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Developing and Evaluating Educational Innovations for STEAM Education in Rapidly Changing Digital Technology Environments

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Abstract: In this paper, we offer three examples from our research projects on both technological and pedagogical innovations to illustrate the impact of rapid technology changes on research. Members of our research team both developed and used technology applications in their research projects, utilizing design-based research (DBR). During the experiments, we encountered new challenges by the end of the research cycle due to updates in technologies. Although we had an idea of how to redesign the project for the next cycle based on the analyses of data, we noticed that we needed to not only redesign our approaches based on the research results but the changes in technologies were so rapid that materials and pedagogies needed to be altered as well. In our article, we propose an additional aspect to be considered in DBR while researching technology integration or innovative technologies. Moreover, the rapid change in technology raises further challenges to teachers' professional development and the integration of those innovative technologies in classrooms. We anticipate our work to contribute to the development of technology resources and related pedagogies as well as the refinement of research methodologies in technology environments. Our contributions for the development of technology resources and refinement of research methods in technology-supported learning environments should, among other things, contribute to a less complex and at the same time more sustainable integration of pedagogical innovations into scientific and school practices.

Keywords: technological and pedagogical innovations; 3D printing; flipped classrooms; augmented reality; steam education

1. Introduction

Numerous studies have shown that, with increasing regularity, digital technologies are being integrated into STE(A)M (Science, Technology, Engineering, Arts and Mathematics) education (see definition below), but these innovations do meet with a variety of challenges [1,2]. These challenges include developing appropriate technologies, resources, pedagogies, and, importantly, preparing teachers to be able to utilize technologies with new teaching approaches [3]. Several studies focus on the various integrations of technologies into current educational settings and some on the future potentials of new emerging technologies [4]. These experiences have deepened students' understanding and boosted their confidence and enjoyment of engaging with mathematics and other science subjects [5–9]. Increasing students' confidence and enjoyment in engaging with mathematics and other science subjects should contribute to sustainable learning, according to [10]. In this context, sustainable learning can be considered as, among other things, approaches that may focus on elements related to learning processes rather than on accumulating knowledge. Based on current research and the experience of developing STE(A)M education technology, the Research Centre at Johannes Kepler University, Austria and the GeoGebra Development Centre, together with an international cadre of colleagues, are experimenting and evaluating the potentials and innovations of educational technologies to address issues with these technologies' current and future uses in STEAM-related education. These issues include addressing the growing emphasis on inter and trans-disciplinary learning environments, connecting subjects more closely to the other disciplines within the STEM framework, and, more recently, the inclusion of the Arts, (broadly, through a sense of design and creativity) to develop teaching from STEM to STE-A-M transitions [11]. Developing pedagogies to nurture skills, in particular creativity and critical thinking, that are increasingly identified as necessary inclusions within the future of education [12]. Critical thinking by students and teachers as well as pedagogies may transcend boundaries of subjects and are also central elements of sustainable education [10]. Adopting, developing, and integrating new innovative technologies, including the technologies of augmented reality, 3D-printing, gamification, and adaptive learning, each integrated into the dynamic geometry environment known as "GeoGebra" [13]. Developing both off- and online teacher training courses and resources that enable teachers to use technologies immediately and to consider how digital innovations may be integrated into teaching in the future [14]. While a large number of studies examine the acceptance of a particular digital technology by teachers, there are only few studies aiming at investigating how teachers adapt to constant changes in educational technologies.

Developing theoretical approaches to be able to better examine these issues. Within this paper, we will focus on the challenges that are created when the technological environment is developing and evolving at a pace that outstrips educational institutions' abilities to adopt and adapt to the innovations available to them. The main goal of the current study was to identify approaches through which teachers and researchers adapt to the changes brought along by fast-changing technologies. Therefore, we hope to contribute to the development of both research methodologies and questions raised by technology integration to further education in our age.

We offer three examples from our research projects (e.g., Da Vinci Machines and 3D printing, flipped learning approaches, and augmented reality applications), which demonstrate the situation wherein a teaching practice employing a new technology was undergoing implementation research only to need significant revision due to the advancement in the technology prior to the research being published. We will argue that research methodologies, especially in our case, and design-based research (DBR) needs to be adapted to suit the fast-paced technology changes. Further, we argue that teachers' professional development also needs to emphasize assisting teachers to keep up with the pace of changes in technology-related practices and pedagogies. In this context, our research projects as well as the need for adaptation of research approaches that we aimed to propose are in line with sustainable education. According to [15], it is a specific characteristic of sustainable education that it should not be viewed only as a simple addition to traditional learning and teaching practices but also that sustainable education should represent a cultural change. For sustainable education it is vital that it utilizes a more ecological or relational view of the world. Contemporary learning approaches, for instance, flipped classrooms, could facilitate large-scale issues, such as ecological questions or problems to be addressed in classrooms, and modern technologies, such as augmented reality applications, may enable concrete elements of complex systems, e.g., ecology, to be explored three-dimensionally and actively by students.

2. Context

Despite the initial slow integration of technologies into education around the turn of the 21st century, currently, mostly in developed countries technologies are being implemented more rapidly. Thanks to substantial investments by both government and industry, combined with the widespread use of cellular technology and educational application development, fewer barriers to accessibility exist than ever before and this is on a global scale [16–18]. Nevertheless, the use of technology is still rather marginal in most countries, but trends show that they are becoming more accepted and utilized [19]. Certainly, there are numerous issues hindering the use of technologies in schools, for instance, the uniformity and continuous reliability of machines and software [20], its demand needing to keep up with its place in curricula and assessment [21], and the novelty of pedagogical approaches needed in their uses [22]. However, according to research, the two areas mainly hindering the spread of technologies in teaching practices are the insufficient preparation and support of teachers [22,23] and the role of technologies in assessment and curricula [24]. According to [25], it is also teachers who are up to date with technological trends that are essential to achieving better and sustainable education for all by 2030. According to [26,27], teachers who keep up with technological trends also have an impact on society in general and a modern educational environment, consisting of highly trained teachers and technological trends, which, among other things, can help students develop skills needed to achieve sustainable development goals.

With respect to the latter, assessment and curricula, in many countries, teachers need to prepare students for tests and standardized assessment. National curricula often include the promotion of technologies in teaching but because assessment is not yet technologically supported, teachers do not have the time and motivation to use technology in their teaching to afford students these exam preparations. There are countries, such as Austria, Denmark, and Finland, that are changing their assessment practices to allow the utilization of advanced technologies in state-wide assessment; however, there are still difficulties in integration because of the persuasion and preparation of teachers for such new demands [28].

The professional development and support of teachers is extremely important because we need to show teachers how to use technologies in their practices and continuous support is needed to strengthen its initial integration into these [29,30]. There are numerous studies offering ideas and knowledge on teachers' professional developments with technologies [31–34] as well as programs offering continuous support in schools [35]. Additionally, there are numerous initiatives developing pedagogical innovations for technology integration [14]. Many of these ideas are powerful and innovative, but a new difficulty started to arise, in that educational technology and the opportunities offered by these technologies are changing so rapidly that it is difficult to keep up with the preparation of teachers.

Interestingly, the development of technologies and educational technology is racing ahead rapidly to support these demands and assist difficulties, but changes in the pace of development pose new challenges. Currently, technologies are developing quickly to offer advanced opportunities to be securely used in large-scale assessment and are aligned with classroom uses and offer similar interfaces. For instance, in Austria and Finland, assessment developments are being explored, which involve utilizing locked mobile phones to use only graphing software or developing sticks that restrict computer use beyond using mathematical software, respectively. Importantly, such technology involvement in assessments requires the important preparation of teachers.

Another issue in education is that software and emerging technologies, such as augmented and virtual reality, 3D printing, adaptive learning solutions, etc., offer entirely new opportunities to be utilized in teaching, besides the continuous upgrades of basic software applications. This trend needs to be followed and adopted in teacher training, not only to prepare teachers to be able to use technologies but also to teach them how to adapt their practices to these new technological opportunities.

Our research team and related groups are developing technology applications and, at the same time, carrying out research on both technological and pedagogical innovations. There are numerous projects in this area, but most of our research projects utilize design-based research (DBR) because it offers suitable frameworks for developing and testing innovations in STEAM education.

3. Design-Based Research for Examining Innovations in Education

DBR is one of the emerging methodologies utilized by numerous researchers in education. According to [36] "Design-based Research is a methodology designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice. In addition, it stresses the need for theory building and the development of design principles that guide, inform, and improve both practice and research in educational contexts".

Cobb et al. [37] characterized design experiments as having the potential to examine the complexity of educational settings and the numerous variables that may be observed with the implementation of such methodology. Similarly, ref. [38,39] claim that DBR and associated research results proved to be promising in overcoming the problems of educational research in complex and multi-layered educational settings. Furthermore, a variety of stakeholders may be involved in research processes (e.g., teachers, researchers, educational developers, program designers, and more). Elements of design-based research may involve tasks given to students; problems that they are asked to solve; tools and related material provided, including instructional materials; and practical means through which teachers can orchestrate classroom activities. The emphasis on the articulation of all these elements leads design experiments to be applied in a variety of configurations that often vary in type and scope. Implementations of the DBR methodology could support our understanding of how students and teachers develop their practices by collecting multiple forms of data through DBR in order to explore the variety of learning processes and practices. DBR necessitates close cooperation and collaboration among researchers and practitioners. In DBR, the roles and the tasks of researchers and practitioners are divided more clearly than in other research approaches which also involve multiple stakeholders [40,41] In DBR the main tasks of researchers and practitioners are to design innovations in education, further develop them, implement them, support students during the implementation of innovations, assess the impact of the innovation, and often begin the process again [42–44]. In this process, special attention is paid to design principles and reflecting on the possible reasons for the success or failure of a design in a specific educational setting [45–48]. Through a cycle of iterations, DBR should not only provide answers to what works and what does not but should also generate practical and theoretical knowledge [49,50].

In our projects, we followed an interpretation offered by [51], who views DBR as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings and leading to contextually- sensitive design principles and theories" (pp. 6–7). We encountered new and heretofore unaccounted-for challenges within DBR during our experiments. By the end of our research cycle, we would have gathered information that would lead to a redesign of the project for the next cycle based on the analyses of data. However, we also were confronting changes in the technologies being implemented. Often these changes were so rapid that they would precipitate alterations in the teaching materials and pedagogies independent of the feedback data acquired during the implementation. This may have serious implications for the validity of DBR projects that are centered on the use of leading-edge technologies. What follows are three examples from our projects based upon a rapidly changing technology. We propose an additional aspect to be considered in DBR while researching technology integration or innovative technologies.

4. Examples of Influences of Rapid Technology Changes upon Educational Innovation Research

4.1. Modelling da Vinci Machines

Lieban and Lavicza researched students' experiences while they used a geometric modeling approach with dynamic geometry software, complemented with physical modeling. Aiming to enhance students' understanding of interconnections between the current trends in Science, Technology, Engineering, Art, and Mathematics education (STEAM), they assisted students in better understanding the functioning of certain physical mechanisms. Emerging from concepts from the history of Mathematics and a book by Leonardo Da Vinci [52], the authors started their study by encouraging students to engage with a double reconstruction (both physical and with GeoGebra) of certain Da Vinci machines prototypes. The tool that was available for physical reconstruction was wood.

The conjecture of the study was that the use of historical models could offer assistance to mathematical concepts and promote students' creative thinking and problem-solving strategies while they immerse themselves in the investigative process of interesting ideas. The study concentrated on Brazilian students, combining the use of physical and digital tools as well as investigating how utilizing physical and digital tools could support students' creative thinking and problem-solving in STEAM subjects.

Inspired by recent studies, ref. [53,54], which supported the benefits of design and implementation of multi-representational approaches to exploring 3D objects using crafts, computer technology, and paper-and-pencil methods, the study attempted to integrate geometry with algebra and trigonometry reaching beyond technical instrumentation. Lieban and Lavicza particularly emphasized the example of joints with circular movements. Principles providing the background for the modeling process shown in Figure 1 were adapted from [55]. The solution can be achieved through both directions.

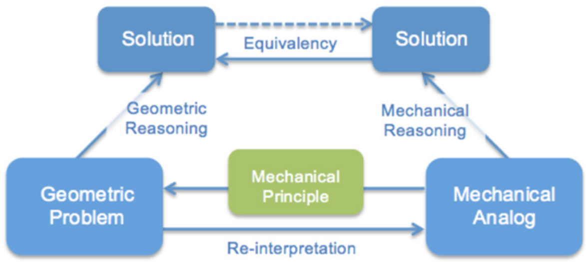


Figure 1. Modeling process from a mechanical analog to geometric problem through a mechanical principle.

This approach considered the importance of applying an methodology to problem-solving at the preliminary stage through constructing mechanical analogies for geometric problems.

The authors added the arrow in the opposite direction, since the reverse case (geometric reasoning supports mechanical reasoning) is equally possible according to their experience. The authors found that although, on the one hand, mechanical reasoning was essential to discussing the ratio for a pulley system in one case; on the other hand, in another case, with the help of rotational simulations (i.e., geometric reasoning) by means of digital modeling, the students discovered how to build a functioning physical prototype.

The researchers conducted their research with 16-year-old students who participated in a vocational (informatics) course and were supported by a teacher of mathematics and a teacher of physics. The project utilized design-based research and included cycles of both physical and digital designs. Students were asked to select Da Vinci machines to investigate. One of the most successful modeling approaches was the construction of the Da Vinci Rotary Bridge (Figure 2) developed by four students who were asked to develop both physical and digital models in order to improve the joints of the existing mechanisms. Students could select any software for their digital modeling, but most groups chose GeoGebra as it was available and suitable for their work.

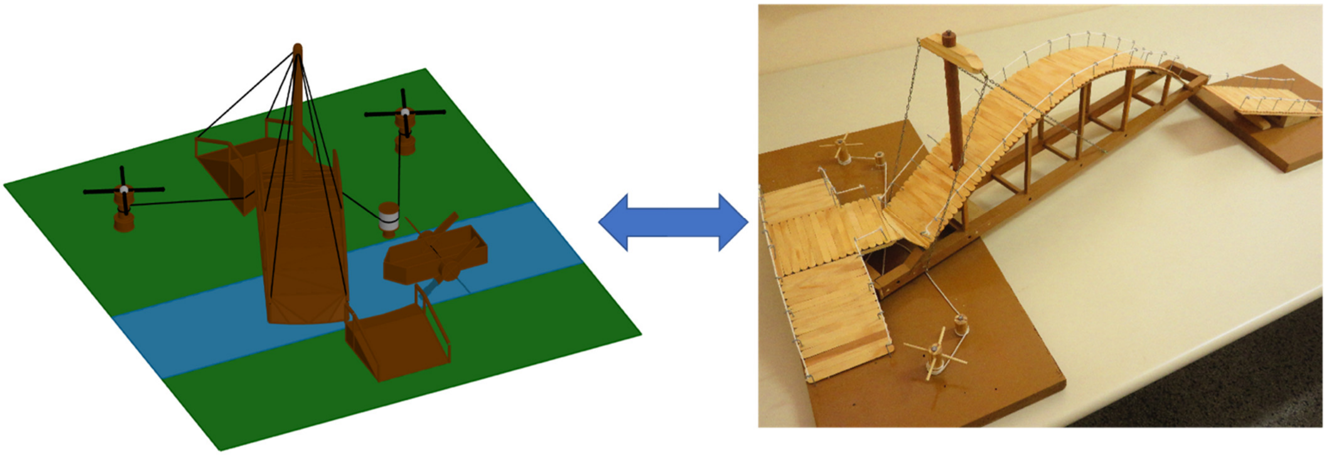


Figure 2. The digital prototype developed using the GeoGebra 3D feature (**left**) and the physical model made of wood (**right**) were developed in parallel (this and other Da Vinci models can be found at https://www.geogebra.org/m/AnHK7nCX, accessed on 12 May 2022).

Students were encouraged to develop the two models in parallel and GeoGebra materials and GeoGebra 3D features were integrated. Students were able to follow the digital modeling process and they concentrated on principles of rotation, translation, and spatial geometry.

Another construction was of DaVinci's catapult, which had a 4D frame with a structure made of flexible material (similar to plastic straws) that is easy for students to manipulate in classrooms. They simplified the physical model using simple elements that made the construction of the GeoGebra model easier (Figure 3).

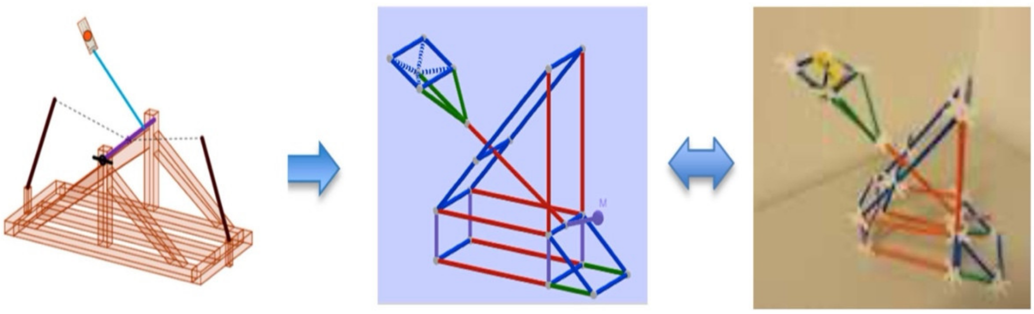


Figure 3. Catapult evolution and becoming easy to represent (by Diego Lieban).

However, the principles of joint motions remained in the models. Additionally, the coloring of specific moving elements contributed to the visualization and spatial understanding of students.

For the purpose of this paper, it is important how the evolution of technology altered the end results of the DBR approach. It can be seen in both modeling approaches that the initial modeling was created by GeoGebra without the features of GeoGebra 3D software available, then by the end of the modeling cycle GeoGebra 3D was released and new modeling opportunities arose. The experiment lasted for an entire semester and the design of the machines was improved continuously in both physical and digital forms. However, the release of new software features of GeoGebra 3D made the initial digital modeling completely obsolete and allowed students to improve their models with more appropriate tools, which also made learning through modeling more interesting. Thus, when writing up DBR results we had to consider the changes in the technological environment and re-calibrate the upcoming cycles with an updated software tool and reconsider challenges emerging from these new features. Furthermore, after the initial release of GeoGebra 3D the software continued improving considerably, allowing further ease of modeling but at the same time adding complexity for solutions because of the sophistication of the tool. In sum, we not only needed to consider results from DBR for the next cycles but also consider designing the next steps with an improved tool. Thus, was added the need to anticipate additional challenges that may appear in both practice and research. We experienced similar changes when working with 3D printing modeling for STEAM-based teaching.

4.2. Rapid Developments of 3D Printing for STEAM-Based Teaching

In line with the previously outlined research [56], the focus on developing resources to connect concrete and abstract ideas through physical and digital modelling and the development of mathematical and technological competencies through physical and digital manipulatives continued. Tasks involved possibilities for students developing mathematical models digitally who converted these constructions, via 3D printing, into physical models to explore the properties of both physical and digital representations. Similar to the Da Vinci project, we also utilized elements of DBR and action research to explore the evolution of these learning environments and offer improved designs for such modeling and learning.

We developed a simple task: dissect a cube into equal volume and surface area parts. Throughout the modeling process, students were immersed in a dynamic, exploratory process, involving constant questioning and reshaping of problems and solutions. The design process started with a brainstorming session as a starting point, followed by a brainstorming session during which students discussed alternatives and restrictions to develop their personal ideas or puzzles.

The next example, for instance, shows how students could combine pieces of a standard pyramid (Figure 4a) in different ways to obtain new solutions. While the initial model represented 1/6 of the cube, when students joined two or three pieces together it became 1/2 and 1/3 of the cube, as shown in Figure 4b,c. When continuing the dissection process as illustrated by Figure 4d–f, the solutions appeared to be a bit less intuitive. At this stage of developing different solutions from the same basic shape, it was important to discuss and show why the volume and the surface area were still the same for all the parts. Observing the symmetry and the fractions involved we realized that opportunities for learning Mathematics go beyond metric geometry.

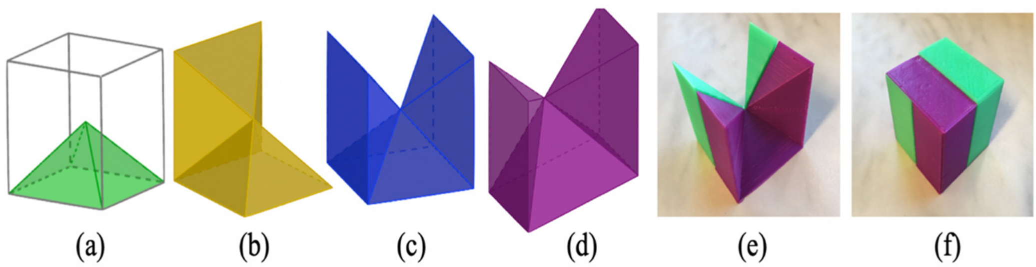
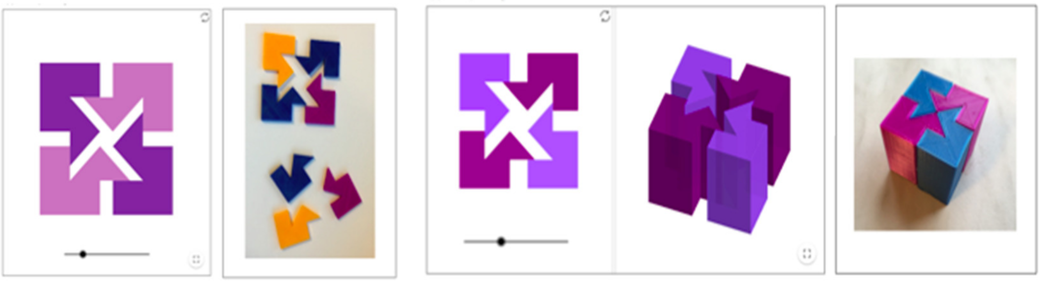


Figure 4. Developing different solutions from the same basic shape: (**a**) shows how a standard pyramid can be combined in different ways with the aim to obtain new solutions; (**b**–**d**) when two or three of them are connected together, they present 1/3 and 1/2 of the cube; (**e**,**f**) continuing the dissection process will provide less intuitive solutions (by Diego Lieban).

This following task provided a fruitful opportunity to extend ideas from a 2D plane to a 3D space. In particular, we used a solution obtained initially in 2D to split a square into four pieces with equal perimeters and surface areas. When students divided a square in such a way, they found that similar conditions were applied in both 2D and 3D spaces, which meant what they had done was equivalent to splitting a cube into four pieces which had the same area and volume, as illustrated by Figure 5.



(a) (b)

Figure 5. From a 2D to a 3D space, analogies are transferred by extrusion. Example of a digital and physical solution obtained initially in 2D to split a square (**a**) and cube (**b**) into four pieces with equal perimeter and surface area; b (by Diego Lieban).

Concerning the physical and digital explorations, we observed that while the physical models allowed more freedom in the sense of testing and assembling the cube, the pre-set model assembled in the digital version was able to highlight certain regularities or behaviors when dragging all parts together to arrange them as a single final piece.

Modeling was performed in GeoGebra 3D, the features of which improved slightly during the DBR process. However, opportunities to print models from GeoGebra 3D (it needs to be emphasized that only a few mathematical software have the capability to export models to 3D printing, and we know of no software that allows for dynamic manipulations in connection to 3D printing) improved considerably during the DBR experiments. We are fortunate in our research group because we can not only utilize the software but also make recommendations for the direction of its improvements. GeoGebra is not a CAD software and does not include Boolean operations, and, as such, may not yet be the best for 3D printing when involving the addition or subtraction of shapes, but it is a mathematical tool that can contribute to students' understanding, and its 3D printing features offer new insights for students to understand Mathematics. However, while defining mathematical objects in GeoGebra may be easier, in CAD software it is possibly more complicated, depending on the desired models. These experiments (and others) contributed to the inspiration for developing features in GeoGebra that utilize the advantages of both mathematical and CAD software to offer new opportunities for teachers to explore mathematics with new depth. Nevertheless, we aim to prepare teachers to be able to decide which software to use for different modeling purposes.

At the beginning of our DBR, the software did not allow the controlling of the thickness of 3D printed models and models had to be exported to CAD software for secondary processing, but through our requests to the developer team, this was resolved after some months and contributed to our experiments. In addition, when modeling digitally before printing, the transparency of models was not appropriate for exploring certain mathematical concepts inside the dissected cubes, but later assisted our explorations. Additionally, the dragging mode of the dynamic software allowed users to customize their solutions and improve their design. The evolution of 3D printing features considerably helped us and there are still continuous improvements to be made in the software, but it also resulted in changes in resources and results at the end of the DBR cycles. Furthermore, during our investigation and experiments with 3D printing the augmented reality (AR) application of GeoGebra became available, which further influenced our DBR results. In AR, besides the original software features utilized for modeling, shapes could be placed onto physical models making the process more fluid and interesting for students. The dynamic design and constructions of mathematical objects emerged in AR, and this again offered new opportunities for digital modelling and complemented our 3D printed models by projecting/merging AR models onto 3D printed models, further altering our DBR cycles. Further details of GeoGebra AR can be found in [57,58], Figure 6 shows an example of AR placement in students' surroundings, and Figure 7 depicts a learning scenario in which a physical 3D printed model is combined with an AR virtual model to further enhance mathematical ideas.

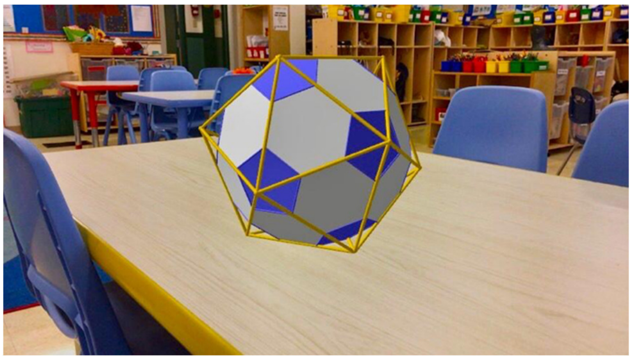


Figure 6. Example of GeoGebra AR (by Diego Lieban).

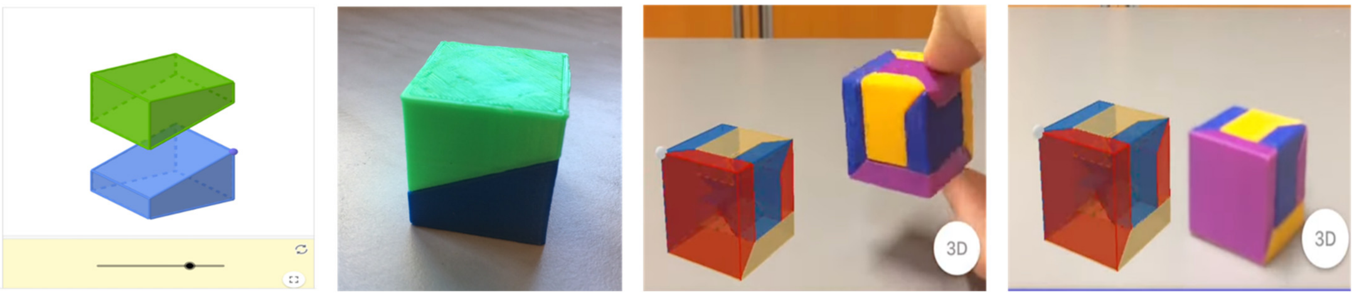


Figure 7. Desktop, 3D prints, and AR (by Diego Lieban).

The description of our project showed that it is becoming increasingly important to count on changes in technologies and complement DBR with attention to technology changes. The next example looks at how pedagogical innovations, such as flipped classroom environments, need to adapt to technology changes as well.

4.3. Adapting Flipped Learning Approaches for Technology Changes

Another example illustrating our argument that rapid changes in technology development impact both research and teaching practices come from our work on experimenting with flipped learning approaches and technology resources. We carried out several projects involving technology uses and flipped learning and experienced the impact of rapid technology changes. We chose one particular topic where students were encouraged to build bridges with physical resources and utilize dynamic mathematics software to model and analyze the mathematical content of their work. This study also employed design research approaches, and changes in technology appeared when the augmented reality application of GeoGebra became powerful enough to be used for modeling, which offered new opportunities beyond utilizing the desktop or mobile versions of GeoGebra. Before outlining the project, we offer a brief introduction to flipped learning approaches (FLA) and the technology-related considerations of the project.

As the pedagogical approach of our study, we chose to develop experiments with flipped learning approaches and utilized DBR as a methodology as the combination was able to offer interesting results for technology integration. Learning with FLA enabled students to be assigned tasks and tools to investigate before coming to classes and class time was mainly devoted to discussion and deepening students' knowledge. Originally, flipped classroom environments were used in the literature, but they were mostly associated with video preparations before classes [59,60] and stricter prescriptions on how flipped classroom methods should be applied. However, for our study, we wanted to extend the pool of technologies and develop wider opportunities for experimentation, and thus we utilized FLA as a further development of flipped classroom methods in the literature [61]. In addition, FLA enables students to decide by themselves whether to learn individually or in groups, which was an important consideration for our study design. Using FLA, ref. [62–64] were able to demonstrate the positive effects of education and we utilized numerous results from these studies for our design. Furthermore, as highlighted earlier, DBR was utilized, which was also supported by [44], who utilized DBR for complex activities in blended learning environments, which could form frameworks for flipped education. Additionally, technology integration into STEAM teaching and learning in such environments could be beneficial and is often valued by students.

Our study aimed to investigate how the modeling of real phenomena and a technology-enhanced mathematization of real-life models could be carried out in higher secondary level classrooms. Thus, we worked with 9th grade students who were asked to examine the properties and constructions of DaVinci or mathematical bridges, build such bridges in groups of three to five students, and then mathematize the self-made bridges using GeoGebra. When planning the study, we considered the desktop version of GeoGebra (Version 6) because this version of GeoGebra allowed us to simplify inserting and modifying images. Students built their bridges in teams and modeled their constructions with the GeoGebra desktop version, and the mobile app was also available for them to check their solutions. Examples of students' modeling can be seen in Figure 8.

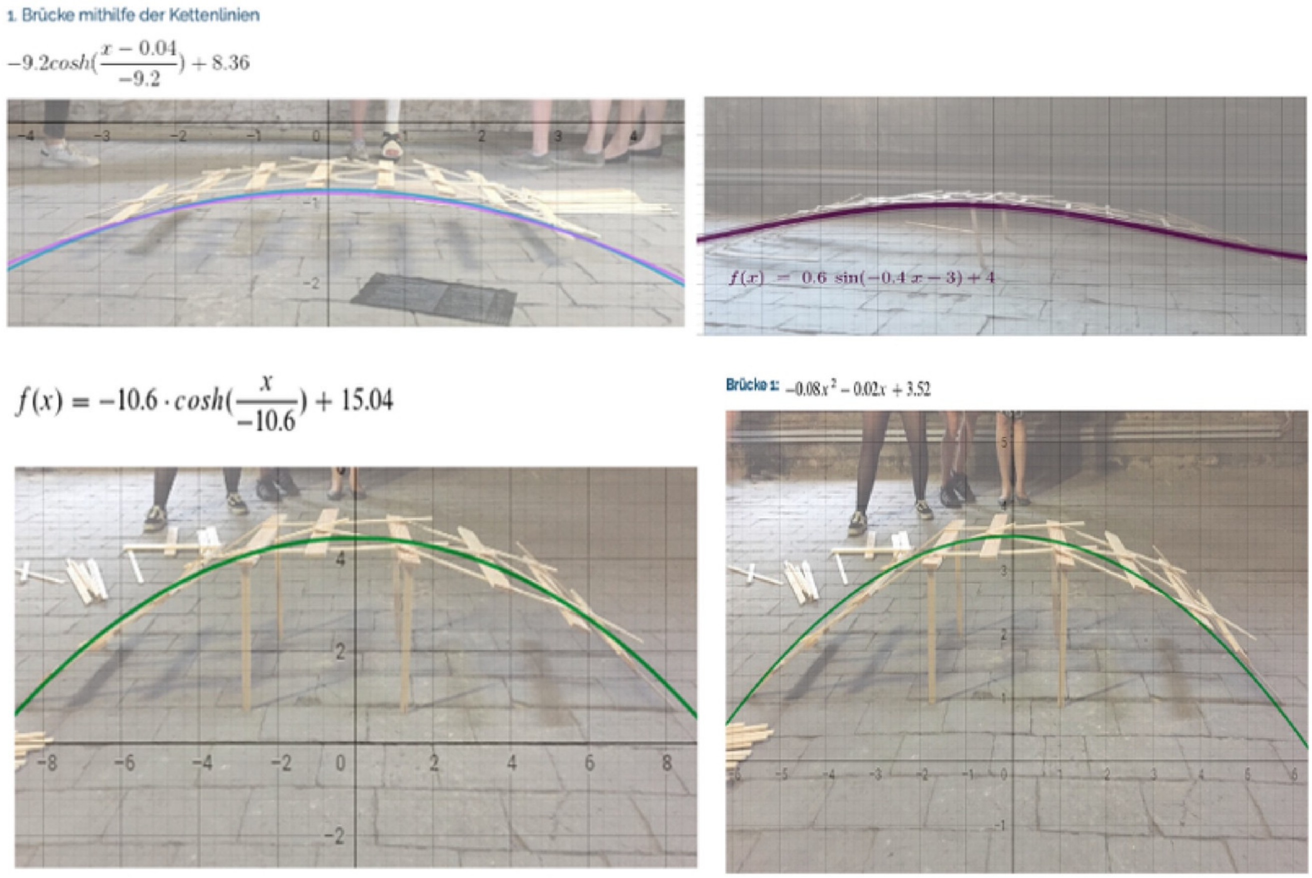


Figure 8. Solutions of Da Vinci bridges (by Robert Weinhandl).

According to DBR, we collected written feedback from students and carried out numerous interviews, besides the observations of their projects. The data were analyzed (we are currently working on further analyses by constant comparative methods) and findings were integrated into subsequent design cycles. Extended results of this study will be published in [65]. In the development of the design cycles, we had to take into account new opportunities that software development offered. Students discovered new features and immediately started to experiment with AR features, but participating teachers were slightly concerned about such quick changes in technology tools.

5. Discussion

With previous examples, we offered an overview of how some of our projects experienced the impact of fast-changing technologies. We suggested with these examples that developing technology-enhanced resources, pedagogies, and the preparation of teachers as well as research approaches need to be updated to keep up with technology changes. This would contribute to more appropriate applications of technologies in education and assist teachers in remaining updated with technological trends that are necessary for leveraging better and sustainable education for all by 2030 [25]. According to McKnight et al. [26], teachers trained to keep up with technological trends are more successful in developing creative, collaborative, personalized, and supportive learning environments. Similarly, Sarker [27] points out that providing resources and support to teachers to follow technological trends not only contributes to the education of students but also has an impact on society in general. The same authors also explained that the educational environment which is consistent with technological trends develops students' skills that are necessary for attaining to sustainable development goals (SDGs). Aligning the development of certain areas of human activity with the development of technologies is one of the key areas for the implementation of SDGs, and education has been identified as one of the key components in this process [66]. Education is critical to achieving SDGs: there is a sustainable goal dedicated solely to education (SDG4), and education and educational technologies are linked to all SDGs in numerous ways [67]. This indicates the great social importance of harmonizing education with constant changes in technologies and adopting research methods related to its rapid changes. In addition, enhancing technological infrastructure and improving digital competencies of teachers through professional development based on contemporary scientific research is crucial for the digitalization of the educational process [68].

In our work, and more generally for researchers working on innovative educational approaches, it is important to develop teaching and learning environments with more interconnectedness of subjects and topics; our examples showed topics connecting subjects and highlighted some aspects of creativity and creation integration into STEAM classrooms.

This is consistent with earlier research suggesting that digitalization opportunities should be maximized in order to make transdisciplinary materials as well as technological resources available to all [69]. Thus, we work with the framework of STEAM education [11] that involves the incorporation of creativity both in innovative classroom resources and related pedagogies [12]. In our case, the connection of physical and digital resources are key components in our projects, and by developing innovations within these frameworks we were able to show positive results in students' learning, motivations, and attitudes as well as influencing teachers' thinking on how technology could be integrated into their practices. The preparation of teachers became increasingly important for us when we observed that teachers were highly concerned about the technological changes happening even over the short period of time we worked together with technologies. We believe, and will further test in our projects, that the skills of adapting technologies and nurturing acceptance for such situations could be a way forward, but we also realized that individual teachers could hardly cope with such challenges; therefore, working within a community of like-minded teachers, these concerns could be reduced considerably. Thus, nurturing teacher communities and sharing resources and approaches could be the key to preparing teachers for the rapidly changing educational technology environment, and pooling various skills of teachers and splitting their knowledge could become increasingly important. In our projects, and future projects, in particular, we will focus even more on fostering such communities and making recommendations and specific actions for designing the training and environments to create a space for such communities. We are fortunate in our team that we could closely work together with the software developer team and offer immediate feedback from our research to improve the development of the software as well as design online training environments for developing teachers and communities. Our software development group has already begun constructing online spaces for virtual and in-class collaboration environments as well as research methodologies related to various research approaches in schools. In particular, to reflect the rapid development of technologies, we started to combine education and user experience (UX) research methods, particularly persona development and A–B testing, beyond the examples presented in this paper. Importantly, results of our study are in line with previous studies [70], in which team collaboration is vital for improving teaching and research capacities with the implementation of fast-changing digital technologies. Such studies also proposed a graduated team-building method, taking into account teams' professional and seniority integration and development. This entails accounts of nationally recognized and integrated innovative educational professionals as a team of curriculum research and development advisors to oversee research and development from macro and professional standpoints.

In connection with developing innovative technology environments and connected educational approaches, we also highlighted the necessity for updating and further developing research methodologies, especially in our case of design-based research. While developing cycles of DBR, we needed to take into account how much technology developed and how we could integrate these new feathers into the next cycles of DBR. It would be important to work on this issue as the development of technology is unlikely to slow down and more research will be carried out in this area. We are already making some recommendations, but in our future projects, we will pay particular attention to understanding the impact of technology changes. Additionally, we see great potential in combining educational research and software development research. Thus, we have begun working with some UX researchers and have made attempts to combine aspects of these two research methodologies to better understand the impact of technology changes as well as to contribute to the development of educational technologies with research insights from various methodologies. As [25] points out, it is of great importance that scientific research support the education system in the process of adapting to changes in technology and science. Thus, well-designed, state-of-the-art, and up-to-date research approaches can greatly contribute to the development of technology integration in education.

6. Conclusions

The present study was aimed at pointing out the impacts of fast-changing technologies on education and related research methodologies. We highlighted that changes in research approaches and teacher training are necessary to enhance innovations and integration in our technological education environments. Therefore, research methodologies need to be continuously updated along with transdisciplinary and technological resources for teacher development. We also highlighted the importance of the involvement of teachers, researchers, and developers as well as teacher training professionals in the process of designing learning environments for the successful applications of technologies in education. Our examples and research suggest that design-based research has an important role in such developments, but DBR needs to be continuously updated to keep up with fast-changing technologies. In our current work, we have already started new methodological experiments and have begun combining DBR with UX research approaches. Nevertheless, further studies are needed to better understand the impact of teachers' skills to adapt to constant, fast changes in technology and their abilities to follow changes in technology through pedagogical approaches as well as meaningfully updating research methodologies.

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