DIGITAL LEARNING ENVIRONMENTS TO SUPPORT DESIGN EDUCATION

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ABSTRACT

In times of the pandemic, universities are increasingly dependent on developing high-quality digital teaching materials and making them available to students for learning. For the development of learning environments, several methodological approaches and concepts already exist in the literature, which consider the pedagogical added value and thus describe rather didactical goals. This paper looks specifically at the technical requirements that can be placed on digital learning environments. In order to identify these, the *Elements of Value* are used as a basis to derive added values of digital learning environments and to establish requirements. Subsequently, the requirements developed in this way are compared with 3D learning environments for engineering design and it is examined whether this comparison could possibly be helpful for the development and extension of digital learning environments.

Keywords: Design education, digital learning, Elements of Value, WebGL, 3D environments

1 INTRODUCTION

Digital learning environments are already frequently used in university teaching and also find an application in design education [1]. The advantages are mainly due to the fact that students are provided with non-linear access to information and that learning environments are available from any place and at any time [2]. In addition, it provides the opportunity for students to influence the level and pace of the learning process themselves and to try out additional learning strategies such as collaborative learning. The provision of interactive learning materials or learning objects in corresponding digital learning environments serves this purpose [3]. Many universities use a hybrid model for teaching, so that digital learning environments are used as a supporting tool alongside lectures, e.g., for preparation in the Flipped Classroom [4]. Digital learning environments open up new opportunities in the design of learning processes due to the multimedia and interactive presentation possibilities [5]. However, there is still a considerable need for didactic and technical design in order to efficiently implement and evaluate digital teaching and learning processes [6].

Especially for the didactic approach in the development and design of learning environments, a variety of methods are described in the literature [7]. The didactic evaluation of digital learning environments usually takes place through an evaluation of the users, whereby the usability and the learning experience are in the foreground [8]. But also, the technical requirements for digital learning environments are considered in literature. However, the establishment of these criteria is mostly done via meta-studies [9, 10]. In this paper, the authors would like to approach the requirements from a different perspective and show a value-oriented derivation of such criteria.

2 THEORETICAL BACKGROUNDS

The value of a product or service is very individual and is therefore always in the eye of the beholder. Nevertheless, it is possible to identify essential elements of value which are close to the customer's heart [11]. With the *Elements of Value* approach, companies can determine what constitutes the true value of an offer from the customer's point of view. This enables companies to differentiate themselves more clearly from the competition and helps them to achieve a higher market share and greater price autonomy [12]. The *Elements of Value* were established by Almquist et al. and break down the solution of customer problems as well as the achievement of customer goals to basic customer needs such as "Fun and

Entertainment", " Simplifies" or " Motivation". Analogous to Maslow's pyramid of needs, the elements break down to the four levels of benefits: Functional, Emotional, Life Change, and Societal Impact. The *Elements of Value* can either be used to develop new value propositions or to enhance existing products and services. A comparison of the *Elements of Value* can also be used to compare different value propositions. As an application example, Almquist et al. consider Amazon's market share growth in connection with the *Elements of Value*. According to empirical studies, eight elements are met in 2005, illustrating the strength of a core offering's value proposition. The company's particular focus has been on reducing costs and saving time. The addition of streaming media to Prime met additional needs such as "provides access" and "fun/entertainment," which also attracted new customers and significantly increased annual fees [11].

3 DIGITAL TEACHING REQUIREMENTS

In the following, the authors present an approach that derives the technical requirements for digital learning environments based on the *Elements of Value* (see Table 1). For this purpose, the authors initially thought it would be useful to group the *Elements of Value* in order to avoid duplications and overlaps in content. Discussions with teachers resulted in eight superordinate groups that summarize the statements of the respective *Elements of Value* with regard to digital teaching. Thus, the added value of digital learning environments could be derived from different points of view. The individual added values were then explained in a brief description. In order to concretize the properties and break them down into recommendations for action, the last step involved interviewing experts to develop requirements that can be used to achieve the established added values.

Table 1. Framework for the requirements of digital teaching

Elements of Value	Added value for digital learning environments	Description	Requirements for digital learning environments
Integrates Affiliation/ Belonging Heirloom	***Promotes teamwork***	Digital learning environments can support and promote the learning process in teamwork. Through collaborative task accomplishment, different participants are integrated into a group structure and can develop a solution by combining their individual competencies. Through teamwork, contacts can also be made, and experiences can be passed on to other learners.	• Enable collaborative work
Self-actualization Wellness Self-transcendence	***Strengthens individuality***	Digital learning environments can strengthen the individuality of the learner. This means that learning content can be processed at an individual learning pace and with an individual learning path. In addition, the learner should be able to work independently of time and place in order to allow flexible learning.	• Create freedoms of use
Sensory Appeal Attractiveness Variety Design/Aesthetics	***Allows appealing and diverse design***	Digital learning environments can present a diverse range of learning opportunities in a high-quality design. A combination of different types of information provides variety and takes different learning types into account. In addition, an appealing design of the environment and simple and intuitive operation lead to increased motivation to use it.	• Multimedia knowledge presentation • Aesthetic and activating design
Connects Provides access Therapeutic value	***Simplifies and promotes interaction***	Digital learning environments can create new and diverse types of interaction. On the one hand, this includes communication with fellow students, which can lead to information exchange and mutual support. On the other hand, communication with teachers can also be significantly simplified and accelerated.	• Provide communication opportunities
Fun/Entertainment Badge Value Rewards Me Motivation	***Increases fun and encourages learning***	Digital learning environments can increase fun and thus encourage learning. For example, learners can be shown their progress, which motivates them to reach further milestones. Furthermore, leader boards and competitions can be used to arouse ambition and reward good results.	• Indicate progress and set intermediate goals • Promote competitions

Nostalgia			
Organizes Reduces risks Simplifies Informs	***Supports knowledge access***	Digital learning environments can facilitate knowledge access through a uniform and systematic structure. The provision of high-quality learning content involves ensuring quality and accuracy on the one hand, and appropriate presentation of the content on the other. For a successful learning process, this should be designed in such a way that new content can be linked to already known knowledge. In addition, navigation can ensure that the required knowledge is accessed in a targeted manner.	• Systematic knowledge presentation • Quality assurance of the content
Avoids hassles Quality Reduces anxiety Provides hope	***Supports the learning process***	Digital learning environments can actively support the learning process by determining the learner's level of knowledge and providing him or her with individual feedback. A wide variety of test formats are used for this purpose, in which the user's learning status is ascertained and reflected. Supportive feedback provides assistance in solving tasks and achieving the learning objective.	• Provide examination opportunities • Survey of learning status • Giving feedback
Reduces effort Reduces costs Saves time Makes money	***Simplifies application and accelerates processes***	Digital learning environments offer the advantage that they simplify the creation of learning units and create the possibility of automating processes. Once a learning environment has been created and implemented, it can be used again and again. In addition, it can be easily adapted or transferred to new learning fields thanks to a systematic structure. By automating teaching processes, for example, the correction of assignments and exams can be taken over, thus reducing the teaching workload.	• Extensible and reusable • Automation of corrections

A total of 14 requirements for digital learning environments were detected during the creation of the framework. These are now to be used as criteria to evaluate already existing learning environments with regard to their technical possibilities. These interactive 3D environments from engineering design are presented below and described in terms of content.

4 INTERACTIVE 3D LEARNING ENVIRONMENTS

Digital learning environments, e.g., physical and digital 3D view models, are particularly suitable for design teaching, as they can create a visual impression of design features that goes far beyond purely textual or pictorial descriptions [1]. To promote design teaching for additive manufacturing, three interactive 3D environments were developed. These were created for free display in a web browser as a *WebGL* plugin and embedded in a web page. Thematically, the developed interactive 3D applications deal specifically with the possibilities of function integration in additive manufacturing. In particular, the powder damping of components and the resulting advantages are to be brought closer to the students here. Powder bed-based additive manufacturing processes can be used to produce the component and the integrated particle damper in a single manufacturing step. The process flow offers the potential to leave unfused metal powder in voids (cavities) and to greatly increase component damping globally or locally through targeted particle friction [13]. Since the environments will not be used for additive manufacturing until later in the event design, a basic knowledge of the users is assumed.

The interactive 3D applications are divided into a theory environment, an application environment and an assessment environment. These can be accessed directly on a learning website. In addition, images and descriptions are listed on the website to embed the 3D applications thematically. In the environments, the user can move interactively through the space by changing the view by rotating and zooming or by clicking on buttons or individual features to activate corresponding activities or further windows. It is also possible to navigate through the model with predefined camera views or to change the view and the material.

The tuning fork environment is the introductory environment for the topic of powder attenuation, in which the students can move freely (see Figure 1a). The centre of the environment are two identical looking tuning forks, which reveal their differences only after clicking on them. As expected, one tuning fork produces a long and high-pitched tone, while the second responds to the animated clapper beat with a short-muffled sound. After this experience, two buttons fade in, offering the user additional information. Clicking the cut button (2) changes the display of the tuning forks so that they become visible in the cut. This makes the cavity of the dull tuning fork visible and thus also the reason for the different vibration behavior. The info button (1) opens an additional window in which the situation is briefly explained with the aid of CT images.

The demonstrator environment serves to deepen the acquired knowledge and to show the relevance of the topic through application examples (see Figure 1b). The centre of this environment is a wooden table with three different demonstrator components, which were additively manufactured and provided with powder damping. These are a wheel carrier, a fork bridge and a turning tool which can be viewed from all directions in the environment. When clicking on a demonstrator, it rises from the table, the camera moves towards the centred object and a rotation of the view around the component starts. In addition, the surface texture is switched transparent so that the cavities become visible in red. A short description completes the display.

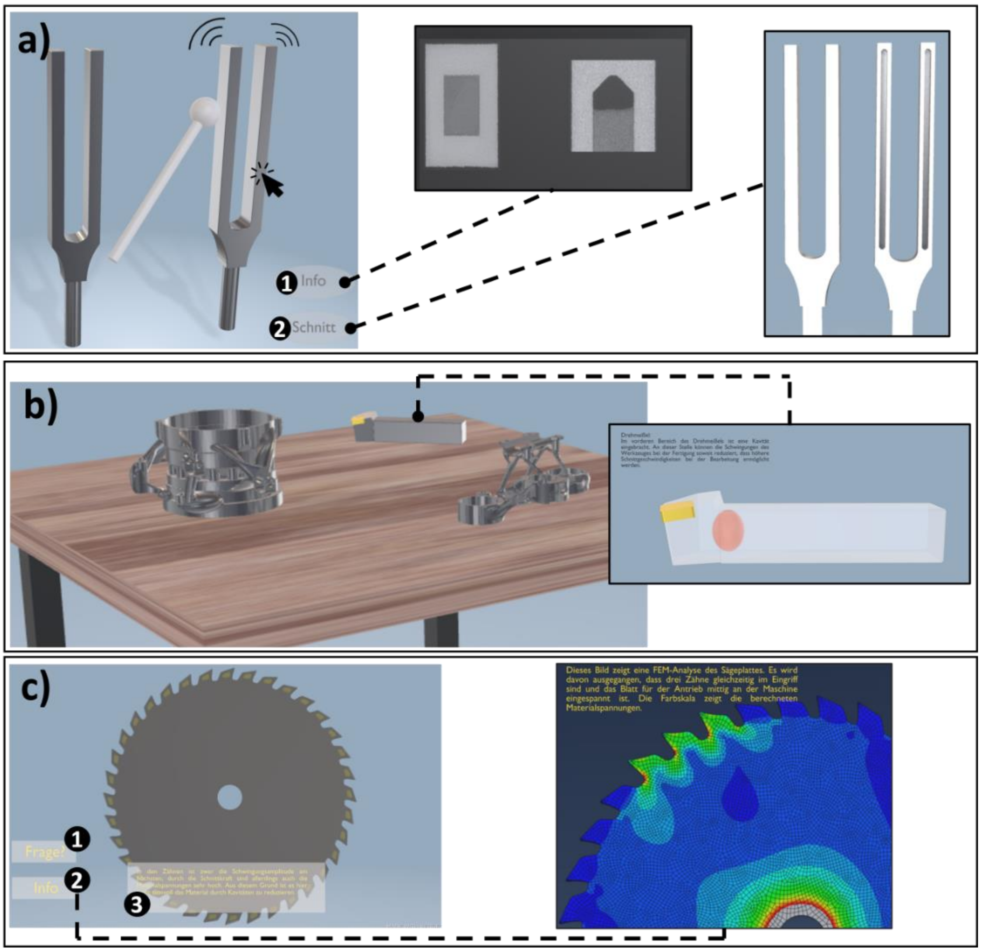

Figure 1. 3D learning environments

The saw blade environment serves as a small assessment environment. Here, the learner can check his knowledge level himself (see Figure 1c). For this purpose, the user is presented with a saw blade model and a task (1), which can be called up again and again via a button. The task is to determine a reasonable position for the cavities in order to reduce the saw blade noise. To edit the task, the texture of the saw blade becomes transparent as a hover effect and three different positions of cavities become visible. These can be selected with a click. Thereupon the system gives textual feedback (3) how good the decision made was and justifies this hint. To make the task easier, additional information on the component stresses in the operation can be obtained via the info button (2).

5 EVALUATIONS

To evaluate the interactive 3D environments, the three environments are compared in a matrix with the elaborated requirements for digital learning environments (see Figure 2). The evaluation was done in a panel of subject matter experts and used the evaluation scheme fulfils the requirements, partially fulfils the requirements, and does not fulfil the requirements.

It can be seen that through the website integration, all three environments are available around the clock and system-independent, creating absolute freedom of use. Through the 3D environments with realistic textures, an activating design could be created. The requirements of quality assurance and extensibility could also be fully met by developing the content with a panel of experts and by developing environment templates. The presentation in the tuning fork environment is even more multimedia-based than in the other environments due to additional audio outputs. The systematics of the knowledge presentation becomes apparent in the tuning fork environment by the fact that certain information must first be unlocked in order to be able to link to what is already known. The Saw Blade Environment, as an assessment environment, does not emphasize the modelling of knowledge. In contrast to the other environments, it is possible to check one's own knowledge, to correct wrong answers and to get short feedback. A survey of the learning status only takes place for the user himself; the system cannot store the answers and attempts and draw conclusions from them. This also means that it is not possible to display the respective progress in the environments. Similarly, the requirements of collaboration, communication and the promotion of competition cannot yet be met in these learning environments.

Requirements / Learning Environments	Enable collaborative work	Create freedoms of use	Multimedia knowledge presentation	Aesthetic and activating design	Provide communication opportunities	Indicate progress and set intermediate goals	Promote competitions	Systematic knowledge presentation	Quality assurance of the content	Provide examination opportunities	Survey of learning status	Giving feedback	Extensible and reusable	Automation of corrections
Tuning fork	○	●	●	●	○	○	○	●	●	○	○	○	●	○
Demonstrators	○	●	◑	●	○	○	○	◑	●	○	○	○	●	○
Saw blade	○	●	◑	●	○	○	○	○	●	●	◑	●	●	●

○ not fulfilled ◑ Partially fulfilled ● fulfilled

Figure 2. Rating matrix

6 DISCUSSIONS

The value-based requirements developed in this paper correspond to a large extent to the existing criteria from the literature. Kurilovas and Dagiene's evaluation criteria for digital learning objects also have a focus on quality standards, design and usability, and reusability. Other functional criteria include user control strategies and appropriate system architecture [9]. Emotional and social aspects such as communication possibilities or freedom of use are not considered in contrast to the framework developed in this paper.

The evaluation of the learning environments clearly shows which technical requirements of the framework are already covered by the connection of the three learning environments and which requirements are not yet met. This means that the teacher can be given a clear picture of the current state of the learning environments. In addition, possible technical enhancements can be shown in order to further develop the environment. However, the question now arises as to whether the goal should be exclusively to fulfil as many requirements as possible with digital learning environments or whether they should not complement the competence transfer of the learning events in the sense of blended learning and thus mainly depend on the learning goals of the event. So, if a lecturer would also want to impart teamwork competences, an accompanying learning environment would make sense, which fulfils the requirements for collaborative learning. The benefit of the framework then also lies in the fact that the teachers can read off the required requirements based on desired added values and implement them for their individual learning environment. If, for example, the environment is to increase fun and encourage learning, progress displays, intermediate goals and competitions can be implemented according to the framework.

7 SUMMARY AND OUTLOOK

In this paper, a framework was established that determines added values for digital learning environments by structuring the *Elements of Value* and derives specific requirements for digital learning environments from their descriptions. Thereupon, 3D learning environments for design teaching were presented and their possibilities were shown. The application of the established requirements to the 3D environments shows that some of the established requirements for digital learning environments can be met. However, it also shows which requirements still need to be met in order to unfold the social added values of digital learning environments in particular. For example, tools such as chats, and forums could be added to the website to provide communication opportunities and promote collaborative work. However, the framework can also be used to define specific requirements based on desired added values for one's own learning environment.

In the future, the framework is to be expanded. On the one hand, the developed requirements will be diversified through in-depth studies with teachers and students. On the other hand, digital learning tools will be identified in addition to the requirements. Through these tools, concrete directions for development could be given for requirements that still need to be met. Furthermore, it should then be found out whether the extended framework can also be a useful tool for the new development of digital learning environments.

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