Augmented reality to support self-directed learning in practical technology teacher training – Presentation of the SelTecAR project and investigation of the conditions for success.

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ABSTRACT

Augmented reality (AR) can be a useful tool to support self-directed learning processes. This possibility is being used in the SelTecAR project (Self-directed Learning in Technical Studies through Augmented Reality) by the Technical Education working group at the University of Oldenburg to improve the manual-practical training of technical education students and to consider more strongly that some students with previous experience can link to previously acquired skills, whereas the other students cannot. Therefor a new learning concept is being developed for the technology teacher training workshop module, which enables AR-supported self-directed learning with flexible learning times and assistance. Within the project, an augmented reality environment is created in the workshops where teaching takes place, in which students can use their own smartphones to view instructions as overlays or video tutorials and call up important information on tools or machines. For the purpose of scientific monitoring, support needs are determined in order to be able to set up the AR environment in a targeted manner; in addition, conditions for success in the use of the AR environment are investigated. The results of the self-directed learning needs assessment show that working with machine tools and circuit design are learning content areas that require support for self-directed learning. The investigation of the conditions for success in implementing such an environment happens within the development. Several points became apparent. Among other things, the selection of the right software plays a major role depending on the support needs. In addition, access must be low-threshold (use of the private smartphone, without login, etc.) and the use must be integrated into the instruction phases preceding the self-learning phases.

Keywords: Augmented Reality, self-directed learning, technical education student, manual training

1. REPRESENTATION

1.1. Initial situation

The engagement with technology in technology education often occurs in a hands-on and product-oriented manner (Bleher, 2001). Typical methods of technology education are construction and manufacturing tasks (Hüttner, 2009). The classroom where the lessons are held should possess a workshop character. This allows for testing manual skills and for the use of various materials such as wood, metal, and plastic. Furthermore, the characteristics of a laboratory should be present for conducting technical experiments and analyses (Röben, 2018).

In order to enable prospective technology teachers to teach in such an environment, competencies for practical work with tools and machines must be acquired during teacher training. According to Geschwendtner & Geißel (2018), these competencies include "solid and applicable knowledge of relevant materials, tools, measuring instruments, machines, safety-conscious handling of tools and machines, maintenance and care, as well as (2) practical skills (manual skills)." In the teacher training programme at Carl von Ossietzky University Oldenburg, this knowledge is taught in a basic module that comprises twelve semester hours. Teaching in this module takes place in small groups with alternating lessons and self-learning phases. The taught skills are repeatedly addressed in project-oriented modules throughout the further course of study.

1.2. Problem statement

At the start of their studies, the prior manual experience of students varies significantly. Some students have completed vocational training before commencing their studies, whilst others have not. This was found in a survey at several locations of teacher training programmes, including the University of Oldenburg (Bünning et al., 2018; Riese & Ermel, 2022). Moreover, there are only a few projects that offer technology education at the gymnasium level in Lower Saxony (Wiemer & Haverkamp, 2020), so only those students who had prior experiences beyond a purely academic education can generally build on them.

As a result, there are key challenges in technology teacher training: While students with manual experience can build upon already acquired skills in practical modules, others cannot. Furthermore, there is a need to reactivate acquired competencies in later project-oriented modules, but this is often postponed.

1.3. The SelTecAR-project as a solution for the problem

The SelTecAR project was developed to create an AR environment promoting self-directed learning. It is supported by the "Freiraum 2022" call for proposals from the Foundation for Innovation in Higher Education (Stiftung Innovation in der Hochschullehre, 2022).Within this project, a new learning concept for the workshop module is being developed for technology teacher training at the University of xxx. This concept enables AR-supported self-directed learning offering flexible learning times and assistance, tailored to individual learning needs. Furthermore, these aids are intended to be utilised throughout the course of study to address individual knowledge gaps in follow-up modules.

As a component of the project, an augmented reality environment is being established in the workshops where teaching occurs. Students can use their smartphones to view instructions as overlays or video tutorials. They can also access crucial information about tools (e.g., screwdrivers, side cutters, soldering irons) or machines (e.g., lathes, jointers, laser cutters). This new approach reduces instructional phases by lecturers and extends individual self-learning phases in the workshop module, allowing students to decide which areas require more information and repetition through the AR environment.

The project's objectives include: development of an AR environment with explanatory overlays and video tutorials for the workshops, development of a seminar sequence adapted to the workshop module and scientific monitoring and evaluation of the implementation.

To fulfil these objectives, machines, tools, and processes that require a high level of explanation are initially identified through surveys of students and teachers. This is followed by restructuring the seminar sequence in terms of instructional and self-learning phases. Simultaneously, a survey is developed and conducted for students participating in the workshop module without AR support. Subsequently, information packages and video tutorials are created for the identified content, and an AR environment is set up for retrieval. Upon completion, internal training of the research group members on using the AR environment takes place. The AR environment will be applied within the restructured workshop module in the summer semester 2023, along with scientific oversight examining its use by students.

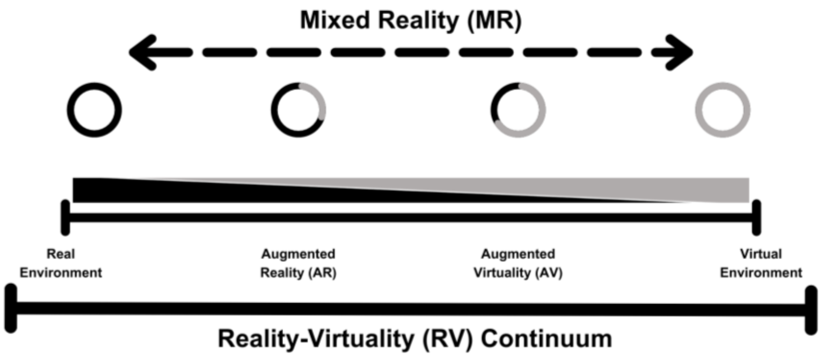
2. THEORETICAL BACKROUND AND PRELIMINARY SURVEY

2.1. Augmented Reality

The technology education of tomorrow requires teachers to integrate forward-looking topics such as 3D printing, robotics, and new technologies, media, and methods into their lessons. Virtual worlds, in which learners can explore technical objects, spaces, and places, should increasingly be part of today's technology teachers' task repertoire (Nepper, 2021).

Augmented Reality (AR) is often used interchangeably with Mixed Reality (MR) and Virtual Reality (VR). Milgram et al. (1994) established the Reality-Virtuality Continuum to clarify these terms. The continuum signifies a gradual transition between real and virtual environments (Mehler-Bicher & Steiger, 2022). Reality is at one end, and virtuality is at the other. The transition between them is MR. AR is part of MR, but not all MR is AR. The distinction lies in the degree of overlay. AR dominates when reality prevails, while Augmented Virtuality (AV) dominates when virtuality prevails (Milgram & Kishino, 1994).

Figure 1.
The Reality-Virtuality Continuum own illustration based on Milgran et al. 1994, S.283



Azuma (1997) defines AR as overlaying reality with virtual objects, complementing reality instead of replacing it entirely. AR is characterized by combining virtual and real environments with partial overlays, real-time interaction, and three-dimensional relationships between virtual and real objects. AR can be divided into a broader sense, which only includes the extension of reality with virtual content, and a narrower sense that fulfills all three characteristics (Dörner et al., 2019; Mehler-Bicher & Steiger, 2022).

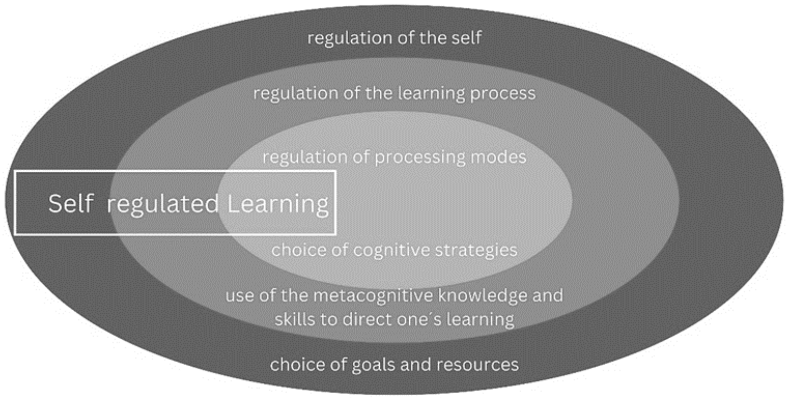
In the context of teaching and learning, AR can be applied in multiple instructional dimensions. A distinction can be made between learning with AR and learning through AR. Learning with AR means that learners use an AR environment to stimulate their learning processes. Learning through AR involves learners creating an AR environment to encourage their learning processes. The SelTecAR project can be considered learning with AR from the students' perspective, and learning through AR from the employees' perspective, as the environment must be built and implemented.

2.2. Self-activity in learning

According to Klafki (2007), self-activity is the central form of education, and the purpose of education is to enable self-determination. Self-determination includes self-regulated and self-directed learning. While these terms fall under the category of self-determination, they can be distinguished in the context of learning. Self-regulated learning is divided into three levels in Boekaerts' (1999) Three-Level Model of Self-Regulation: regulation of processing, regulation of learning, and regulation of self. Bastian (2007) adapted these levels to the terminology of planning, monitoring, and reflection.

Self-directed learning requires highly structured self-learning materials. These materials structure learning paths but do not prescribe them. It is not intended to relieve teachers of responsibility for the learning process, but to provide meta-competencies that enable learners to respond to new demands. Firstly, learners must develop an appropriate self-understanding in their capacity as learners. This self-understanding includes a corresponding role understanding in the institutional learning context, a willingness to take conscious responsibility for one's own learning process, knowledge of one's own learning patterns and behaviors, and the ability to use individual preferred learning strategies effectively.

Figure 2.
The Three-Level Model of Self-Regulation (Boekaerts 1999, S. 449)



AR support is situated in the field of self-directed learning, as it can be used to offer students additional support options that they can use independently to react to and solve new challenges. It must be ensured that learners are offered as many different learning paths and media as possible.

2.3. Preliminary survey on support needs

Creating an AR environment to support self-directed learning requires identifying the areas where students need assistance. This involves analyzing the module contents and surveying students to determine which topics they find challenging.

Therefore, a questionnaire was used to collect data from students in workshops, where they learn to operate various machines and tools. The questionnaire included a four-point Likert scale for self-assessment of support needs (Porst, 2014). The data were analysed employing descriptive statistics and box plots. Bivariate correlations were utilised to probe the relationship between the level of study and support needs.

The results showed that the average level of support needed was 1.43 out of 4. The highest level of support was needed in the area of automated manufacturing, with the widest range of support needs observed in the area of electrical engineering. The highest support needs were observed for the laser cutting machine and 3D printer, and for circuit building in electrical engineering. Female students reported significantly higher levels of support needed compared to male students. No significant differences were observed between bachelor and master students. These findings can be used to develop an AR environment to support self-directed learning, with a focus on addressing the support needs identified in the study (Autor 1 & Autor 2, 2022).

2.4. Conditions of success as a measurable construct

If educational research is practice-oriented, it should investigate whether an innovation in the field of education succeeds (Gräsel & Pachmann, 2004). The conditions for success are diverse. In general, two models can be distinguished when implementing innovations in education, and accordingly, two different approaches can be assigned to investigating the conditions for success (cf. ibid.). The first approach is a top-down strategy. In this method, responsible authorities (such as researchers and education officials) determine the innovations and hand them over for implementation. Measurable success factors are whether the innovations are implemented and to what extent the implementers make changes during implementation. Another approach is the symbiotic implementation strategy. Here, the innovations are developed in cooperation with the implementers and introduced together, and may be further developed in the process. Measurable success factors are the improvement of the situation to be changed and the success of the cooperation of the participants (cf. ibid.).

To successfully implement a project, potential influencing factors on implementation should be considered in the development process (cf. Schulte & Wegner, 2021). These can also provide indications of appropriate research questions to investigate the conditions for success. Jäger identifies three factors for this purpose (Jäger, 2004). The first is the content factor. An attractive innovation project forms an advantage over the previous practice, corresponds to the values of the implementing teacher, and is not too complex. The second factor is structure. This refers to the relationship between the goal and the initial structure, which ideally should not be too far apart. The third point is the people, whose cooperation and interaction are a success factor in the implementation of innovations.

In summary, it can be stated that conditions for success are a measurable construct for the implementation of innovations. How they're investigated varies based on the implementation type. The decisive factors for this are content, structure, and people.

3. INVESTIGATION OF SUCCESS CONDITIONS

3.1. Research Questions

Generally, the question is whether the system has been successfully implemented, which leads to the first research question, "How did the roll-out succeed?" (Q1). The other questions relate to the points mentioned in 2.4 regarding the conditions for success: In terms of person, these include the question, "Are lecturers regularly referring to the AR environment and allowing appropriate time for self-learning phases?" (Q2) concerning content: "Is the AR environment used to support self-directed learning processes?" (Q3) and to the area of structure, the question, "Which areas of the AR environment's structure are used preferentially?" (Q4).

3.2. Research Design

In order to measure the success of the implementation of the AR environment to support self-directed learning processes, a research design has first to be developed. Based on design-based research projects, where innovations are implemented in a regulatory process (Baumgartner et al., 2003), there should still be opportunities for adjustment during the implementation. To ensure this, a two-stage survey was planned. The first survey point is six weeks after the start, after which there is an opportunity to readjust and the second is eight weeks later, just before the end of the semester.

The project examined here can be considered a top-down implementation in relation to Chapter 2.4. Although the teachers in the training workshops participated inthe selection of content for the AR environment, the implementation was planned by the project managers and presented to the teachers for implementation. In terms of the three conditions mentioned in 2.4 - content, structure, and people - it must therefore be examined in the content area whether the AR environment is used as planned, i.e. to support self-directed learning processes. In terms of structure, the functional integration of the AR environment into teaching must be assessed. This involves determining whether students can effectively use the mobile application (app), identifying which sections of the app are frequently accessed, and recognising any issues related to its use. In the area of people, it must be examined whether the teachers regularly point out the app and whether they also allocate times to work with the app. Since there is only a moderate amount of experience gained at the first survey point, especially in the area of use, it is also asked to what extent the students plan to use the app in the future. For this reason, for the first survey presented here, the last two questions (Q3 and Q4) are asked as forecast questions of future usage, which can then be compared with actual usage behavior after the 2nd survey.

3.3. Methodology and Sample

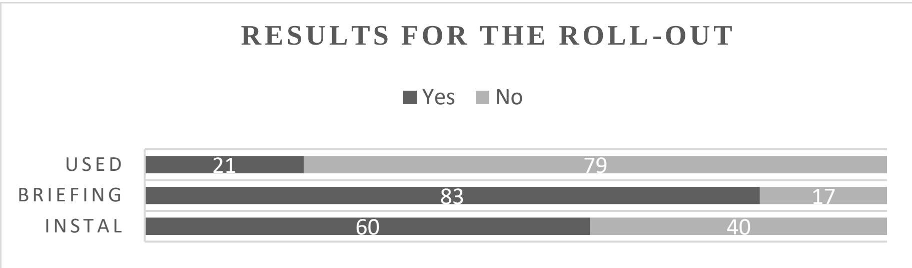
To gather a comprehensive database, all students participating in the workshops will be surveyed. The sample thus consists of all students of one year, so approximately 70 people can be surveyed. For the survey of such a large number of people, the use of a questionnaire is recommended (Döring & Bortz, 2016). The content of the questions are the items mentioned in 3.1. These are mostly assessment questions, such as the frequency of use of the app in different contexts. For such a type of question, the use of a Likert scale is suitable (Porst, 2014), which is constructed as an endpoint-oriented scale and can therefore be analysed with methods for interval-scaled data (Hollenberg, 2016).

Specifically, the questionnaire is structured as follows: firstly, participants are coded to allow for comparison across the two survey points. Then it is also asked how many workshop courses have already been taken and whether there is previous experience, for example through training. Afterwards, the questions about content, structure, and people are asked. The conclusion consists of questions about the estimated future use of the AR environment.

3.4. Results

Seventy students took part in the survey six weeks post-roll-out. The survey showed that 83% had received an introduction to the environment, 60% had already installed the app and 21% had already used the app (excluding the introduction) in the seminar for self-directed learning (see figure 3). For Q1, this means that the roll-out can be considered a success.

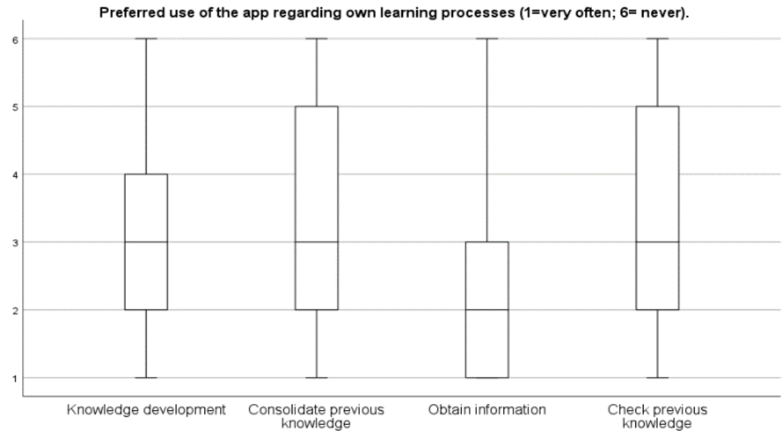
Figure 3.
Results for the Roll-Out



In terms of the restructuring (1= very often; 6= never), the questionnaire showed that the students are rarely pointed to the AR environment so far (M=4.53; M=5.00; SD=1.491). Additionally, students are currently still not given enough time for their self-study phases during the seminar (M=4.79; M=5.00; SD= 1.339). For Q2, this indicates that that consistent mentions of the AR environment, paired with dedicated self-study intervals, need enhancement. This may be related to the fact that only 21% of the students use the app so far.

As noted in 3.2, these questions are asked as prediction questions. This leads to the following results: Preferably, students would use the app to obtain self-directed information (M=2.71; MD=2.0; SD=1.687), followed by use for knowledge development (M=3.23; MD=3.0; SD=1.486). A broad spread observed in the box plot can be attributed to the initial roll-out phase and the ongoing innovation establishment.

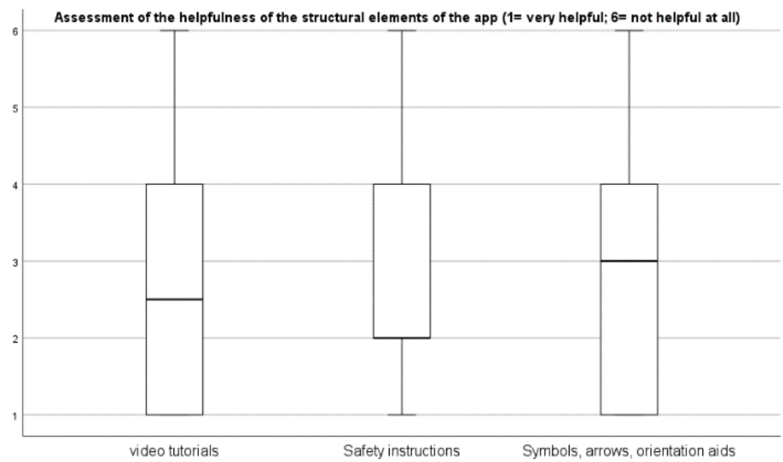
Figure 4.
Preferred use of the App.



For Q3, it thus emerges that students would use the AR environment mainly for obtaining information and acquiring knowledge with regard to their self-directed learning.

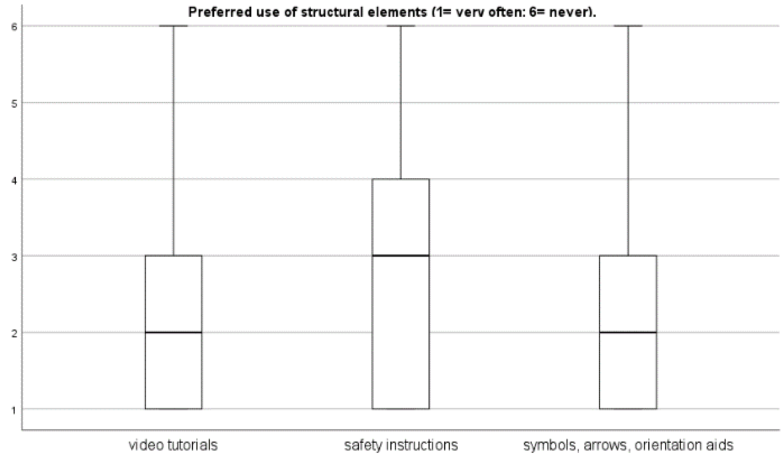
At the structural level, all three structural elements are rated as equally helpful, with video tutorials slightly predominating (videos: M=2.74; MD= 2.5; SD= 1.603; safety instructions: M=2.80; MD= 2.0; SD= 1.575; icons: M= 2.79; MD= 3.0; SD=1.623).

Figure 5.
Assessment of the helpfulness of the structural elements



The students would prefer to use the video tutorials (M=2.51; M=2.00; SD=1.549) as well as the symbols, arrows and orientation aids (M=2.53; M=2.00; SD= 1.683). Here again, there is a large spread in both, which can also be attributed to the roll-out and the innovative character

Figure 6.
Preferred use of structural elements



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Q4 suggests that while all AR environment's structural components are deemed beneficial, students are inclined towards incorporating video tutorials and illustrative symbols and aids in their autonomous learning journey.

4. CONCLUSION

Augmented Reality can be used to activate self-directed learning processes by providing individual support needs to students through an AR environment. Whether the implementation of an AR environment is successful depends on the factors content, structure and people. The results of the study presented here on the conditions for success show that the roll-out worked well and that the first students also used the AR environment. The potential that the students see in the app can be highlighted as positive at the content and structural level. For example, students want to use the app to obtain information and acquire knowledge in a self-directed manner. To do this, they would prefer to use video tutorials as well as the icons, arrows and orientation aids. After the roll-out phase, however, there is still room for improvement in terms of compliance with the new seminar structure. For example, the data shows that too little time is still allocated for this and also that too little attention is still paid to the AR environment. For this reason, the next steps within the project consist of intensive support for the transformation of the seminars. This result also shows that a key condition for the successful implementation of a new technology is the successful restructuring of the seminars in which it is to be used.

5. REFERENCES

Azuma, R. T. (1997). A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 6 (4), S. 355-385.

Bastian, Johannes (2007): Einführung in die Unterrichtsentwicklung. Weinheim: Beltz.

Baumgartner E. et al (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. http://www.designbasedresearch.org/reppubs/DBRC2003.pdf, Stand vom 12.05.2023.

Bleher, W. (2001). Das Methodenrepertoire von Lehrerinnen und Lehren des Faches Technik: Eine empirische Untersuchung an Hauptschulen in Baden-Württemberg. (Didaktik in Forschung und Praxis 3) Hamburg: Verlag Dr. Kovac.

Boekaerts, Monique (1999). Self-regulated learning: where we are today. International Journal of Educational Research 31 (6), S. 445-457.

Bünning, F., Haverkamp, H., Lang, M., Pohl, M. & Röben, P. (2018). Lehramtsstudierende mit dem Unterrichtsfach Technik. Eine Ausbildungsstandortübergreifende-Analyse. Journal of Technical Education (JOTED), 6(4), 52-66.

Dörner, R., Broll, W., Grimm, P. & Jung, B. (Hrsg.) (2019). Virtual und Augmented Reality (VR/AR). Grundlagen und Methoden der Virtuellen und Augmentierten Realität. Berlin, Heidelberg: Springer Berlin Heidelberg.

Döring N. & Bortz, J. (2016). Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften. Heidelberg: Springer.

Ermel, D. & Riese, J. (2022). Entwicklung und Evaluation eines Fachpraktikums für das Techniklehramt. Journal of Technical Education (JOTED), 10(1), 25-47. Zugriff am 14.11.2022.

Geißel, B., Geschwendtner, T. & Nickolaus, R. (2020). Technik in der Lehrerinnen- und Lehrerbildung. Das Fach im allgemeinbildenden und berufsbildenden Schulwesen. In C. Cramer, J. König, M. Rothland & S. Blömeke (Hrsg.), Handbuch Lehrerinnen- und Lehrerbildung (557-564). Bad Heilbrunn: UTB.

Gräsel, C., Parchmann, I (2004). Implementationsforschung - oder: der steinige Weg, Unterricht zu verändern. Unterrichtswissenschaft 32 (3), S.196-214.

Hamann, K., Kannewurf, A., Link, M., Münzinger, A. & Schnalzer, K. (2020). Lernen mit Virtual und Augmented Reality. Zugriff am: 14.11.2022. Verfügbar unter: https://www.transwork.de/wp-content/uploads/2021/03/Hamann-et-al_2020_Arbeitspapier_LernenmitVRAR-1.pdf.

Hollenberg, S. (2016). Fragebögen. Fundierte Konstruktion, sachgerechte Anwendung und aussagekräftige Auswertung. Wiesbaden: Springer.

Hüttner, A. (2009). Technik unterrichten: Methoden und Unterrichtsverfahren im Technikunterricht. Haan-Gruiten: Verl. Europa-Lehrmittel.

Jäger, M. (2004). Transfer in Schulentwicklungsprojekten. Wiesbaden: Verlag für Sozialwissenschaften.

Kaiser, Arnim (Hrsg.) (2003). Selbstlernkompetenz. Metakognitive Grundlagen selbstregulierten Lernens und ihre praktische Umsetzung. (Grundlagen der Weiterbildung) München: Luchterhand.

Klafki, W. (2007). Neue Studien zur Bildungstheorie und Didaktik. Zeitgemäße Allgemeinbildung und kritisch-konstruktive Didaktik. Weinheim: Beltz.

Kultusministerium Niedersachsen (2012): Kerncurriculum Technik für die Realschule. Zugriff am: 14.11.2022. Verfügbar unter: file:///C:/Users/Amin/Downloads/2010-8-2_technik_rs.pdf.

Latcheva R. & Davidov E. (2014). Skalen und Indizes. In N. Baur & J. Blasius (Hrsg.), Handbuch Methoden der empirischen Sozialforschung (745-756). Wiesbaden: Springer.

Mehler-Bicher, A., Steiger, L. (2022). Augmented Reality. Theorie und Praxis. München, Wien: De Gruyter Oldenbourg.

Milgram, P. & Kishino, F. (1994). A Taxonomy of Mixed Reality Visual Displays. IEICE Transactions on Information and Systems 12 (12), S. 1321–1329. Zugriff am: 14.11.2022. Verfügbar unter: https://www.researchgate.net/publication/231514051_A_Taxonomy_of_Mixed_Reality_Visual_Displays.

Milgram, P., Takemura, H., Utsumi, A. & Kishino, F. (1994). Augmented reality: a class of displays on the reality-virtuality continuum. Proceedings of SPIE - The International Society for Optical Engineering 2351, S. 282-292.

Nepper, H. H. (2021). Virtuelle Rundgänge für den Technikunterricht gestalten. tu - Zeitschrift für Technik im Unterricht 46(180), S. 43-46.

Porst, R. (2014). Fragebogen. Ein Arbeitsbuch. Wiesbaden: Springer.

Röben, P. (2018). Technikdidaktik: Chancen und Risiken in einem kleinen Fach mit grossem Potential. In B. Geißel & T. Gschwendtner (Hrsg.), Wirksamer Technikunterricht (Unterrichtsqualität: Perspektiven von Expertinnen und Experten, Bd. 10, S. 96-108). Baltmannsweiler, Schneider-Verlag.

Schulte, A., Wegner, C. (2021). Gelingensbedingungen für die Implementation von Unterrichtsmodellen aus der Perspektive der Lehrpersonen am Beispiel von Science-Klassen. Bildungsforschung, 1, S. 1-23.

Stiftung Innovation in der Hochschulbildung (2022). Förderentscheidung „Freiraum 2022“. Zugriff am 14.11.2022. Verfügbar unter: https://stiftung-hochschullehre.de/wp-content/uploads/2022/08/stil_foerderentscheidung-freiraum_liste.pdf.

Wiemer, T. & Haverkamp, H. (2020). Das Forschungsprojekt „TeGym – Technik am Gymnasium“. In M. Binder, C. Wiesmüller & T. Finkbeiner (Hrsg.), Leben mit der Technik. Welche Technik wollen ‚Sie‘? (22. Tagung der DGTB in Paderborn 17. – 18. September 2020, S.102-118).

Wiemer,T. & Rothe, M. (2022): Augmented Reality zur Unterstützung des selbstgesteuerten Lernens in der praktischen Techniklehrkräfteausbildung Vorstellung des Projekts SelTecAR und erste Befunde zu Unterstützungsbedarfen bei Studierenden. In: technik-education (tedu) - Fachzeitschrift für Unterrichtspraxis und Unterrichtsforschung im allgemeinbildenden Technikunterricht, 4(2), S. 15-22.