Augmented Reality in Higher Education: An Active Learning Approach for a Course in Audiovisual Production

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Augmented reality (AR), as a future-oriented technology, is of growing interest in recent times. It is listed by Gartner not only as a general technology trend, but also as an important future perspective in the field of education and as a technology "on the rise" (Gartner, 2019).

Although the technological part is very important for the development of educational augmented reality applications, "innovations in digital teaching are not just technical innovations but rather academic, curricular, organizational and structural" (Hochschulforum Digitalisierung, 2015). Therefore, in this paper we examine the combination of suitable didactic methods and innovative technologies, in particular of augmented reality, in an audiovisual production course.

The goal of the presented didactical concept and its corresponding AR-application is to solve problems, identified in our case study, a university-level course in audiovisual production, and at the same time to integrate the advantages of augmented reality technology in the developed application and teaching scenario. We present which tasks and methods are useful in combination with augmented reality and discuss obtained results and future issues.

Definitions and Theoretical Fundamentals

According to Azuma, three conditions must be met in augmented reality: the real environment must be combined with virtual objects, there must be interaction in real time, and registration in 3D (Azuma, 1997).

There are a lot of different characteristics for the active learning approach. As said by Bonwell, active learning "involves students in doing things and thinking about the things they are doing" (Bonwell, 1991). Students must do more than just listen and they should be engaged in activities. In our approach, augmented reality technology is used to encourage the active participation of the students.

Related Work

The combination of augmented reality and didactic scenarios in higher education has been evaluated by different researchers. In this section some examples are described. Fehling discusses social learning, mobile learning and augmented learning, combined with specific teaching-learning forms and didactic concepts, although not at a university but at professional school/trainee program (Fehling, 2016). Technologically, they use smartphones and tablets, which do not fully exploit the benefits of current AR devices.

Considering our case study – audiovisual production – there are mobile apps for film planning like Shot Designer for shotlist creation, storyboard integration and camera diagrams (Hollywood Camera Work, 2019). However, these applications developed for filmmakers are often intended for individual work and are unsuitable for the group work desired in a teaching-learning situation. Among HoloLens apps, there are also applications that make scene design or planning possible. Project Aura (Lab3, 2019), for example, offers the manipulation and storage of 3D objects, but this has no reference to teaching and learning. A suitable didactic concept therefore does not exist for these applications and the usage of augmented reality in this field of education is, according to our investigations, not (completely) studied.

Augmented Reality in Higher Education

With the popularity of mobile devices (smartphones, tablets, etc.), the use of AR as e-learning and mobile learning technology has also been spreading. However, both the use of AR in teaching and the development of appropriate didactic approaches is largely limited to AR as a combination of the camera image of the hand-held mobile device with additional information or interaction possibilities added to the image (FitzGerald, 2013). In some studies, AR with a computer, in combination with cameras and markers, is also implemented. The use of augmented reality has been investigated in many educational areas. Examples are physics laboratories (Akçayır, 2016) and chemistry (Wojciechowski, 2013 and Cai, 2014). Many of the studies show some advantages in this kind of use, but technologically and didactically do not exploit all benefits of the current possibilities of AR. Replacing handheld devices and markers with AR devices like the HoloLens glasses and appropriate teaching methods can eliminate some specific disadvantages in the current state of the art.

The use of AR glasses is especially suitable for setups in which learners should practice and work practically with their hands, which was previously problematic with the use of handheld devices. Learners can keep an eye on the actual subject in their environment instead of fixating the device with their gaze. With newer hardware, such as AR-glasses, it is not necessary to be connected to a computer by cable, or to use handheld devices in combination with markers. Users can move freely and interact with virtual objects without additional markers. For the German higher education system, where our case study is set, Thees and Kuhn describe the use of HoloLens glasses in physics labs (Thees, 2016). In their example, however, the possibility of moving freely in space is not fully explored.

There is also research on the application of AR in anatomy classes (Nørgård, 2018). Although HoloLens glasses were used here, attention was paid only to the visualization of the contents. Nevertheless, it is known from teaching and learning research, that the most effective way to learn is to be active oneself and not only to act as a recipient of content (Waldherr, 2014). The use of AR creates not only better spatial possibilities for activeness of the students, but also for communication and interaction in the teaching-learning situation. This active learning approach is implemented in our work through the assignment of a more active role to the students by using the AR application and tasks developed by us.

Akçayır lists in his systematic review paper a lot of advantages of AR in education like: enhancing learning achievement, enhancing learning motivation, helps students to understand, increases enjoyment (Akçayır, 2016). Some specific aspects of AR technology are also mentioned: combining the physical and virtual worlds, enabling visualization of invisible concepts, events, and abstract concepts, reducing laboratory material cost, providing interaction opportunities (student-student). A lot of these advantages are given also in VR or while using different technologies, but the combination of some of them is only possible in AR.

In a recent review of AR in education (Hantono, 2018) it is described that most AR applications only demonstrate the possibilities of AR technology. "There is still enough homework to be considered by researchers to make AR technology more useful and effective." Our concept is intended to do more research on using AR for teaching purposes and combining it with useful didactic tools and methods. Additionally, the benefits of working in space are applied and researched in our case study in an audiovisual production course.

Active Learning in Higher Education

Pirker (2014) lists several active learning formats, used or developed in different universities: peer instruction, student-centered activities for large enrollment undergraduate courses, studio-physics and Technology-Enabled Active Learning (TEAL, 2005). The project TEAL combines collaborative activities with modern technologies such as networked laptops or whiteboards and was used for physics teaching at MIT. A lot of other universities have active learning classrooms (ALC) which support small group work and the usage of technology (Baepler, 2014). Although we do not use a special ALC, the laboratory, in which the course in audiovisual production is held, does facilitate group work. A more detailed description of our setting is given in the next section.

Case Study Audiovisual Production

In this paper, we approach our research on the use of AR in higher education as a case study in a course on audiovisual production. The course is held at a university of applied sciences. This implies some of the setting details described in the following.

Most students participating in the course specialize in the field of media informatics. The size of the group varies, but it is always a small group – between 10 and 15 participants. In our case study, 10 students tried the AR application that we developed. The AR sessions took place on three different days during the audiovisual production course with a duration of about three hours each day.

The AR-supported parts of the course are supervised by one lecturer, who also acts as a researcher. The audiovisual production course is offered every semester. It consists of a lecture and a laboratory, which take place on the same day. The main themes of the course are planning a short movie (pre-production), shooting a film (principal photography) and post-production. The topic of the film used for the exercises was "Students' opinions (testimonials) about the computer science bachelor degree program". In short movies the students talk about their study of computer science and their experiences. The location for the shootings was indoors, in the lab, where the lecture takes place.

The course takes place in a room similar to ALCs, which "…typically feature tables with moveable seating that support small group work…" (Baepler, 2014). It is possible to move the tables to the side and in that way to offer an open space, which is suitable for working in a group and with AR-glasses, i.e. in our case with the HoloLens as AR-hardware.

Initial Analysis and Preliminary Design Assumptions

In the beginning of the case study, we analyzed 28 students' works and film projects from three semesters (fig.5 in grey). We identified a couple of problems, one of them being that most students did not submit requested pre-production documents like storyboards, lighting diagrams, or screenplays. However, learning about planning and pre-production is part of the goals of the course. Thus, we focused on how to make this part of the lecture more interesting for the students and how to increase their intrinsic motivation.

Research on motivation and the self-determination theory of Ryan and Deci (Ryan, 2000) show three important needs that influence the intrinsic motivation of learners:

– competence – autonomy – relatedness

The didactic methods and the augmented reality app developed in our work aim at strengthening these three aspects.

Furthermore, many studies have shown that learning does not function according to a transmitter-receiver principle. It is not limited to the mere perception of an input, see e.g. Böss-Ostendorf and Senft (Böss-Ostendorf, 2010). However, the situation in a lecture is very often characterized by frontal teaching, which places students in a rather passive "recipient" role. In digitally supported exercises, students are often more active, but they usually sit in front of a "personal computer", a workplace that is best suited for one person. In the case study presented here, these forms of teaching are extended by the use of spatially-aware augmented reality as an additional interaction possibility in an active learning approach. Also, compared to virtual reality (VR), the social competence is supported better in group exercises, executed in the room with AR, because the students and teacher still can see the environment and each other, and thus communicate more easily. With VR the immersion is bigger and the person is more isolated from the real world.

The courses' topics of storyboard, lighting setup, and framing can benefit from the spatial work with AR-glasses. More detailed information on the exact way of implementation is given in the next section.

Development of a Didactic Scenario for a Course in Audiovisual Production

An overview of our conceptual work about educational methods and media is given in Figure 10. Starting with pre-analysis and the identified problems we decided step-wise how to integrate augmented reality in an active learning approach and which topics are best suited for the technology and for solving problems.

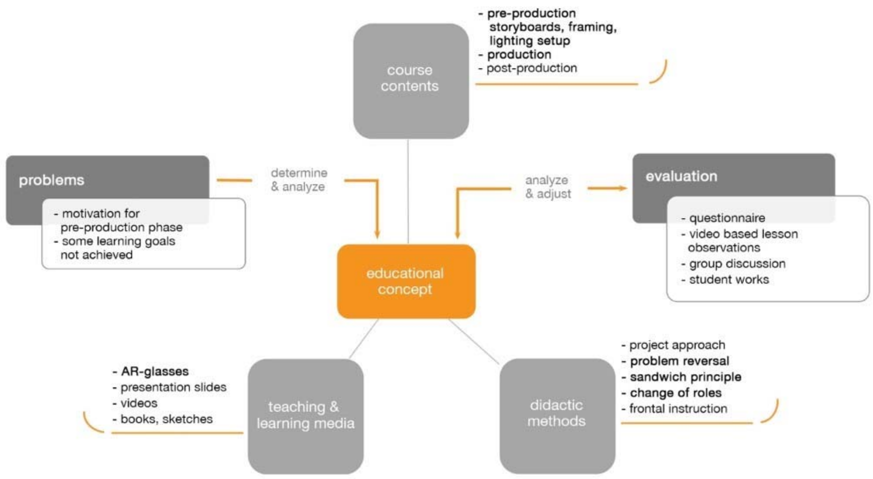

Figure 10. Development of the educational concept for the course in audiovisual production with the use of augmented reality and active learning methods

Analyzing and evaluating the test phases in the course give us hints on how to adjust the mix of teaching methods (active formats, traditional/frontal), topics and media (AR application, presentation slides, videos). For example, in a very early (short) test in the course last year we explained the usage of the HoloLens glasses (gesture, gaze, speech) and the usage of our application in one step. This was a little bit confusing for the students. Therefore, for our next (the actual) test we modified the scenario and separated the introduction of the HoloLens from the introduction of our application (step 2 in Figure 11) in two sessions on two different days.

For the first usage of the app the teacher applies the *problem reversal* method (Waldherr, 2014), (step 4 in Figure 11). The students have to build a "wrong" storyboard - a given screenplay should be transformed into a storyboard, which does not fit the story or has wrong framing. This method is used because the application and the usage of gestures is new to the students. In this first task they should concentrate more on the new interaction possibilities and have fun doing "pictures" with the application. With this method the creativity can be strengthened and in the next step the students have more ideas of what could be a good storyboard. For correcting the "wrong" storyboards, the method *change of roles* (Methodenpool, 2019) is used and the students can correct each other in groups (Figure 10 and step 4 in Figure 11). This way they have to go over the designed storyboards again and have to think about the discussed topics. This step is also a good motivation for social interaction as the students have to decide in small groups what is good and what should be changed.

In a group discussion at the end of the exercise, the created storyboards are discussed and the teacher can show off mistakes or good examples.

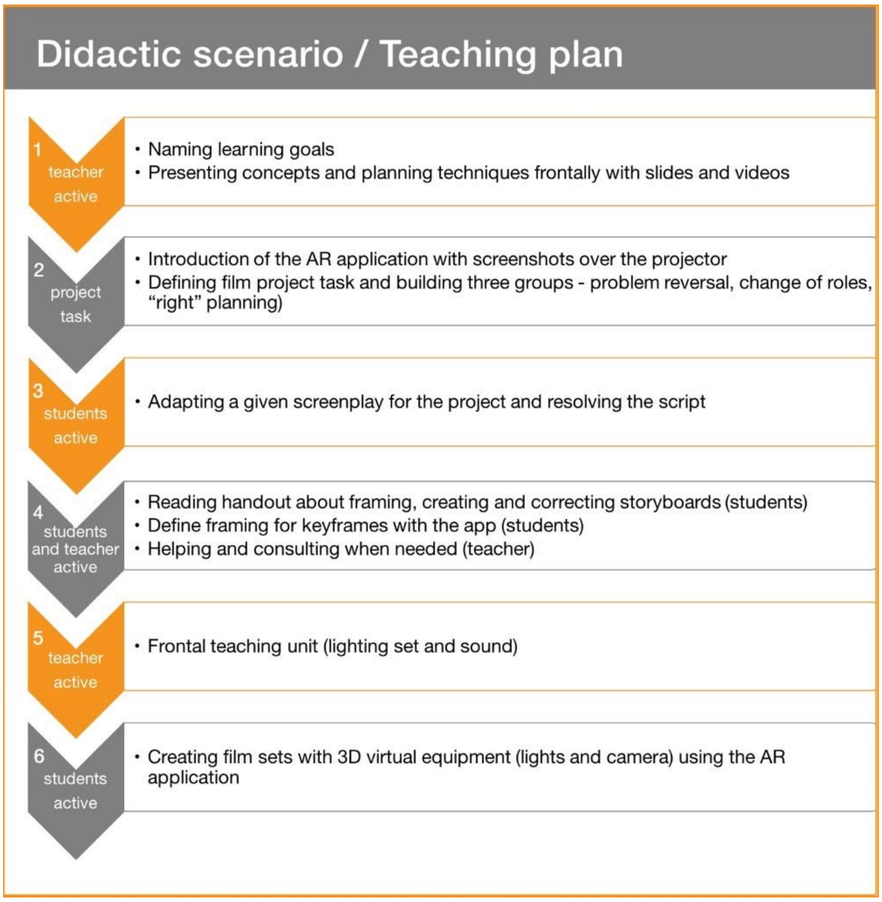

Figure 11. Didactic scenario for the second session with usage of AR in the audiovisual production course.

The topics "lighting" and "technical equipment setup" are first presented traditionally by the teacher with slides (step 5 in Figure 11). In this phase the students have a break from the active work. In the next step (step 6 in Figure 11) they can practice again with the AR application by constructing a virtual light setup for the previously designed storyboards. More about this step is described in the next subsection.

Augmented Reality Application for a Course in Audiovisual Production

During the design process of the application, we addressed and concentrated on the learning objectives, the problems encountered, and the possibilities of augmented reality as a technology. The target groups are the students and the teacher. One of the defined goals is to increase the activity of the students, so the application was constructed to provide a lot of interaction possibilities. We conducted user tests at an early stage of the development and improved the app incrementally.

We used the interaction possibilities given by the HoloLens - selection with gaze and gestures – "AirTap", "AirTap and Hold", etc. (Microsoft, 2019). For bigger movements of virtual objects and for their translation far away from the initial place the movement with hand gestures ("AirTap and Hold") can be difficult, as the HoloLens has a small field of view and the hand has to stay in it, when moving the object. For that reason, we provided an additional option for repositioning – the object is attached to the gaze and when the desired position is fixated with the gaze, an AirTap places the object at the position. The virtual objects used in our application can also be rotated, because the orientation is important for lights and camera planning. Every 3D object has a submenu located next to it which is used to perform this action.

In early versions of the application we tried to position parts of the user interface directly on real objects, e.g. the menu and storyboard panels hung on the wall. User tests showed that the natural position could be a problem, because the reconstruction of the real world by the HoloLens is not always very precise. Effectively, users were unable to select menus, because they were located in the wall instead of in front of it. We decided to deal with this problem by letting the ray cast for selecting and activating items penetrate the walls. Probably because menus are not real-world objects, selecting menus inside walls did not feel unnatural for the users.

Because the motivation of most students for the pre-production phase is not that high, several of the courses' themes were integrated into the application: The students do not have to use many individual programs, but can learn film planning and filming with AR usage in a single application. Not all the contents and tasks are implemented with AR. For example, the use or creation of a film script was not integrated into the application, since AR does not offer any obvious advantages for text design. With AR, reality is only extended and it is still possible to deal with analog information such as texts while using the application. This is also one of the benefits of AR, which is not possible with VR.

Some functions of the AR application and the tasks given by the teacher are designed to motivate the students to participate actively in the exercises for the course topics discussed earlier: storyboards, framing, camera perspectives, and lighting setup.

As described in the last subsection, given a screenplay the students have to build an AR-storyboard (Figure 12). A storyboard is a graphic version of the screenplay with defined framing and perspectives (Klant, 2008). Instead of sketching each frame of the storyboard, the students can setup the scene with virtual props and use the "take photo" function of our AR application. When creating a storyboard with people in it, the students can be part of the picture. Doing this, they have to consider how to stand and position themselves or the virtual 3D objects. They move in the room and automatically have to think about framing, perspectives, and the storyboard picture. The spatial character of the AR technology is a big benefit for this task and for the students' understanding of the space dimension in film making. Discussions concerning the spatial situations were observed during the exercises in the course. We recorded them for later analysis.

Figure 12. Augmented reality storyboard, positioned on the wall (low quality of the picture, because taken with the HoloLens).

The course topics "lighting" and "technical equipment setup" are also supported by the AR application Figure 12. After building the storyboards, the students can plan a setup for every keyframe. To do this they can position virtual 3D lights and cameras in the room and try out some of the typical setups, as presented by the teacher by slides, e.g. "three-point lighting". This exercise gives them more intuitive demonstration of the methods used in film planning and making, because with AR the diagrams or "sketches" are built in 3D (in the room) and not on paper or screen.

In the next step of a film project – the shooting – the saved 3D setups can be brought up at the film location and the real equipment can be aligned to the planned, virtual objects. This kind of 3D planning is much more intuitive then sketches on paper or a 2D screen. For that reason, it is useful for beginners and additionally motivates them to work on planning. Using AR with hand-held mobile devices is also possible, but with a head-mounted display (HMD) like the HoloLens, the students have their hands free for moving the real technical equipment to the virtually planned positions. The combination of the real and virtual equipment was part of the third session with usage of AR in our study.

Methods and Data Collection

As one of the goals in our study is to integrate the augmented reality tool to be useful for teaching and learning, we need to know when and how our concept and app are helpful. In section *Initial Analysis and Preliminary Design Assumptions* and *Analysis and Results* we discuss the points relevant for our study. Further on in the current section, we describe how and what kind of data was collected.

Here, we combined different research methods. We did a participant observation in the course. As already mentioned, one of the instructors also carries out the research. Teaching and simultaneously taking notes for the observation could be problematic, so we chose to film the teaching-learning situation in the lecture and exercise. Since the course topic is about audiovisual production, the students are used to handling a lot of technical equipment. Therefore, the situation of being filmed is not that uncomfortable and unfamiliar for them. The camera and microphone were put in one corner of the room, so they do not disturb the lecture and the activities in the room. For analyzing activities with augmented reality technology, the filming of the entire surroundings enables us to have more detailed information on the spatial interactions of the group. For coding and annotating the video materials we used the ELAN software (Max Planck Institute for Psycholinguistics, 2019). When building categories, we considered the identified problems and the benefits coming with the augmented reality technology, discussed in previous sections.

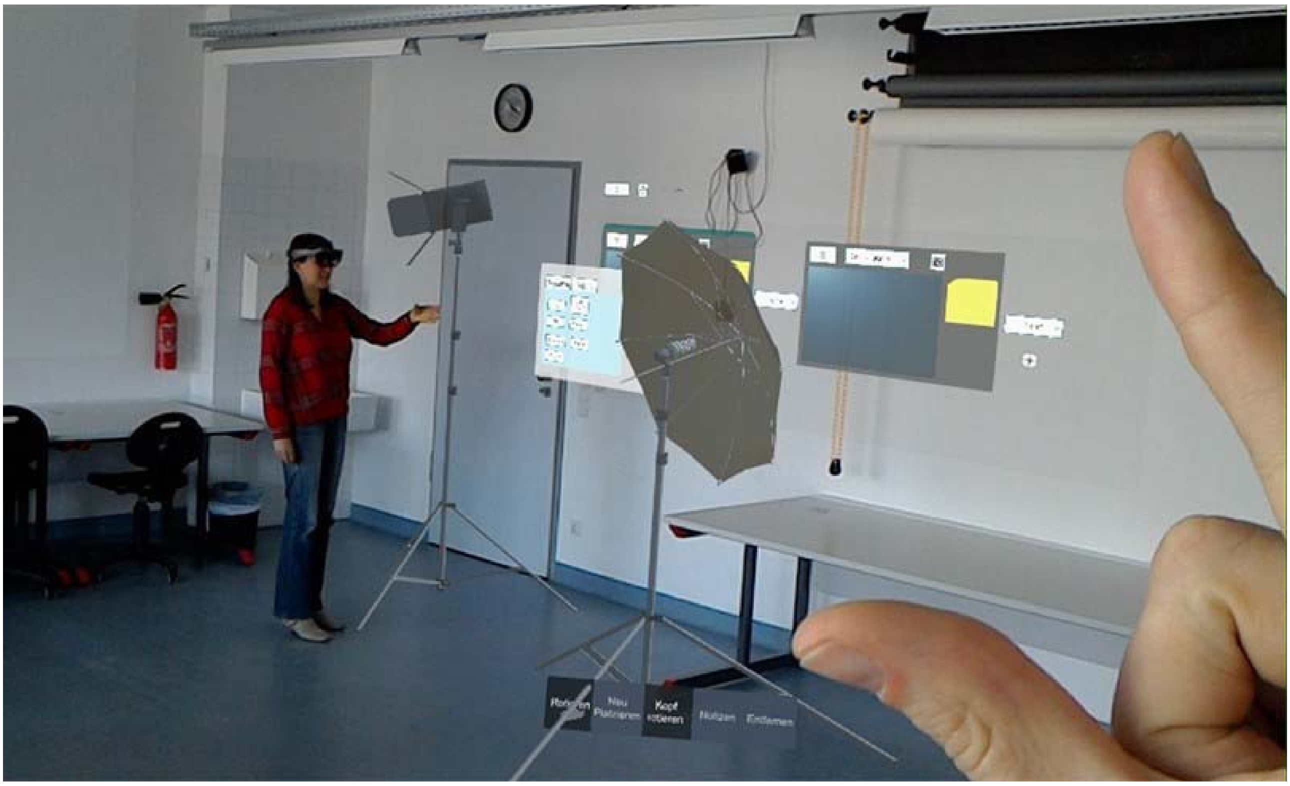

Figure 13. Learning with 3D virtual objects (spot and umbrella light) for planning a film set in the room. In the background: virtual storyboards for the scene.

While undertaking the observation and the analysis afterwards, attention was paid to the various aspects in the "field", i.e. in the teaching-learning situation in the laboratory. We adapted the list described by Daymon by *augmented space* and *virtual objects* (Daymon, 2010). We need the augmented space dimension, because when using augmented reality, we extend the reality and it differs from the real space. With the HoloLens glasses we have a small field of view, and it has to be observed how the students deal with it. Additionally, the virtual objects play an important role in our augmented course. For our field, we had dimensions such as real space, augmented space, actors, activity, virtual and real objects, time, goals and feelings or mood.

Because observation alone does not provide direct information about what the person is thinking during an action (Eriksson, 2008), we decide to collect more answers and ideas during a group discussion with open questions at the end of the lecture. This provided our study with more data to analyze and to support the other used methods.

For more specific data, we also used a questionnaire (fig. 6 in the appendix) with a Likert-like scale (Likert, 1932), based on Intrinsic Motivation Inventory (CSDT, 2019). We combined the results with the video observation and the group discussion. The questionnaire included 22 statements with a 1-to-5 Disagree-Agree response scale (fig. 6 in the appendix). Because the application was tested in three different sessions, some students were not present on all days. Thus, we added a sixth answer ("I didn't use this") for statements referring to tasks or functions of the AR application, that were not performed or used by these students. For our questionnaire we developed categories and then assigned statements to the categories. For example, for the category "competence", which was defined based on the discussion in section *Initial Analysis and Preliminary Design Assumptions*, we had five statements assigned (no. 9, 13, 16, 17, 18 in fig. 6 in the appendix).

Analysis and Results

We calculated the mean value (Table 1) for a statement from our questionnaire (Figure 14) in the appendix) filled by the students. Because we have a five-scale questionnaire, the highest score for a statement was five and the lowest was one.

Table 1. Some results from the questionnaire (Note: results are mean values).

Categories	Results
Active work	4.1
AR technology is interesting	4.6
Social interaction	3.6
Competence	4
Working with gestures and gaze in space	3.7

80% of the students experienced better understanding of the themes storyboards, framing and film planning ("competence" in Table 1) and confirmed their active participation using the AR application in the classroom ("active work" in Table 1). 8 of 9 students think that the augmented reality application and technology are interesting (answer "is true"). 8 chose a positive answer for usage also in other lectures (6 - "is true", 2 - "is more likely to be true").

A statement about taking notes with the application was included in the questionnaire and the results show very low mean value (1.9). Even though the notes field was thought to be only for short 1-2 words notes, the students found it exhausting to type "in the air" with virtual keyboard using gestures. This is an issue which has to be considered for future work.

Results and notes according to the dimensions of the field, presented in the previous subsection, are described next.

After examining the observation recordings, it is positive to note that the students *participated* much more *actively* in the exercise by using the AR application. This observation matches the results from the questionnaire. The work in the room and not in front of the desktop computer is more visible to everyone and motivates for participation. Nevertheless, it should be mentioned, that this is not that easy for all students. The students are often accustomed to frontal teaching or computer work and need some time to start actively moving around in the room. This must be considered when planning the teaching time with AR. Regarding the *time* dimension it can be said, that a too long duration of the active parts in the exercise showed some negative effects towards the end of the lecture. In the afternoon (which is the time setting of the course) the active parts have to be short or interrupted with breaks, because most students looked tired at the end and this can affect the motivation and the *mood*. The fatigue could be also an issue regarding the work in *real space* while standing and working with *virtual objects* using gestures.

Observing the dimensions *activities* and *actors*, it is noticeable that some students do not want to act in front of the camera and be part of the storyboard image. In this case virtual characters can be used, which are then placed by exactly these students. Consequently, they also participate actively, but do not have to be in the picture if they do not feel comfortable with it.

Analysis of the group discussion, which has also been recorded, showed that the highest total duration time was in the category "ideas and new features for the application". Almost the same total duration had the categories "spatial work", "framing in the storyboards" and "does not function optimal". Some of the categories were defined before the discussion, some of them were brought up by the students, as the teacher started the discussion with open questions and the students decided which topic to discuss longer.

Analysis of the questionnaire (Figure 14 in appendix) shows mean values 3.6 and 3.7 for the categories "social interaction" and "working in space with gestures and gaze" (Table 1). The lower acceptance was confirmed by the observation and the group discussion. One of the most discussed themes "does not function optimally" was associated with working in space and with gestures. It was mentioned also that after a familiarization phase it was easier to work with the virtual items. Some students also had problems with the tracking and recognition of the room by the HoloLens glasses. Therefore, attention has to be paid to issues regarding the *real space* and *real objects*. The HoloLens glasses work well in a space which is not too big or small. The optimal zone for hologram placement is between 1.25 and 5 meters in front of the user (Microsoft, 2019). Too many real objects could affect the group work in the room, as the students need a free area to move.

The social interaction was higher than when doing tasks on the computer, since the computer is usually used by a single person. But it was not that easy to work together in the *augmented space* directly, as only the person wearing the glasses sees the virtual augmentations. Improvements for this problem are discussed in the future work section.

Several students mentioned in the group discussion that they prefer to use the augmented reality application rather than paper and pencils or web program. There were a lot of ideas for the program, which indicates interest for the topic. The group discussion shows, that the active participation and motivation of the students for the preproduction phase was successful.

At the end of the semester we analyzed the students' assignments as we did in the initial analysis mentioned in previous section. This way we were able to compare data of the course with AR usage with results achieved without AR. Our results show an increase of the percentage of submitted pre-production documents, which the students had to create as a part of their project report (Figure 14 in orange). This is an indication, that the pre-production phase is considered more important by the students than without AR and their motivation for that phase seems to be higher. Analyzing the projects reports in the next semester will help to collect more data and to verify the results.

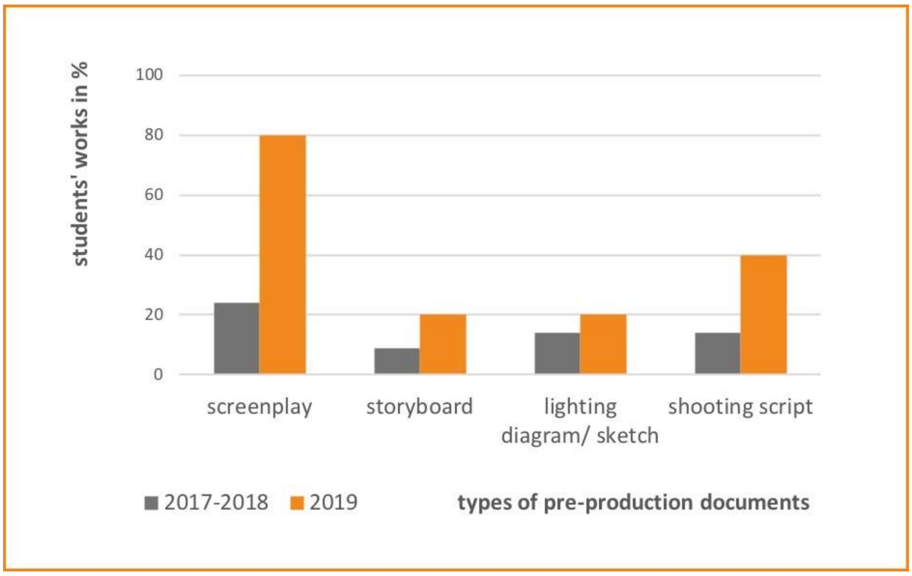

Figure 14. Comparison of number of students' pre-production documents

Lessons Learned

We would like to emphasize a number of lessons we learned during our tests. They are results of observations and our case study on how to deploy AR in an optimal way and what activities are recommendable to integrate.

A special introduction to working with AR glasses is necessary.

It is better to explain the AR application with standard tools (like presentation slides) instead of using the app and showing time-delayed via projector.

Alternation of active and passive phases for the students is helpful to prevent fatigue.

AR activities in the room help students to participate more actively during the course.

Small groups are more suitable for using the AR application, because for working with AR in the room one needs more space.

Conclusion and Future Work

Teaching and learning at the university is no longer thinkable without digital media. Therefore, innovative scenarios should continue to be conceptualized, tested and researched. It is important to develop and investigate approaches at an early stage of technology so that the universities do not fall behind, but remain innovators and one step ahead. In our case study "audiovisual production" some of the assumed advantages of augmented reality were confirmed. AR is suitable both for use in spatial work and for increasing the activity and motivation of students. As to be expected, challenges could also be identified. The social interaction is supported with the use of augmented reality, but it can still be optimized. The "augmented space" should be visible for more than one person. The integration of shared experiences is the next step for our future work on the application. Another feature to implement and test is audio notes, as the results from the questionnaire showed that writing notes (even short ones) is exhausting using gestures in AR.

Regarding the didactic scenario, it is planned to add a fourth session for using the AR application in the course. This way the students can have more time for learning to work with gestures and gaze. In the next semester, the active parts with the AR application will be shortened and mixed with different tasks or frontal presentation. For the AR sessions in the future an additional instructor or assistant is planned, as the three groups in the exercises need more attention or support with the new interaction and hardware.

The developed AR application and the corresponding teaching scenario will be tested in similar lectures at other universities in the near future. This will be helpful to determine which differences the changed context (different rooms, different group size, technical equipment etc.) brings and where similar advantages or problems arise from the use of AR.

In order to integrate AR into teaching permanently, hardware-specific upgrades are necessary. At the moment, the technology is still expensive, but there is the expectation that it will become more accessible over time and that the universities will then be able to purchase a higher number of AR devices.

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Appendix: Questionnaire

The questionnaire for evaluation of the case study is shown in Figure 15.

Feedback for the educational AR application in the course *audiovisual production*

Dear students,

with this questionnaire we would like to examine your experiences with the AR application in the exercise. How did you find using the application? In the following statements, check the column that most closely corresponds to your opinion.

Thank you very much.
The SAARTE project team

I was present during the exercise on 11.4.2019. Yes / No
I was present during the exercise on 18.4.2019. Yes / No

		is not true	is rather not true	is partly true	is more likely to be true	is true		I didn't use this
	Statements on specific functions							
1	Selecting the framing/shots via drop-down was possible without much effort.							
2	Creating a storyboard image was easy.							
3	Creating notes was exhausting.							
4	The placement of the objects/menus via gaze was easy right from the start.							
5	The placement of the objects/menus via gaze was unproblematic after a familiarization phase.							
6	Selecting the transitions between the storyboards was possible without much effort.							
7	Displaying the storyboards in the room was not optimal.							
8	Saving the storyboards was unproblematic.							
9	The application was helpful for the tasks I had to perform.							

		is not true	is rather not true	is partly true	is more likely to be true	is true		I didn't use this
	More general statements							
10	The application gave me enough visual hints to the current input position or action (e.g. textual hint, color, cursor etc.).							
11	I found the use of the application in the exercise interesting.							
12	It was not difficult for me to learn how to use the application.							
13	I am satisfied with my performance in the exercise.							
14	The terms used in the application were understandable for me.							
15	By using the application, I was able to actively participate in the exercise.							
16	I was able to practice subject terms such as storyboarding, framing, shots.							
17	I learned a lot about film planning.							
18	I think I was pretty good at creating storyboards.							
19	To use the application, I had to move around in space a lot.							
20	In order to use the application, I had to remember many details.							
21	While using the application, I worked and discussed a lot with other students.							
22	I would also use this technology in other teaching and learning scenarios.							

Thank you very much for your participation!

Figure 15. Questionnaire for the students (translated)

References

Akçayır, M., Akçayır, G., Pektaş, H.M. and Ocak, M.A., 2016. Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. Computers in Human Behavior, 57, 334-342.

Akçayır, M. and Akçayır, G., 2017. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review, 20, 1-11.

Azuma, R.T., 1997. A survey of augmented reality. Presence: Teleoperators & Virtual Environments 6(4), 355–385

Baepler, P., Walker, J. and Driessen, M., 2014. It's not about seat time: Blending, flipping, and efficiency in active learning classrooms. Computers & Education 78, 227–236

Bonwell, C.C., Eison, J.A. and Staff, A., 1991. Active Learning. Jossey-Bass

Böss-Ostendorf, A. and Senft, H. 2010. Einführung in die Hochschul-Lehre: Ein Didaktik-Coach. Budrich, Opladen, 1 edn.

Cai, S., Wang, X. and Chiang, F.K., 2014. A case study of Augmented Reality simulation system application in a chemistry course. Computers in human behavior, 37, pp.31-40.

CSDT (Center for Self-Determination theory): Intrinsic Motivation Inventory (IMI), https://selfdeterminationtheory.org/intrinsic-motivation-inventory/, last accessed 2019/08/19

Daymon, C. and Holloway, I., 2010. Qualitative research methods in public relations and marketing communications. Routledge.

Eriksson, P. and Kovalainen, A., 2008. Qualitative Methods in Business Research

Fehling, C.D., 2016. Social augmented learning: Lehren und Lernen in einer erweiterten Realität.

FitzGerald, E., Ferguson, R., Adams, A., Gaved, M., Mor, Y. and Thomas, R., 2013. Augmented reality and mobile learning: The state of the art. International Journal of Mobile and Blended Learning.

Hantono, B.S., Nugroho, L.E. and Santosa, P.I., 2018. Meta-review of augmented reality in education. In: International Conference on Information Technology and Electrical Engineering (ICITEE).

Hochschulforum-Digitalisierung, 2015. Diskussionspapier - 20 Thesen zur Digitalisierung der Hochschulbildung. Arbp.-Nr. 14, Hochschulforum Digitalisierung, Berlin, Germany

Hollywood Camera Work 2019. Shot designer - software, https://www.hollywoodcamerawork.com/shot-designer.html, last accessed 2019/03/26.

Klant, M. and Spielmann, R., 2008. Grundkurs Film. Kino, Fernsehen, Videokunst, 74-79.

Lab3: Projekt Systementwicklung: Aura - HoloLens Projekt, https://www.lab3.org/de/projekte/aura-hololens/, last accessed 2019/03/25.

Likert, R., 1932. A technique for the measurement of attitudes. Archives of psychology

Max Planck Institute for Psycholinguistics, Nijmegen, ELAN: Computer software, version 5.5, https://tla.mpi.nl/tools/tla-tools/elan/, last accessed 2019/06/28

Methodenpool: Rollenspiel, http://methodenpool.uni-koeln.de/download/rollenspiele.pdf, last accessed 2019/08/15

Microsoft: Hologram stability, https://docs.microsoft.com/en-us/windows/mixed-reality/hologram-stability, last accessed 2019/06/28

Microsoft: Core building blocks, https://docs.microsoft.com/en-us/windows/mixed-reality/gaze, last accessed 2019/08/27

Nørgård, C., O'Neill, L., Nielsen, K., Juul, S. and Chemnitz, J., 2018. Learning anatomy with augmented reality. EDULEARN18 Proceedings pp. 1413–1422.

Panetta, K. 2018. Gartner top 10 strategic technology trends for 2019. October 2018 https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2019/, last accessed 2019/03/20.

Pirker, J., Riffnaller-Schiefer, M. and Gütl, C., 2014. Motivational active learning – engaging university students in computer science education. Proc. 2014 Conf. Innov. Technol. Comp. Sci. Educ., June 21-25, 2014, Uppsala, Sweden pp. 297–302

Ryan, R.M., and Deci, E.L., 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American psychologist 55(1), 68–78.

TEAL Project Team: Technology-enabled active learning. 2005. http://icampus.mit.edu/projects/project/?pname=TEAL, last accessed 2019/06/26.

Thees, M. and Kuhn, J., 2017. gLabAssist - Smartglasses als Assistenzsystem für natur- und ingenieurswissenschaftliche Hochschullaborpraktika. In: BMBF-Fachtagung "Hochschule im digitalen Zeitalter"

Waldherr, F. and Walter, C., 2014. Didaktisch und praktisch: Ideen und Methoden für die Hochschullehre. Schäffer-Poeschel, Stuttgart.

Wojciechowski, R. and Cellary, T. 2013. Evaluation of learners' attitude toward learning in ARIES augmented reality environments. Computers & Education pp. 570–585.