (O'Brien & Toms, 2008). This includes aspects of usability, the degree to which the system can draw and maintain attention, as well as aesthetic aspects and perceived reward (O'Brien, Cairns, & Hall, 2018). The aspects can be considered separately or conjointly as a holistic approach for an entire system (O'Brien & Toms, 2010). Both approaches are very common in the area of human-computer interaction. A benefit of the holistic approach lies in the possibility to assess engagement of very diverse systems using the same scale (Nguyen & Meixner, 2019). This can also be applied to compare different technologies used in educational settings (Rabe-Hemp, Woollen, & Humiston, 2009). In the learning context, engagement describes the active involvement and workload of the learner and is directly related to a potential learning outcome (Beer, Clark, & Jones, 2010). Learners can be expected to spend more time with technology that is considered as engaging, because it captures their attention, is easy to use and feels rewarding to interact with.

2.2. Social Robots

Social robots are designed to interact with people in a natural, interpersonal manner (Breazeal, Dautenhahn, & Kanda, 2016) using both verbal and non-verbal signals. They are employed in many domains, including assisted living, entertainment or education.

Social Robots in Learning and Education

A large amount of research exists in the field of social robots in education. Originally, embodied agents that support learners in technology-enhanced education were virtual (Lester et al., 1997). Both representations of pedagogical agents can act in the role of an instructor (teacher or tutor), a peer, or a learning companion and enhance a student's learning process in a variety of ways. In a systematic review of the research on pedagogical agents, Schroeder and Adesope (2014) resumed that learners may prefer pedagogical agents to non-agent multimedia systems. Amongst others, they analyzed the effects of pedagogical agents on learners' motivation and summarized that overall, researchers found positive effects compared to text only or voice only learning environments. Although most studies reported positive aspects of pedagogical agents on motivation it should be mentioned that some found no effects or even negative effects such as more interest in the non-agent system or higher rated subjective cognitive load with a pedagogical agent.

Albeit pedagogical agents already provide benefits to learners, research about social robots indicates that the physical presence of a robotic tutor has positive effects on learning outcomes compared to a virtual agent/representation or no learning assistant. Li (2015) presented a survey of experimental work comparing physically present robots, tele present robots and virtual agents. The results of most studies suggest that users prefer a co-present robot to tele present robots and virtual agents with positive effects on participants' behavior, performance and attitude. For example, Leyzberg, Spaulding, Toneva, and Scassellati (2012) set up an experiment in which participants had to solve puzzles on a screen and either got lessons from a physically present robot tutor, which was setup next to the screen, from a virtual representation of the same robot, or no lessons at all. Results indicate that a physically present robot induces better learning gains compared to the other conditions. Kennedy, Baxter, and Belpaeme (2015) set up an experiment in which children learned either with a co-present robot in combination with a touchscreen or with a touchscreen only. In line with previous findings, results showed that a robot, which teaches students information while being physically present, significantly increases their learning gains compared to the other condition.

Most studies in the field of robots in education focus on educating children. However, there is a growing interest in teaching adult learners in higher education (Maximova & Kim, 2016). Learners can benefit from feedback provided by a social robot regarding their learning outcome and general perception of the learning process (Deublein et al., 2018; Donnermann, Schaper, & Lugrin, 2020; Pfeifer & Lugrin, 2018).

Effects of Social Robots on Motivation and Engagement

The positive effect of a social robot on learning outcomes is potentially a result of an increase in motivation and engagement of the students. Saerbeck, Schut, Bartneck, and Janse (2010) showed that a robot's socially supportive behavior could increase students' performance, intrinsic and task motivation in learning a language. These findings are supported by Lee et al. (2011), who conducted a long-term field study in an elementary school where children practiced language learning with educational assistant robots twice a week for a duration of eight weeks. Besides an increase in cognitive learning outcome such as speaking skills, the authors reported a large enhancement of motivation. Shin and Shin (2015) compared robot-assisted language learning to computer-assisted language learning in a middle school and found higher ratings of participation and satisfaction in the robot condition as well as a marginally significant higher motivation. There is more evidence that robots may increase motivation during learning as Alemi, Meghdari, and Haeri (2017), and Hsiao, Chang, Lin, and Hsu (2015) report an increased motivation of children learning languages with a robot. As no standardized measurements for motivation were used the results of Alemi et al. (2017) and Hsiao et al. (2015) need to be considered carefully.

As mentioned, most research in this field focusses on learning for children. How a robot can increase college students' motivation has been systematically investigated by Deublein et al. (2018), who explicitly tested different versions of motivational behavior, however without finding significant differences in the participants' motivation.

In terms of engagement, Chang, Lee, Chao, Wang, and Chen (2010) proposed that social robots are able to create not only an interactive but also an engaging learning experience. Through their ability to use non-verbal cues, social robots can capture the attention of the user, and subsequently increase engagement (Anzalone, Boucenna, Ivaldi, & Chetouani, 2015). This idea is supported by further studies in which a robot induced engagement by interacting with its audience, for example by talking and using gestures (Sidner, Kidd, Lee, & Lesh, 2004; Sidner, Lee, Kidd, Lesh, & Rich, 2005). Engagement is even claimed to be a "characterizing feature of the quality of the experiences with social robots" (Anzalone et al., 2015, p. 466).

2.3. Gamification

Game Elements

Gamification has been defined as "the use of game design elements in non-game contexts" (Deterding, Dixon, Khaled, & Nacke, 2011, p.2), and has been implemented into various contexts, including health programs, marketing campaigns, and education (Baptista & Oliveira, 2019). Research in gamification is diverse, because an element is considered relevant for gamification if it fosters game thinking, indicating that cognitive processes are active which are comparable to those when playing games in general (Kapp, 2012).

Gamification in Learning and Education

Education is one of the most popular fields of gamification research and related work was able to demonstrate a positive impact of enriching a learning environment with game elements regarding time of use and learner performance (Hakulinen, Auvinen, & Korhonen, 2015; Todor & Pitică, 2013). The integration of gamification in an educational context also holds promising possibilities to enhance the learning experience, by making it more enjoyable and satisfying for the learner (Baptista & Oliveira, 2019). Because educators can struggle to motivate and engage their students for the respective learning material and tasks, the use of gamification could be a sensible addition to traditional learning scenarios (Lee & Hammer, 2011). When using gamification elements in educational settings, it is important to not just add a game element to the learning material but linking it with the contents for learners to benefit from the integration of gamification (Nah, Zeng, Telaprolu, Ayyappa, & Eschenbrenner, 2014).

Four game elements were identified to be most relevant in educational contexts: (1) points, (2) badges, (3) levels, and (4) leaderboards (Dicheva, Dichev, Agre, & Angelova, 2015; Mekler, Brühlmann, Tuch, & Opwis, 2017):

Points are the most basic game element. They provide immediate feedback for successful behavior and, since they can be added up, are suitable to document progress (Sailer, Hense, Mayr, & Mandl, 2017). Points can also be part of another game elements.
Badges represent a predefined achievement in the gamified environment. It is composed of a name, a visual component (i.e., a picture of a medal) and a description of the achievement (Hamari & Eranti, 2011). Similar to points, badges can provide positive feedback and document the completion of tasks. As a badge is always linked to a certain pre-defined assignment, it can support the user to set goals for the interaction with the gamified system. Consequently, badges are able to increase the long-term user activity (Hamari, 2017). To do so, it is important that the conditions under which a badge can be obtained, are clear and precise (Denny, 2013). *Levels* of three different types were defined as relevant for gamification purposes (Kapp, 2012): 1) *game levels*, representing a stepwise increase in the degree of difficulty, 2) *playing levels,* a general level of difficulty that the player can choose, and 3) *player levels*, levels that can be reached whenever the user has gained enough experience points. Reaching a new level can also be perceived as a form of reward for engaging with tasks and assignments for a longer period of time (Nah et al., 2014).
Through *leaderboards*, users can compare their results, points or badges to those of other users (Kapp, 2012). Leaderboards can therefore be useful to display simple, comparable services. Complex achievements, on the other hand, are difficult to standardize and compare on a ranking list (Landers, Bauer, & Callan, 2017).

Effects of Gamification on Motivation and Engagement

The positive influence of game elements in different educational systems is thought to be caused by influencing two crucial learning factors: Motivation and engagement (Domínguez et al., 2013). Even though these concepts are linked to each other, they are affected by different game elements (Seaborn & Fels, 2015). Different approaches have been suggested to raise motivation through gamification in learning . Game elements such as positive feedback, points, and levels are considered in terms of their motivational affordances (Zhang, 2008), i.e., their effect on the basic needs competence, autonomy and relatedness of self-determination theory. If game elements are used in a way that addresses one or more of the basic needs, the internalization of external motivation is supported. Concerning the positive effect of gamification on engagement, several studies indicate benefits for students in a learning environment (Darejeh & Salim, 2016; Nah et al., 2014). Points, badges, levels and leaderboards have helped learners to keep engaged in their tasks (Barata, Gama, Jorge, & Goncalves, 2013; Santos, Almeida, Pedro, Aresta, & Koch-Grunberg, 2013). This also holds true for more recent developments, such as online discussions, where gamification elements also positively influenced student engagement (Ding, Er, & Orey, 2018).

However, extrinsic rewards such as points and badges might also affect motivation and engagement in a negative way. They can reinforce extrinsically motivated behavior and might tempt learners to focus on the reward rather than on their individual learning process (Gladun, 2016). Leaderboards can also be problematic, since they automatically add a social comparison to the environment (Sailer et al., 2017). This comparison enables users to compete with each other, though the perception of this social pressure and its effect on motivation varies between individuals (Domínguez et al., 2013; Mekler et al., 2017). Additionally, extrinsic rewards can both increase and decrease intrinsic motivation depending on the type of reward (Fang, Gerhart, & Ledford Jr, 2013; Ryan & Deci). To this end, game elements as a non-material form of reward, such as points or badges, can, if carefully implemented, enrich a learning environment (Deci, Koestner, & Ryan, 2001).

2.4. Contribution

The use of social robots as well as gamification elements in learning scenarios have been shown to positively influence the learners' engagement and motivation. So far, a social robot and gamification have never both been added to a learning scenario to potentially further increase the support of learners.

For this contribution we implemented both additions in a learning environment. With our setup, we demonstrate how both additions can be implemented in a plug-and-play functionality. Thus, it allows to systematically investigate the impact of gamification, a social robot, or both additions in combination. Through the comparison to a control group, using the same learning material without a social robot or gamification elements, the effects of the additions can be quantified. Subsequently, we evaluated the additions to the learning environment in terms of motivation and engagement. We focused on established but also subjective measures, mainly intrinsic motivation and engagement and did not include behavioral measures, such as the performance in the learning scenario. Based on the literature review above, we formulate the following hypotheses:

H1a: Adding a social robot to the learning environment increases motivation.

H1b: Adding a social robot to the learning environment increases engagement.

H2a: Adding gamification elements to the learning environment increases motivation.

H2b: Adding gamification elements to the learning environment increases engagement.

For the combined version, we could expect an even higher increase in engagement and motivation based on the predicted positive impact of either addition. However, adding both additions might also cause a detrimental effect and distract from the actual learning content. Therefore, we formulate the potential interaction as an open-ended research question:

RQ1: How does the combination of a social robot and gamification elements affect motivation and engagement?

3. Implementation of the Learning Environment

To investigate whether the integration of gamification elements and a social robot has an impact on the learner's motivation and engagement, an extensible learning environment was created. Our implementation makes use of the modeling software Visual SceneMaker (Gebhard, Mehlmann, & Kipp, 2012) tied to a learning framework including a HTML environment and a Reeti[1] Robot (Deublein et al., 2018). The learning material is presented to the user on a screen and allows for interaction with mouse and keyboard in each of the four conditions. In the experimental conditions including a social robot, the social robot is set up next to the screen to be able to interact with the user and in regards of the learning content within their field of view (see Figure 1).

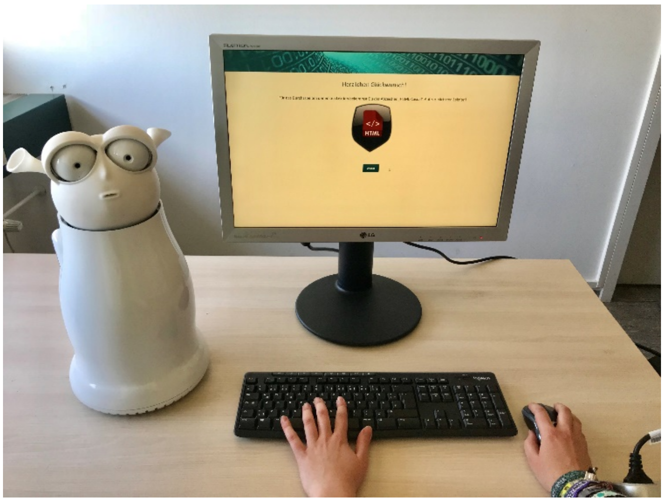

Figure 1. Setup of the learning environment with the social robot.

The HTML environment presenting the learning material was set up in a predetermined sequence to allow adequate comparisons. For an overview of the workflow, see Figure 2.

The basic learning experience starts with a short introduction in text form, which gives an overview of the learning content and the following interactive sequences. The learning material is presented in form of videos on a screen followed by a set of mulitple choice questions. The learning experience includes three lessons, each consisting of one video and four questions.

Following Shute (2008), we implemented short motivating feedback via text display on the screen at the end of each exercise and lesson. The feedback is always formulated positively.

[1] Robopec Reeti: http://www.reeti.fr

Therefore, in case of a wrong answer, feedback relates to the content and contains a short explanation about the correct answer.

The content of the learning environment as well as the additions of the social robot and gamification elements are described in the following subsections.

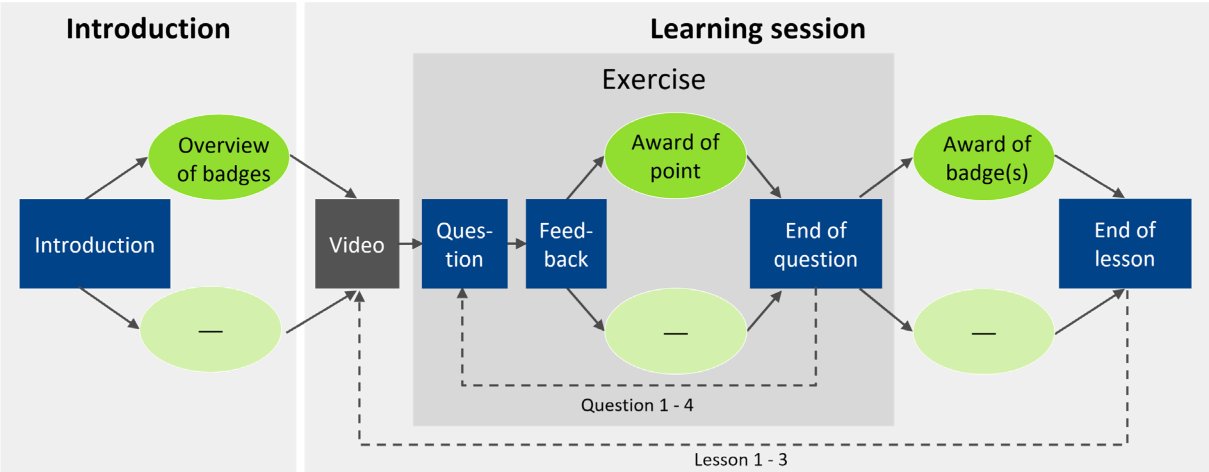

Figure 2. Workflow of the learning experience. The upper path describes the conditions with gamification, the lower path the conditions without (both highlighted in green). The common sections (highlighted in blue) are either presented via text displayed on the screen or spoken by the social robot, depending on the condition. The videos containing the learning content were the same across all conditions.

3.1. Interactive Learning Material

The learning materials are excerpts from the curricula of the undergraduate course "Digital Media 2" at blinded-University. One topic covered in the course is the introduction to web development, which is typically considered difficult by many students. The learning material is therefore relevant for students as additional training for exam preparation. Because the contents were of particular relevance for the participants, which is a relevant positive indicator for the assessment of learning in non-classroom scenarios (Walker & Fraser, 2005), the participants are expected to benefit as much as possible from the learning scenario.

In more detail, the material recaps the course content concerning HTML and CSS. The content was split into three lessons, two focused on HTML and one on CSS. For each lesson, we created a video of 3-4 minutes showing source code that is further explained by a voice overlay. For each of the three lessons we prepared four multiple-choice questions, which had to be answered after watching the respective video.

3.2. Social Robot

For the social robot addition, the robot Reeti[2] is used. The Reeti robot is an expressive communicative robot with numerous engines in the face, head and eyes with a total of 15 degrees of freedom. Therefore, the robot is capable of displaying different emotions and facial

[2] Robopec Reeti: http://www.reeti.fr

expressions as well as head movements. In the social robot conditions, the introductions, the questions, the feedback and the awarding of badges and points are spoken by the robot's text-to-speech component (in contrast to the basic condition where information is displayed in text form on the computer screen).

We consider the social robot in the role of a tutor to be most suitable to address the need for relatedness, based on self-determination theory. Encouraging statements were added during the explanations to support the perception of this role (e.g., *"Lesson one is about HTML. Have fun!*"). Feedback on right or wrong answers uses exactly the same wording as the texts in the basic condition. To convey relatedness, all text spoken by the robot is supported by emotional non-verbal expressions. For example, the robot encourages the learner with positive facial expressions, e.g. a smile. Also, for the display of negative emotions, supportive non-verbal behavior is implemented, e.g. a brief sad facial expression followed by an encouraging smile.

3.3. Gamification

For the gamification addition, we implemented points and badges, based on the guidelines of van Roy and Zaman (2017) and Aparicio, Vela, Sánchez, and Montes (2012) with a focus on supporting the need for competence. One point is given for each correct answer, thus a maximum of twelve points can be achieved. The points act as additional feedback for each multiple-choice question. At the end of each lesson, the participant is informed about the current score. The points are also relevant to achieve the implemented batches.

The badges are also targeted to the need for competence, by setting challenging but manageable goals (van Roy & Zaman, 2017). To raise attention to the gamification elements, an overview of all badges is displayed to the user before the first lesson showing information on their requirements. Further, three badges were rewarded for completing each of the lessons, regardless of performance. Thus, one or multiple badges are awarded after each lesson.

3.4. Combination of Social Robot and Gamification

To combine the social robot and gamification, all changes described in Section 3.3. and Section 3.4. are integrated in the learning scenario, e.g. motivating feedback spoken by the robot and introduction to gamification elements. For a convincing integration, the social robot also presents the additions of the gamification manipulation, including positive non-verbal behavior. The use of the robot to convey the elements might emphasize each respective game element while simultaneously strengthening its role as a tutor due to the presentation of reward-like badges. Thus, the need for competence and relatedness could be even more positively affected. However, the effect might also be a cognitive overload and distract from learning.

4. User Study

We conducted a user study with a 2 x 2 between-subject design. The absence or integration of the social robot, and absence or integration of the gamification elements, resulted in four conditions:

- Basic Condition (BC): No addition was made to the learning environment.
- Robot Condition (RC): The social robot was added to the learning environment.

- Gamification Condition (GC): The gamification elements were added to the learning environment.
- Combined Condition (CC): The social robot and the gamification elements were added to the learning environment.

As dependent variables, intrinsic motivation and engagement were measured. To assess intrinsic motivation we used the ‘Academic Motivation Scale’ (AMS; Vallerand et al., 1992), excluding the amotivation subscale. The AMS was adapted from the original college context to the e-learning context in relation to the specific course covered by the learning material of the present study (i.e. ‘Why do you go to college?’ changed to ‘Why did you work through the learning environment?’). We considered this adaption adequate because we do not expect a single experimental study to alter motivation regarding going to university, but instead for a detectable effect in regard to learning with the specific learning environment. Furthermore, one item of extrinsic motivation had to be excluded due to its lack of adaptability (‘Because eventually it will enable me to enter the job market in a field that I like.’). For comparability with the UESSF, we used a scale from 1-‘strongly disagree’ to 5-‘totally agree’ in the same manner as Durso, Cunha, Neves, and Teixeira (2016).

We measured engagement with the ‘User Engagement Scale Short Form’. The short form scale has been shown to be sufficiently reliable as well as valid and has often been used in the digital context (e.g., Capra, Arguello, O'Brien, Li, & Choi, 2018; Mackamul & Esteves, 2018; Speakman, Hall, & Walsh, 2018). Because of its low relevance for the present study, the last subscale ‘Reward Factor’ was excluded, which is an appropriate approach as stated by O’Brien et al. (2018). The questionnaire uses a Likert scale from 1-‘strongly disagree’ to 5-‘totally agree’.

To have an indicator whether the learning scenario was helpful to the participants we used the ‘Perceived Usefulness’ scale of the E-Learning Acceptance Measure (ElAM) (Teo, 2010). Furthermore, we examined fun on a seven-point Likert scale with the statement ‘Working through the learning environment was fun.’ from 1-‘strongly disagree’ to 7-‘totally agree’.

The demographic part of the questionnaire collected data about gender, age, number of completed semesters, familiarity with the robot used, attitude towards the subject and as a control of suitability whether the participant took part in the lecture and/or exercises of ‘Digital Media 2’. At the end of the questionnaire, we gave participants the opportunity to comment on the study and the respective addition(s) to the learning environment. All scales were translated into German and adapted to the context of the experimental design.

4.1. Participants

A total of 80 students (70 female, 10 male) took part in the study. All of them were enrolled into the course ‚Digital Media 2‘ and planned to take part in the corresponding exam at the end of the semester. The mean age of the participants was M = 20.09 (SD = 2.44) range 18 - 38 years. The social robot Reeti was already known by 57 participants. The mean score for liking the course was M = 4.43 (SD = 1.45) on a seven-point Likert scale, 1= ‘not at all’ to 7 = ‘very much’.

The participants were randomly assigned to the four conditions, resulting in $N_{BC} = 21$, $N_{GC} = 20$, $N_{RC} = 19$, and $N_{CC} = 20$. Participation was rewarded with partial course credit and the advantage of an additional training in the contents of the course.

4.2. Procedure

The study took place in an office with a simple desk, a desktop computer, and the social robot (depending on the condition). After a short introduction to the study by the experimenter, participants had the chance to ask questions about the experiment. Afterwards the participant was asked to take a seat in front of the monitor and to follow the instructions of the system. The experimenter then retreated behind a room divider.

The experiment consisted of completing the learning environment with the additions depending on the condition. Participants therefore completed three lessons consisting of twelve associated questions and feedback. Each learning experience took about 20-30 minutes depending on the condition. After completing the learning session, participants were automatically forwarded to the digital questionnaire. The whole procedure lasted 35 minutes on average.

5. Results

For further analysis all quantitative data was imported into the stats program ‘SPSS’ using Version 25. An alpha-level of 0.05 was applied for all statistical tests.

5.1. Quantitative Data

A 2x2 MANOVA with the factors social robot (absent/present) and gamification (absent/present) was conducted for engagement and intrinsic motivation (see Figure 3 for descriptive data). All data was tested for normality and homogeneity. Intrinsic motivation ($p = .205$) was approximately normally distributed, as indicated by a non-significant Shapiro-Wilk test. However, the deviation from normality was significant in case of engagement ($p = .023$). Levene’s test indicated that homogeneity of variances could be assumed for engagement ($p = .973$) and intrinsic motivation ($p = .094$). Engagement and intrinsic motivation showed a significant positive correlation ($r = .43, p < .001$).

Using Wilks’s statistic, we found no significant main effect of adding the social robot on engagement and motivation, $\Lambda = 0.97$, $F(2, 75) = 1.03$, $p = .363$, as well as no main effect of gamification, $\Lambda = 0.99$, $F(2, 75) = 0.26$, $p = .775$. However, there was a significant interaction of the factors on engagement and motivation, $\Lambda = 0.89$, $F(2, 75) = 4.48$, $p = .015$, $\eta_p^2 = .11$. Subsequent univariate ANOVAS indicated a significant interaction of the factors for engagement, $F(1, 76) = 7.02$, $p = .010$, $\eta_p^2 = .09$, but not for motivation, $F(1, 76) = 0.01$, $p = .938$.

Regarding the perceived usefulness, Levene’s test ($p = .534$) revealed homogeneity of variances. The 2x2 ANOVA showed no significant effect of the social robot $F(1, 76) = 0.02$, $p = .902$ or gamification $F(1, 76) = 0.04$, $p = .834$, as well as no interaction $F(1, 76) = 0.42$, $p = .518$. The perceived usefulness showed no significant correlation with intrinsic motivation ($r = .18, p = .121$) or with engagement ($r = .09, p = .424$).

Concerning fun, homogeneity of variances was confirmed by Levene’s test ($p = .463$). The 2x2 ANOVA showed no significant effect of the social robot $F(1, 76) = 0.00$, $p = .967$ or gamification $F(1, 76) = 0.52$, $p = .473$, as well as no interaction $F(1, 76) = 0.35$, $p = .558$. Fun showed a significant positive correlation with intrinsic motivation ($r = .42$, $p < .001$) and engagement ($r = .67, p < .001$), but not with perceived usefulness ($r = .01, p = .933$).

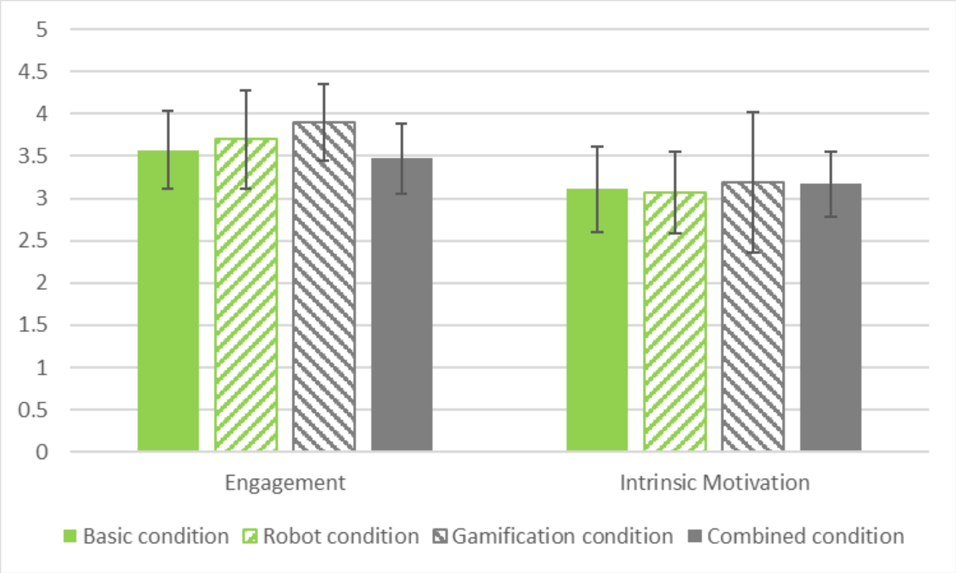

Figure 3. Means for engagement and intrinsic motivation, error bars represent SDs.

Furthermore, the attitude towards the topic was positively correlated with intrinsic motivation (r = .38, p = .001) and perceived usefulness (r = .37, p = .001). Attitude towards the topic showed no significant correlation to engagement (r = .04, p = .722) or fun (r = .14, p = .220). Means and standard deviations for perceived usefulness, fun and attitude towards the topic are listed in Table 1.

Table 1. Means and standard deviations for perceived usefulness, fun and attitude towards topic (scale 1-7)

	Perceived usefulness		Fun		Attitude towards topic	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*
Basic Condition	5.34	0.57	5.24	0.77	4.81	1.08
Robot Condition	5.25	1.03	5.37	1.34	4.47	1.39
Gamification Condition	5.18	1.02	5.55	1.19	4.15	1.69
Combined Condition	5.33	0.64	5.40	0.88	4.25	1.65

5.2. Open-Response data

Out of the 80 participants 39 used the 'further comments' section for qualitative input. The main aspects as classified by two independent raters were: Learning material, questions, usage and implementation of gamification, the wording of instructions and feedback.

The learning scenario was mentioned positively by 16 participants, with a strong emphasis on the quality and helpfulness of the videos, which were mentioned by twelve participants ("The videos were designed and structured very well"). Positive aspects of the social robot were emphasized by five participants, which was mainly based on the feedback given by the robot (n = 4) ("I liked Reetis confirmation when the answer was correct"). There were less positive comments regarding the badges, however four of the participants mentioned them positively ("The badges were motivating").

Some participants referenced negative aspects of the learning environment (*n* = 8), such as the content being too simple (*n* = 2) and content which participants considered was missing in the learning scenario (*n* = 3). For the social robot, 15 out of 39 participants in the conditions with the social robot mentioned that the noise of the robot's movement was distracting ("The loud noise when Reeti was blinking was a bit annoying and distracting."). They mainly complained about the noise of the eyelids while blinking, which had interrupted their learning process. Additionally two of the participants considered some of the feedback as negative ("I perceived words like ‚oh dear' as inappropriate"). For the badges, there was only one negative comment, which considered the badges too easy to achieve.

6. Discussion

There were no significant increases, in either motivation or engagement, due to either the gamification elements or the social robot alone. Therefore, our hypotheses of a positive effect on motivation or engagement by either of the additions were not supported. The learners might have been too focused on the videos, which were present in all conditions because they conveyed the learning content. The positive reactions to the control condition might indicate that the learning material itself triggered motivation and engagement. Potentially because the learning material was especially crafted for this study and tailored to the participants. This is particularly interesting, because a review of research in gamification has pointed out that many positive results on the impact of gamification did not make use of a control group (Seaborn & Fels, 2015).

However, we found a significant interaction effect of the social robot and gamification on engagement as addressed by our research question. This interaction indicated a negative influence on engagement if both manipulations are present at the same time, for which we consider three potentially interdependent effects. First, we assume that combining the additions might have caused a detrimental effect in terms of distraction, and thus requiring too many mental resources (van Roy & Zaman, 2017). Second, the learning content in form of videos was perceived as central aspect of the learning environment. Each respective addition might have been perceived as adequate framing for the videos, however adding both might have been perceived as diverting from the relevant content. This line of thought would be consistent with the missing increase in motivation, because the interaction would have been perceived as less engaging if the interaction feels impaired by the additions (O'Brien et al., 2018). Third, utilizing the social robot for verbal feedback and the screen for badges, the setup with both additions established two different feedback areas, potentially splitting attention and therefore lowering engagement with the learning environment.

As outlined in the related work section, several other studies found no effects of pedagogical agents for example on motivation and interest (Schroeder & Adesope, 2014). Furthermore, there are studies that found no or even negative aspects of the physical presence of a robot, e.g. on participants' performance or persuasion compared to a virtual agent (Li, 2015). Other studies found a positive impact of a social robot on the learning process, were conducted mainly with children (e.g. Alemi et al., 2017) or as long-term studies (e.g. Lee et al., 2011), which makes results only partially comparable with the present study. Therefore, additional research is needed to systematically assess the influence of social robots, gamification and their interaction on motivation, engagement and learning especially in adults.

The additional measures fun, perceived usefulness and attitude towards the topic were not significantly affected by the manipulations. The presented correlations are in line with theory, such as finding a significant positive correlation between the attitude towards the topic and intrinsic motivation, which matches self-determination theory, indicating that an intrinsically interesting topic should result in more intrinsic motivation. Due to its similarity to engagement, the positive correlation with fun also matches current theory (e.g., Lucardie, 2014).

Finding a significant positive correlation between the attitude towards the subject covered in the learning scenario and intrinsic motivation supports the proposed high relevance of the subject to the learners. Also in the control condition, participants received positive feedback and encouragement which in itself is beneficial to the learner (Krause, Stark, & Mandl, 2009). The aspect of personal relevance of the contents of the learning scenario is also noteworthy when considering the result in terms of self-determination theory. Frameworks to enhance motivation based on self-determination theory (Aparicio et al., 2012; Nicholson, 2012) propose to use gamification to address the basic psychological needs for competence, autonomy, and relatedness. It is however crucial that the means to convey this sense of fulfilment are not perceived as external motivation, because this could result in a detrimental effect on motivation. We assume that the moderately high motivation across all conditions can be attributed to two main causes, in relation to self-determination theory. First, the personal relevance of the contents of the learning material resulted in an intrinsic motivation towards the learning scenario. Second, the learning environment contained, even in the control group, several features, which can be considered as support for the basic psychological needs. This is especially prominent for the need of competence, which should be addressed by positive feedback that was present in all conditions.

Furthermore, the qualitative feedback indicates that participants focused their attention on the videos and not on the manipulations. The prominent positive role of the videos might have prevented a significant influence of the social robot and the gamification elements. Because the present contribution is the first to implement both simultaneously, it also has to be tested if the negative effect of the interaction persists if additions, which by themselves have a positive effect, are combined. Based on the open comments and our assumption that the learning videos played a critical role and significant correlation between attitude towards the subject and intrinsic motivation, the context of learning should be more prominent in future research. Ideally, this could be addressed by a detailed assessment of the relevance and interest in the topic prior to learning. The potential problem of establishing two feedback areas should also be addressed in future work. This could be investigated by presenting badge feedback on a separate screen, relative to giving feedback on exercises and badges on the same screen. Once the effects of social robots and gamification on motivation and engagement in controlled short-term settings have been sufficiently established, learning performance should also be included in future studies.

7. Conclusion

For the present contribution, we implemented a learning environment based on social robot research and guidelines for implementing gamification with the aim to enhance motivation and engagement for students in higher education. In the learning environment, we used videos to convey the learning content, multiple-choice questions to test the participants' knowledge, and positively formulated feedback to support the learners. The learning experience can be augmented by a social robot, or gamification elements, or both. In a user study, the impact of the four resulting versions on motivation and engagement was evaluated.

Against our expectations, we were not able to demonstrate a significant increase in engagement or motivation by adding gamification elements or the social robot separately. We consider the rather positive feedback in the control condition as well as the short interaction of the learners with the learning scenarios as potential reasons for the missing effects.

Interestingly, we found a significant interaction between the additions implying that adding a social robot and gamification elements might lower engagement. We suspect a mental overload through too many features that distract from the actual learning task. However, because this study is the first to implement both, findings have to be replicated first and considered with varying contexts and setups.

Our contribution is twofold. Firstly, we demonstrated how a learning environment can be implemented in a plug-and-play functionality, which allows to integrate a social robot or gamification elements exclusively or simultaneously. The resulting learning environment can be adapted with varying learning materials, or additional features for future studies. Secondly, we systematically investigated the impact of the adaptions, gamification elements and social robot, using a complete 2 x 2 design, including a control group. Our findings provide valuable insights for the research areas of social robotics, gamification and technology-enhanced learning.

In our future work, we plan to further investigate the impact of social robots, gamification, and the interaction effect of both additions in several manners, e.g. by further adaptation to our learning environment, the social robot’s behavior, the gamification elements, their delivery of feedback, as well as the impact on learning gain in longer-term studies.

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