Effects of Collaborative Augmented Reality on Communication and Interaction in Learning Contexts – Results of a Qualitative Pre-Study

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Abstract

Modern digital technologies like Augmented Reality (AR) are assumed to foster the learning process due to their hands-on nature. AR has the advantage of visualising processes, objects or data and information that would under regular circumstances not be visible or perceptible for the user, since it integrates virtual objects into the real world by an overlay display of these objects. Moreover, collaboration via AR can be realised by using smartphones and tablets. This comprises the advantage of using devices which the students do not need to learn the operation of since they are in everyday use. However, there is still a lack of research on the impact the use of AR has especially on team communication, learning processes, and the general outcomes of collaborative teamwork.

Against this background, a prototype of a collaborative AR app was developed as well as a study design was set up for investigating the effects of AR on the teamwork in collaborative learning processes. The study comprises a pre-post-test design in combination with an experimental setting. While the pre- and post-tests are realised by standardised questionnaires and qualitative, semi-standardised focus group interviews, the experimental setting is recorded by video camera in order to qualitatively analyse the video data of the communicative and work-based processes and interactions of the collaboration.

When comparing the test and control group (AR team vs. paper-based, non-AR team) the verbal communication of the AR team was lower in terms of number and frequency of statements. However, the product presented as result of the collaboration phase was of comparable quality and detail as the non-AR team's product. With respect to communicative structures during the collaboration and the outcomes of the respective team products, the study also investigates the effect of AR on these aspects. The focus of this paper, however, is the examination of the effect(s) of the collaborative AR app developed on the process of the teamwork in terms of communication and interaction. It aims at understanding to which extent AR changes the way people communicate in collaborative settings, i.e. when they pursue a common goal. Moreover, the results of the study aim at identifying recommendations for action (e.g. for university teachers) in terms of the design of collaborative (learning) processes that will be enriched by AR.

Tags: collaboration, Augmented Reality, communication, interaction, team

1. Augmented Reality in collaborative learning

1.1. Augmented Reality

In higher education, modern technological trends often find their way into higher education and thereby contribute to changing traditional teaching methods. One of these modern technologies is Augmented Reality (AR) that has currently found its way into university teaching. Over the past years, a large number of AR applications and scenarios for various disciplines and use cases have been developed and implemented into the curriculum [1, 2, 3]. These applications are e.g. used for presenting a car engine and its components in a lecture hall without having to bring a real engine into the lecture, decreasing cost and material resources. The advantage of this technology, thus, particularly shows for large audiences since each student is able to participate individually e.g. on their smartphones, laptops or tablets. In order to do so, the devices need to be AR-capable, i.e. equipped with a screen, a backward camera, an Internet connection, and the respective AR app. The students are able to access the demonstration by scanning an AR marker[1] or the object shown on the stage by the lecturer. Then, interactive virtual objects or additional information (e.g. the car motor or information on the combustion) are displayed on their device screen.

The AR technology influences or enhances the users' perception of reality by supplementing the real world with virtual objects or additional information (e.g. text, images, models) [4]. With AR, thus, reality is enhanced, i.e. augmented, by mapping virtual objects and information onto the real environment. The main functions of AR are 1) embedding virtual objects into reality, 2) interaction in real-time, and 3) correct alignment of the virtual objects in the real 3D world. AR is often realised with the help of mobile devices (e.g. smartphones, tablets or AR-specific glasses) that have a rear camera at their backs (e.g. all current smartphones and tablets) and a specific AR application. When scanning the environment (i.e. object-based or markerless tracking) or a particular AR marker (i.e. marker tracking), virtual objects can be placed into the environment by appearing on the device screen at the respective point in the environment.

Most of the current AR applications, however, mainly serve demonstrative purposes or are merely interactive in terms of one person being able to interact with the technology. Due to the increased number of collaborative elements e.g. resulting from the "shift from teaching to learning" [23] in the context of the Bologna reform in higher education, suitable and particularly effective didactical tools and methods need to be taken into account. By creating network connections between different devices, for instance, collaborative settings can be realised by means of AR. This way, students can conduct digitally supported group work, e.g. by role-plays, that is even fostered by the collaborative nature of a specifically developed AR application or scenario [5, 6].

1.2. Collaboration

In the context of people working or learning together, there are five stages of interaction: networking, cooperation, coordination, coalition, and collaboration [9, 24, 25]. In these stages, the level of communication, sharing of ideas and information, and decision-making increases. Collaboration is assumed to be the closest form of interaction due to the necessity of direct contact and coordination (e.g. to be carried out by AR instructions or simulations)

[1] An AR marker is a visual trigger that determines the location of the virtual objects in relation to the real world causing the display of virtual objects or additional information, e.g. a picture or QRcode [16, 17]. It does not require many performance resources in terms of computing power in smartphones and tablets. Recognising predefined markers in the scene is possible with a vast spectrum of devices like smartphones, tablets, and laptops [16].

[7]. It is characterised by emergence and the exploitation of synergies [8]. Wood and Gray [14] define the occurrence of collaboration as "when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain". In conclusion and as a definition for this study, collaboration needs 1) different individuals working on a common task that combine their competences, 2) distribute subtasks onto these people, and 3) creating a dependent relationship for finishing the common task.

Education is also increasingly pervaded by a collaborative and social interactive learning. This style of learning is characterised by knowledge discovery as well as the development of competences via group- and team-based teaching and learning formats [10]. Since understanding the competences, capabilities, and tasks of the other team members is an important foundation for teamwork and collaboration in particular, specific instructions and supportive means of the teamwork e.g. realised by digital means like AR, are necessary to work efficiently.

1.3. Communication in teams

When collaborating, the process is majorly influenced by the way the team members communicate and interact with each other since e.g. "unmanaged (or free) social interaction often leads to poor decision-making […] and ineffective communication, practices, and products" [18]. There are several ways of failing communication (e.g. the distortion angle of communication, irony, different layers of a message etc.) that, in turn, can lead to delays in the process of a team working on a common task or problem.

Depending on the severity of the case, a failed, undirected or a lack of communication can also result in a decrease of the team members' satisfaction with the process, the team itself and/or the outcome of the collaboration [18]. Particularly when it comes to digital media and modern technologies in collaborative (learning) processes like AR, there often is an impediment towards their use. It is assumed to reduce "face-to-face communication as a result of technology" [19] e.g. when using these technologies in everyday work or learning since.

Despite different studies suggesting a negative effect of technology on quality and quantity of verbal communication [e.g. 19], trends like AR still increase in terms of their presence in everyday situations, work, and learning. In opposition, technology is considered to change communication without a specific positive or negative connotation [e.g. 20, 21, 22]. The effect of technology on (verbal) communication, however, depends strongly on the context it is used in. One use case, i.e. AR in collaborative learning contexts, is presented in this paper in the following.

2. Purpose and goal

As far as AR in higher education and learning contexts is concerned, the majority of research focuses on individual settings or the use of AR applications in groups. There is a lack, thus, of research on interactive group-based and particularly collaborative work using AR in higher education. Moreover, this lack predominantly implies the examination of the user's behaviour when using the technology. The research focus in this field was so far broadly put on the technical aspects of developing and implementing group-based or specifically collaborative AR applications and scenarios. This study focuses on the human factors in the use of collaborative AR in higher education group settings with respect to the communication and interaction during the collaboration.

As first insights into collaborative AR used by university students have shown, there are different communicative strategies during the conduct of a group task depending on the materials used for finishing the task. Similarly to clichés towards smartphones, there is also the conception of modern technologies reducing communication and social interaction. The basic hypotheses in this context are as follows:

1) AR changes the way people communicate in collaborative group settings.
2) When using AR in collaborative settings, verbal communication (oral and written) decreases strongly.
3) AR provides a visual and, thus, a new way of communicating with one another without (spoken or written) language.

In order to investigate these hypotheses, an empirical study will be conducted. The method and results of a pre-study for validating the survey methodology are presented in the following as well as first insights into the discussion of the effects of AR in collaborative settings. It also gives first insights into the fit of the design of the empirical survey for confirming or rejecting the hypotheses.

3. Method

3.1. Role-play

In order to investigate the effect of AR on the communication and interaction in a collaborative setting in higher education, a role-play was developed and implemented into an exemplary lecture on Agile Management in Technology and Organisation at the RWTH Aachen University. The lecture mainly addresses students of Mechanical Engineering who have hardly or not had contact with agile project management during their studies before. Thus, this way of organizing tasks is a completely new, mostly uncommon and often abstract way of working to them. For fostering the conception of the learning content "scrum" from the field of agile management[2], the role-play serves the purpose of experiencing how scrum teams work.

Moreover, the role-play aims at showing the principles of agile project management by making it more concrete for the students by setting them into a fictitious, but realistic simulation of a scrum team's working processes. The students, thus, receive different roles of

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[2] „Scrum is an agile software development process designed to add energy, focus, clarity, and transparency to project teams developing software systems […] (and) was designed to increase speed of development, align individual and organizationobjectives, create a culture driven by performance, support shareholder value creation, achieve stable and consistent communication of performance at all levels" [27].

a scrum team that they have already learnt prior to the role-play in the context of the respective lecture. These roles include a “Product Owner” (PO), a “Scrum Master” (SM), several “Scrum Team Member – Developer” (Dev), and the “PR Team Member” (PR). While the roles PO and SM are assigned to one student each, the roles Dev and PR can be assigned to up to three students each. Ideally, the role-play is conducted with a group of four to eight students forming one scrum team.

The task of the fictitious scrum team is the development of a product that is in alignment with the requirements set up by their clients. The product to be developed is a shared apartment for three students and its interior furnishing in particular. For finishing the task, different materials were given to the participants: the control group, i.e. non-AR team, has worked with paper-based materials (e.g. printed sheets with role descriptions, tasks, and supportive data) and Lego bricks for building the output of the collaboration. For the test group, i.e. AR team, an AR app has been developed for the test group combining the paper-based materials into one application. It runs on both smartphones and tablets. However, the use of tablets is recommended during the role-play since the display size is large enough to see every detail of the virtual objects and the scene.

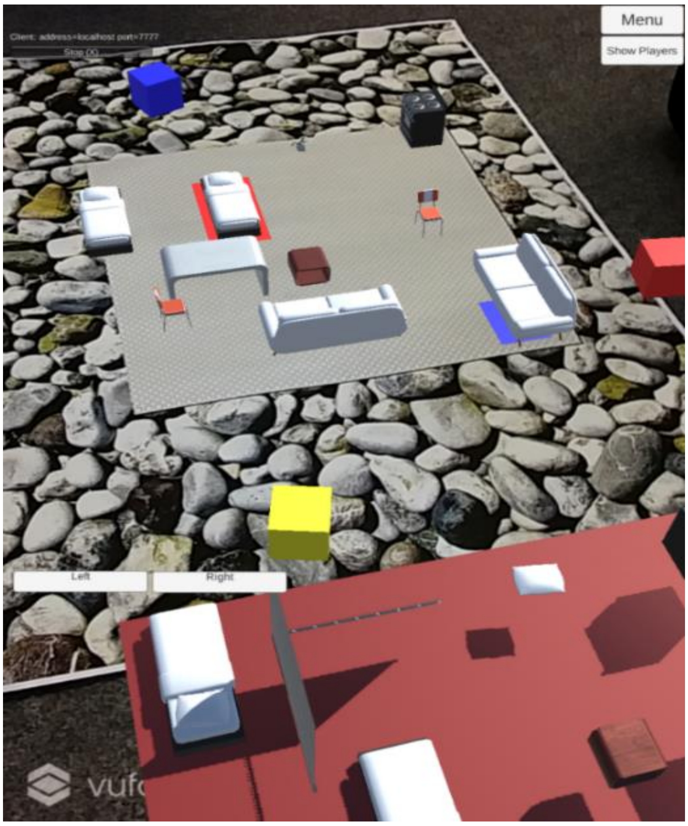

Fig. 1: Screenshot of the collaborative AR-app while simultaneous use

The prototype of the collaborative AR app allows every participant of the role-play to choose virtual objects, i.e. furniture and walls in this scenario, from a catalogue area displayed on the screens of their mobile devices. Once in the scene, the participants can manipulate the virtual objects e.g. by turning or moving them. This manipulation is simultaneously visible for all team members on their respective individual mobile devices. With this functionality, everyone participating can help form the outcome of the product development process by shaping the product itself collaboratively.

The AR app, thus, also allows a parallel collaboration on the same product since every team member can see the virtual objects and changes made to them during the whole process and in the second they are made. By means of entering a user name and choosing a colour for each team member, the interaction and comprehensibility of each team member’s actions are fostered since the team member’s colour is displayed under the virtual object he or she manipulates (cf. Fig. 1: blue and red markings under the virtual objects).

3.2. Study design

In order to investigate the effects of using AR in collaborative learning processes on the communication and interaction within a team, a multilevel mixed methods study design was set up. While the AR team used the collaborative AR app for completing the given task of the teamwork, the non-AR team conducted the study by means of pen and paper-based materials in order to compare the results with respect to the change of media. Besides combining different quantitative and qualitative empirical survey methods, the study design also includes a separation into an experimental setting, a pre- and post-test survey (cf. Fig. 2). As Figure 2 shows, the pre-test is realised by a quantitative questionnaire, while the post-test combines a quantitative questionnaire and qualitative interviews. The participants are separated into two groups resembling the requirements "augmented" (i.e. AR) on the one hand and "analogue" (i.e. non-AR) on the other. The experiment is conducted simultaneously with both groups and recorded by means of a video camera (cf. Fig. 2).

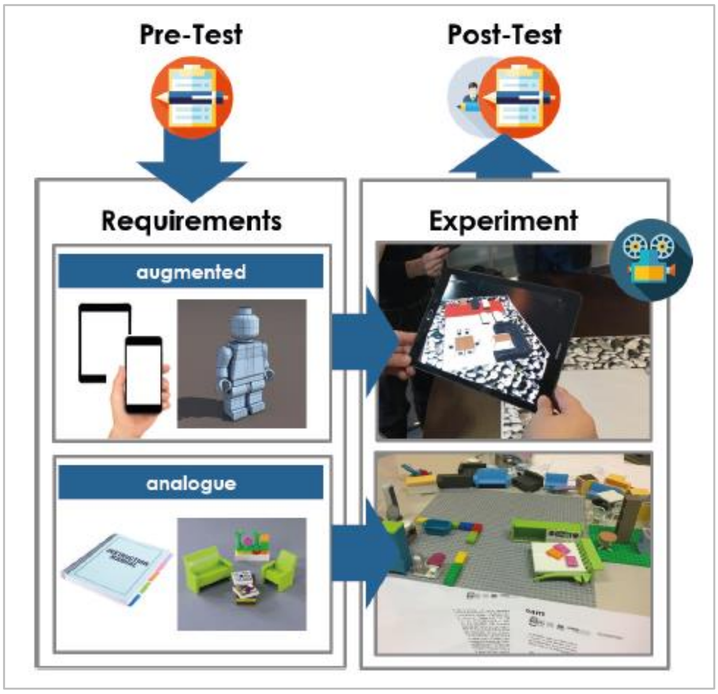

Fig. 2: Study design

The pre-test is of quantitative nature and realised by a standardised questionnaire. It comprises items on demographic details (e.g. "age", "gender", "subject of studies"), the locus of control in terms of using digital technologies (e.g. smartphones, tablets, AR and VR devices like HoloLens or Oculus Rift), a subjective estimation and preference of conducting role-plays, and the emotional activation immediately prior to the experiment. The post-test, in comparison, aims at investigating the experiences and assessment of the experiment as well as the related role-play and AR app. It, thus, includes items on the teamwork, the AR app (e.g. in terms of perceived usefulness, usability, and general assessment of it), the process of finishing the task, and the emotional activation after the conduct of the experiment. The emotional activation is realised in both tests by means of the Affect Grid [15] as a standardised measure to compare the participants' activation before and after the role-play, i.e. before and after using the collaborative AR app in contrast to using the paper-based materials.

In between these tests, an experimental setting is realised by means of the afore-mentioned role-play providing the framework requirements and specifications of the given scenario. During the experiment, the non-AR and AR team work simultaneously, but spatially separated from each other on the same task. In order to gather information and data on the communication within the respective groups, cameras were set up in each room in order to record the collaboration during the role-play.

4. Results

With respect to the sample, 13 students have taken part in the qualitative pre-study on the effects of AR on communication and interaction in collaborative settings. From this sample, the two sub-samples “non-AR team” (n = 7) and “AR team” (n = 6) have been formed randomly. There has been no guided or predefined selection process e.g. in terms of age, gender, preferences etc. in order to form random sub-samples. As far as the demographic details are concerned, the participants are distributed evenly on the subjects of study “Production Technology”, “Automation Engineering”, “Computational Engineering Science”, “General Mechanical Engineering”, and “Technology-Communication”. The average age is 24.08 years which is in alignment with the target group of the lecture, i.e. Master degree students. Besides demographic details, the items on the participants’ locus of control with digital technologies show a high technical affinity in both non-AR and AR teams. In average, the KUT model items [26] were assess with 5, resembling the answer “agree”. Moreover, the ease of use in terms of digital devices is ranked high that is displayed by averages of 5.8 (“very easy”). It is, thus, assumed that the participants will not be having much trouble when initially handling the AR app. Due to a high technical affinity and a high locus of control for digital devices and applications, the transfer of these competencies to new devices and software is expected to be intuitive.

In this study, an independent variable towards communication in collaboration is the emotional activation. It has been gathered by using an Affect Grid that has been given to the participants immediately before and after the role-play for assessing their current emotional status. With regard to the Affect Grid, a difference between the non-AR and AR team shows: while the non-AR team is rather homogeneously highly activated and has a predominantly pleasant feeling in the post-test, the post-test of the AR team shows a heterogeneous and more negative result. The participants in the AR team feel less pleasant and show a tendency towards exhaustion after using the collaborative AR app (see Figures 3 and 4). In terms of a qualitative gathering of feedback on the AR app, the students state the app to be hard to handle without a tutorial and not as visually aesthetic as they wish for it to have a high usability for them.

When conducting the role-play with the non-AR and AR team simultaneously, two cameras have been set up in each of the group’s room in order to record the collaboration process. With this method, it is also possible to analyse the frequency and contents of the verbal communication (not) taking place during working on the collaborative task within each team. In terms of the non-AR team, i.e. working with paper-based materials and Lego, a high verbal communication shows throughout the collaboration process. As is observed in the recordings, all members of the non-AR team engage in an introduction round before starting the actual role-play task. This introduction round is considered basic and essential for the course of the collaboration by the non-AR team in order to distribute tasks most efficiently and most reasonably. As a member of the non-AR team states this introduction was helpful to “know who gets which tasks” in order to economise the time and personnel resources available.

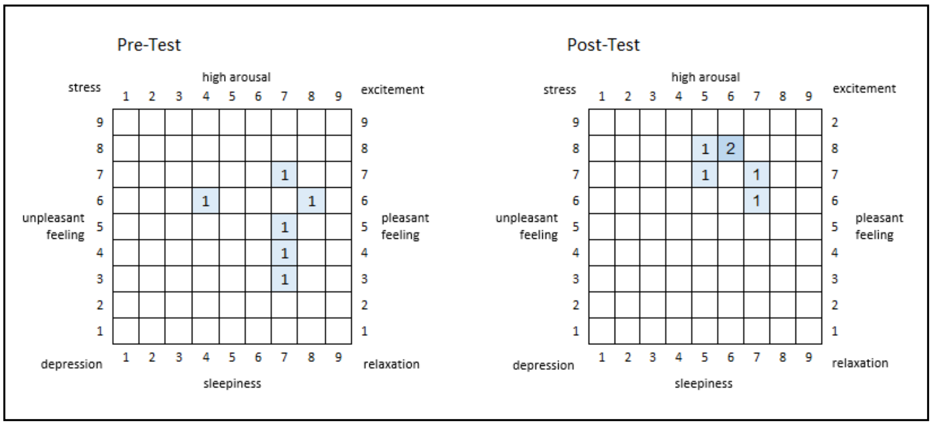

Fig. 3. Affect Grid (non-AR team): comparison of the emotional activation in pre- and post-test

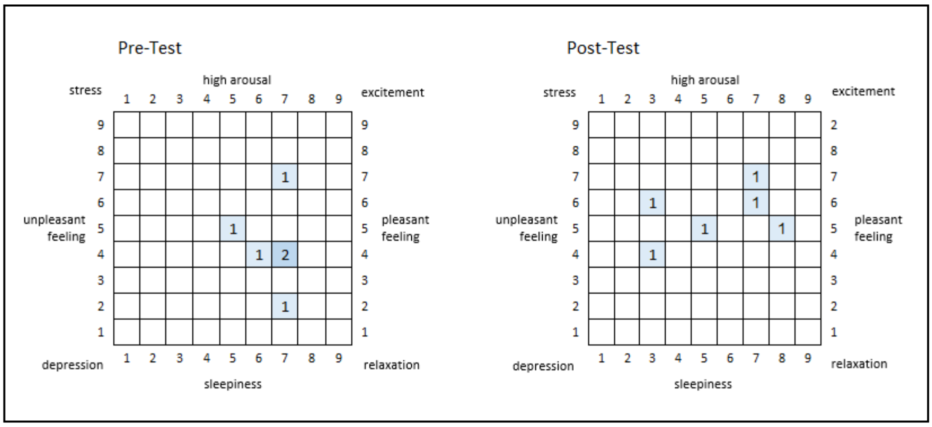

Fig. 4. Affect Grid (AR team): comparison of the emotional activation in pre- and post-test

In direct comparison, the results of the qualitative pre-study show a reverse collaboration process when focusing on the communication. While the non-AR team verbally communicates much during the first half of the process time, the communication in the AR team actually starts off in the second half of the process time and increases even further when the presentation and, thus, end of the role-play approach. The non-AR team uses the verbal communication (e.g. in the introductory round and first planning phase) particularly during the conception phase of the shared apartment's model in order to discuss who takes which task in order to meet all the requirements given. The AR team, in opposition, does not use verbal communication for conceptualising their model of the shared apartment, but immediately takes the tablets with the AR app into usage.

When comparing the timestamps creating different phases of the collaboration, it is identified from the given data that the process divides into three phases for both teams that, however, differ in their length and contents: the first phase for the non-AR team resembles the introductory phase, making use of all the materials handed to the participants, e.g. role and task descriptions, scenario introduction, and clients' requirements. The second phase describes the conceptualisation of the model to be presented to the fictitious clients, i.e. discussing the distribution of tasks onto the different team members as well as the ideas for meeting the requirements. It starts around minute 13 of the role-play. Finally, the non-AR team's third phase displays the preparation of the model of the shared apartment as well as the preparation of the PR Team's preparation for the clients after the 30-minute role-play.

The first phase of the AR team, in comparison, directly resembles the working phase, skipping the conceptualisation first. Without much hesitation, the team members take the tablets with the collaborative AR app starting to move the virtual objects. After around three minutes, the PO is advised by the lecturer to think of his role as “voice between the clients and the scrum team” since the requirements are not considered so far by neither the Devs nor the SM. The second phase of the AR team’s collaboration displays a problem phase. In this phase, the host’s AR app breaks down, causing the closing of the virtual room for all participants in the AR team. This also results in the loss of the model built so far. The third phase, conclusively, is also a preparation phase for the AR team, similarly to the non-AR team’s last phase. In it, the team members of the AR team re-build the model that they have worked out before. Simultaneously, the PR Team prepares the presentation for the clients using screenshots of the model in the AR app taken before phase 2 and during phase 3 in order to show the development of the model throughout the collaboration process.

During the course of the role-play, a reverse picture in terms of the communication shows: the non-AR team reduces their verbal communication among the team, decreasing the discussions in accordance with an increase of concentration on building the model, preparing the presentation, and finishing the task in time, whereas the AR team’s communication increases during the process. A starting point for the verbal communication in the AR team is the second phase including the problem of losing the model built so far. After this event, the team members need to organise themselves more efficiently than before because they have to start building the model from scratch, also losing time on restarting the AR app.

5. Discussion

In terms of the Affect Grid, the post-test shows that the technology AR displays a high motivating factor for students to concern themselves with a specific task, which they actually are not positively disposed at, i.e. the role-play. However, the Affect Grid is merely informative on the overall perception of the AR-supported role play. When investigating the different phases of the collaboration process in more detail, events like the breakdown of the AR app cause a brief and temporary motivational decline but do not seem to have an incisive effect on the general motivation towards using the AR app or participating in the role play. Although the breakdown of the host’s AR app and the subsequent loss of the model on all participating devices, the overall perception of the role play and its outcome is not negatively affected. However, this event causes the increase of verbal communication among the AR team members in the pre-study. Due to the loss of the model and the lack of time, it is assumed that it is necessary to communicate via verbal signals instead of merely using the visual possibilities provided by the tablets and the respective AR app.

As has been described in the results section, the most striking result of comparing these phases of the non-AR and AR teams with respect to communication is the difference in frequency and quantity of verbal communication. While the non-AR team starts with a high frequency and quantity of statements and turns of speakers, the AR team hardly verbally communicates with one another. Instead, the AR team’s participants immediately starts moving the virtual objects within the collaborative AR app without making arrangements with one another. In opposition, the non-AR team immediately start their collaboration with an introduction round: They aim at introducing themselves and their respective role including competences, preferred tasks, and a description of their part in the scrum team to the other team members.

In terms of the start of the role-play it is striking that the AR team hardly talks to one another resulting in a lack of discussions on the outer appearance of the model, the meeting of the given requirements, and the distribution of tasks. However, each team member builds a part of the shared apartment without getting into someone else's way though combining their individual building steps into one coherent model. As the collaborative AR app is a visual tool for fostering the collaboration, it is assumed that the team members do not necessarily need verbal communication in order to arrange themselves, distribute tasks, and find a common concept on the model to be built. It is suggested, thus, that AR changes the way people communicate and interact in such a collaborative setting since the AR app helps visualise the process of building a product together. When merely talking about a concept, the outcome of the collaboration is an abstract one – with the help of AR this abstract output can be made visible and, thus, tangible for every team member already during the process.

With respect to the hypotheses, the results of the pre-test hint at a decrease of verbal communication in the AR team's collaboration as has been suggested in the second hypothesis. As far as the first and third hypothesis are concerned, there are first insights and trends perceptible by means of the results gathered, but the data from the pre-test is not yet enough to confirm or reject the hypothesis. In fact, the results of the pre-test have rather derived new hypotheses in terms of the collaboration and the respective communication in the process: it is suggested that the use of AR has an effect on the satisfaction of both the collaboration process and the outcome of the collaboration, which is to be put under investigation in the subsequent empirical study.

6. Outlook

As the results of the qualitative pre-study display, the use of AR has affected the communication and interaction in collaborative teamwork in this exemplary learning context: Changes in the communicative procedure and, thus, collaborative structure clearly showed. While the non-AR team decreased in their verbal communication – starting with a high frequency and quantity reducing it over the course of the collaboration –, the AR team hardly verbally communicated at the start of the role-play but increased towards the end. In the subsequent study planned, the presented study design will be conducted with a larger sample in order to gain a more quantitative insight into the effects of collaborative AR on communication.

The authors' future studies will also open up research on the influence of the design of the AR app in terms of usability and user experience on the communication and interaction as another variable in this context. In order to further investigate the hypotheses, the empirical survey will be conducted with a larger number of participants. With this study, it is aimed for describing the way people communicate in collaborative settings when using the technology AR as a supportive means not merely on a qualitative, but also a quantitative level in further detail, e.g. by investigating the frequency and durations of turn-taking, the integration of standardised items from validated scales on technical affinity and communication, and the communicative structures that show during the collaborative process.

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