German University of Digital Science

2 SCIENTIFIC REPORT

Innovative Formats for Online Teaching

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The COVID-19 pandemic has amplified digitalization across various domains and areas of the daily life. Due to the various lock-downs many activities that used to be offered face-to-face suddenly had to be re-organized remotely. Particularly, educational institutions, schools, universities and other training institutions alike, have been challenged by this unprecedented pandemic as they were not prepared at all. Most solutions to tackle these challenges have been improvised and as makeshift approaches were far from perfect. As soon as the pandemic was announced to be over, the common reaction in these institutions was to switch into an "everything back to normal" mode, which in the light of more recent disasters, such as the Russian invasion of Ukraine or the ubiquitous symptoms of climate change has to be considered as being naive at best.

Furthermore, the digitalization of education should be considered as a chance rather than a challenge as it can improve the quality of education and the availability of education also for less privileged learners; if done right. Buying smart boards for schools without training teachers in educational concepts how to use them is a waste of money and rather decreases the quality of education. Similarly, educational online tools also can be both: a curse or a blessing depending on how they are used.

Over the past 10 years, the Hasso Plattner Institute (HPI) has provided online courses on various topics on the online education platform openHPI. Massive Open Online Courses (MOOCs) as provided on openHPI have similarly experienced a surge during COVID-19 lockdown periods in which learners had little activities to do and therefore pursued online training. In the context of online education on openHPI and our contribution to several research projects in this context, we have been able to test various concepts for education in digital contexts. We are aware that MOOCs are just one form of e-learning in a very special setting. However, we are convinced that due to the large amount of learners and their often very different socioeconomic backgrounds, MOOCs are predestined to experiment with different approaches and technologies. Building on our experience, with this report, we provide an overview of educational concepts, methods, and formats and evaluate them according to well-known learning taxonomies and frameworks, such as Bloom's taxonomy or the ICAP (Interactive, Constructive, Active, and Passive) framework. We analyze for which online contexts the corresponding methods are applicable. A further focus is the scalability of the tools, formats, and methods.

Contents

1. Introduction

The COVID-19 pandemic has amplified digitalization across various domains and areas of the daily life. To prevent infections and enhance public health safety, one of the central aspects of life in young ages—education—has had to shift to remote options across vast areas of the world. Similarly to trends in workplaces, many educational institutions, schools, universities and other training institutions alike have kept at least parts of digital training. Unfortunately, the quality provided in online educational concept differs strongly depending on *how* the lecturer prepares their content. While many, e.g., study programs already integrate variety across their digital content landscape, others are lacking tremendously.

Over the past 10 years, the Hasso Plattner Institute (HPI) has provided online courses on various topics on the online education platform openHPI[1] [84]. Massive Open Online Courses (MOOCs) as provided on openHPI have similarly experienced a surge during COVID-19 lockdown periods in which learners had little activities to do and therefore pursued online training. In the context of online education on openHPI, we have been able to test various concepts for education in digital contexts. Building on our experience, with this report, we aim to provide a summary of educational methods and and concepts that can be applied in online education.

1.1. Problem Statement

One of the biggest challenges for digital education is the lack of physical student interactivity or support regarding feedback. This is often reported as one of the significant reasons for dropout during MOOCs [38]. The internet enables access to educational content across the world, and thereby, scalability of the education to thousands of learners. However, educational methods focusing on online pedagogy must be researched to provide interactivity and motivate learners throughout courses [175]. Fellow researchers' works on experiences from remote education often highlight how a specific form of teaching and the respective presentation medium could influence the success or failure of the teaching program [25]. In this context, some researchers have highlighted measures to increase interactivity during online education, such as time-anchored peer comments to enhance social presence while consuming educational videos [71]. For example, discussion forums have proven essential to foster community during online studies, as they allow learners to get to know each other and build connections [76]. In previous studies on forum activity,

[1] Website: `open.hpi.de`

fellow researchers further observed positive results with guided ice-breakers [42]. In addition, field tests of a few educational design principles, such as the Flipped Classroom, have already succeeded in online scenarios [27]. However, only a few teaching methods and best practices have been developed and adopted for online education based on MOOCs due to technical infeasibility and the burden for teachers to (re-)prepare teaching content [46, 93]. These illustrate the need for evidence-based digital teaching concepts, especially for MOOCs, in which the teaching and learning processes differ from traditional forms regarding requirements to scalability and timing of the educational content transmission.

Therefore, two challenges have to be covered in particular when considering the overarching goal of appropriate and engaging online education throughout different fields of application [89]:

(1) Educational formats are required to present some form of **Scalability** to ensure concepts for digital education programs can handle large amounts of participants.

(2) Particularly online education has to engage (with) the students to ensure the success of the teaching program [110]. This engagement is usually to large extends created by the inclusion of **Interactivity** into online concepts.

1.2. Contribution of this Report

In this report, we provide a suitable overview of educational formats that can be used by educators in various different online- or hybrid education scenarios. To allow for appropriate decisions for, or against, certain educational formats, we highlight, how well the different formats can be used to educate for certain soft skills, or specific educational objectives. We furthermore provide an in-depth assessment—fueled by long lasting experience and related literature—of online applicability of the different formats. Overall, this report can serve as basis for decision to anybody interested in pursuing education, supported or enabled by digital tools.

1.3. Report Structure

The remainder of the report is structured as follows: Chapter 2 gives an overview on a selection of popular learning theories. The list is far from being complete, but elements of these theories can be found in several e-learning contexts. Chapter 3 dives a little deeper and examines strategies, such as self-regulated learning, deeper learning, or problem-based learning. In Chapter 4 we provide an overview of the development and operation of the openHPI MOOC platform. The authors have had a significant influence on this development and have an extensive experience in providing courses on this platform to thousands of learners. The experience throughout the last ten years inspired this report. Chapter 6 introduces frameworks on educational objectives, such as Bloom's taxonomy, or the ICAP and ESCO frameworks. In Chapter 7 we examine the applicability of these formats in online contexts. Chapter 8 adds some critical reflection to the picture and, finally, in Chapter 9 the new German University of Digital Science is introduced as the logical next step to follow up the experience on openHPI.

2. Learning Theories

Learning, a concept often strongly formalized today, has its roots thousands of years ago. Ancient philosophers already discussed the world around them, attempting to derive and promote knowledge and understanding [52, 113]. *Rationalism* as one of the earliest epistemological theories[1], can be considered a form of learning, followed by philosophers such as Descartes, Spinoza, or Leibniz to understand the world around them [55]. In Rationalism, the thought and mind are used to derive knowledge, potentially disconnected from the actual matter around the learners. The thought and appropriate reasoning were considered critical for successfully deriving correct knowledge.

Another direction for understanding the concept of learning developed around *Empiricism*, promoting the idea that experience is the only reliable source of knowledge [114]. Central advances in this theory have been made by Aristotle, a student, and successor to Plato. One of Aristotle's core contributions to psychology in this context was his theory of association in the context of memory. It indicates that the more similar two objects or ideas are in memory, the more likely it is that recall of one will automatically also recall the other [113]. Another strong promoter of Empiricism was British philosopher John Locke in the 17^{th} century [49].

Building on a foundation of hundreds of years of epistemology, developing empirical, almost experimental, learning methodologies, psychologists worldwide have started to develop more structured concepts around knowledge acquisition in the 19^{th} and 20^{th} centuries. With the emergence of technology in the 20^{th} and 21^{st} century, technology further fueled the development of cognitive concepts. It is challenging to provide a short overview appropriately highlighting all relevant learning theories used in education. Furthermore, the various theories are constantly being expanded and developed further building on dialogue by researchers and philosophers around the world. Some learning theories have their foundation in previous theories, others where developed based on other concepts from different fields of study. In this section, we attempt to provide a short overview of some important learning theories generally connected to online education as is the main focus of this report. We hence present four concepts and theories that find major application and validity today in various contexts around the world:

- **Behaviorism** (Developed: Late 19^{th} - Early 20^{th} Century)
- **Cognitivism** (Developed: Mid-20^{th} Century)
- **Constructivism** (Developed: Late 20^{th} Century)

[1] *Epistemology* covers an area of philosophy concerned with how knowledge is being acquired.

- **Connectivism** (Developed: 21st Century)

2.1. Behaviorism

Research around the concept of behaviorism by scientists such as *Ivan Pavlov*, *Edward Thorndike*, or *Burrhus Frederic Skinner* involved systematic, experimental approaches to study the behavior of humans and animals. Core assumptions covered the concepts of behavior as a reflex or consequence built by reinforcement. Experiments often involved positive or negative stimuli, such as ringing a bell to induce salivation in dogs, conditioned through the provision of food [99], or children being stimulated with sounds, to induce fear of, e.g., animals [167].

Behaviorism still finds usage today. Schools or universities still strongly rely on good or bad stimuli, e.g., using marks, to induce behavior (change) in pupils or students. Similarly, online education contexts with rapid verification of achieved knowledge gain by using, e.g., multiple-choice exercises implement core aspects of behaviorist theories. Even newer aspects, such as *gamification*, promote behaviorism by awarding trophies and achievements for extraordinary behavior [3]. Many educational software products still strongly rely on behaviorist principles, as they are easy to integrate into e-learning contexts. However, the extrinsic motivation generated by ideas such as gamification often displaces intrinsic motivation, thereby negatively influencing the overall future learning process of a participant [151].

2.2. Cognitivism

In 1959, American linguist *Noam Chomsky* challenged the predominant position of behaviorism. He observed and questioned that behaviorism alone cannot explain how humans learn new languages [19]. Cognitivism as learning theory involves thought processes within the minds of subjects and explores how learners actively receive, organize, store and retrieve information. Cognitivist educators help to refine and elaborate information so students can refine their thinking [**2022_Cochrane**].

Instructivism can be considered as a subarea of Cognitivism. Instructivism mainly describes instructor-focused methods of education that provide very objective learning paths with very little room for individual development [134]. Significant instructive examples can be observed in large-scale universities, where professors lecture to thousands of students without questioning the individual's current state of learning [**2022_Cochrane**].

2.3. Constructivism

Constructivism emphasizes the learner's active engagement in the process that results in learning. Constructivism states that individuals construct knowledge through an active process of experimenting and discovering. The individuals' experience and their interaction with their context and social contacts is emphasized. An influential actor in the field was Jean Piaget, a Swiss psychologist who investigated the educational development of children and authored various works in developmental psychology [90]. According to Piaget, learning basically consists of the processes assimilation and accommodation. Assimilation describes the process of organizing existing schemata, while accommodation describes the process of changing existing schemata to fit a new situation [**2001_Bhattacharya**].

Constructivist approaches often center around problem-based learning, building on the idea that a learning process is always subjective to an individual based on prior knowledge, facilitating discovery-based learning [152]. In 1991, Seymour Papert developed the psychological concept of Constructivism into a pedagogical methodology, which he termed *Constructionism* [96], particularly, to improve the teaching of mathematics by immersing the students into a mathematical environment building on their interaction with simple robots.

Lev Vygotsky developed the concept of a *Zone of Proximal Development* (ZPD) in the early 20th century Soviet Union. It achieved recognition in the West around the 1960s [125]. The concept describes that learners alone can usually only develop new knowledge in a very small zone (the ZPD). He highlights that there are always concepts that are too disconnected from the learners' current knowledge to be properly integrated into their knowledge base. So the learning process needs to take smaller steps. However, the ZPD can be significantly expanded when the learners are integrated in a social context and can push or pull each other to the next level. The ZPD is one of the elements that led to the learning theory known as *Social Constructivism*. *Social Constructivism* is a concept underlying various online education platforms. This social context can be provided by teachers, but as the "Hole in the Wall" and "SOLE" experiments by *Sugata Mitra* have shown are often even more effective when there are other learners on the same or a slightly more advanced level [87, 88].

2.4. Connectivism

With the rise of technology, in 2004, George Siemens and Stephen Downes coined the theory of Connectivism [33], which has since been widely studied in research, application, and industry. Building on Web 2.0, that suddenly enabled users to interconnect with thousands of others and assess their thoughts and ideas, Siemens and Downes developed a learning theory, which assumes that the interconnection of different aspects is more important than any aspect alone. In 2008, Siemens and Downes ran the online course "landmark in the small but growing push towards open teaching", which is often considered to be the first MOOC [98].

Connectivism has often been considered one of the most prominent learning theories for learning networks, such as those often used in e-learning. Current critiques, however, claim that Connectivism often disregards the impact of, e.g., (individual) educators in online learning scenarios, which, however, are often of utmost importance to guide or help a learner through their (connected) learning process [36].

2.5. MOOCs in the Context of Learning Theories

Online courses originated about twenty-five years ago, when the University of Tübingen published the first lecture videos in 1999. Similar projects, such as MIT's OpenCourseWare, Carnegie-Mellon's Open Learning Initiative, or the HPI's Tele-TASK started around 2002. It took about another ten years until the concept of online courses really gained traction when the first Massive Open Online Courses (MOOCs) were offered around 2008 to 2012. Many of the core concepts to facilitate the challenge of education for ever-increasing numbers of learners involve the strictly one-directional promotion of knowledge. Thus—with the exception of the so-called cMOOCs, which were explicitly built to explore and experiment with an implementation of the connectivist learning theory—the original concepts of many MOOCs mainly facilitated methods and measures known from Instructionism, with courses revolving around a specific learning path that is identical for all participants in a particular course and only leaves little room for active involvement of the learners.

With increasing technical developments and possibilities, however, MOOCs can nowadays integrate concepts from Constructivism, such as problem-based learning or team tasks and, therefore, are slowly shifting towards implementing a form of education that goes beyond providing instructor-driven videos. Stronger communities in online learning courses facilitate this enrichment. Fellow learners can provide the required push to slightly shift posed learning problems into less experienced learners' *Zone of Proximal Development*, e.g., by providing hints or solution examples to their peers. In MOOCs on the online education platform openHPI[2], we have accompanied and attempted to help shaping that development by providing courses in the field of information technology (IT) education. Over the past years, we have integrated more and more problem-based exercises—such as in our programming MOOCs [84, 117, 123]—or peer assessed team tasks in a wide range of courses and topics [135].

[2]Website: `open.hpi.de`

3. Digital Learning Strategies

Online learning differs from face-to-face learning in various aspects. Challenges such as decreased attention span, lowered engagement, lack of community, and challenges towards equity are yet to be entirely overcome [39]. In the past years, various researchers have developed different approaches to cover different challenges of online education. In the following sections, we briefly present some approaches that have received greater attention in the research and education community. We shortly outline core aspects of the respective digital learning strategy as these help to foster a better understanding of critical overall aspects of online education. For in-depth explanations and discussions of the respective strategies, the interested reader is invited to investigate any sources provided in this report. Furthermore, to avoid misunderstandings, it has to be mentioned that this report is mostly focusing on the area of *andragogy* (the facilitation learning for adult, self-directed learners) and not *pedagogy* (the teaching of children), although we also successfully have provided several slightly modified MOOCs to be used in school classes.

3.1. Self-Regulated Learning

Each learner learns individually. Teachers in schools usually pay close attention to students' individual success in their learning progress. They then intervene and support if they identify signs of failures during the learning process. Developing such a learning process is an individual task. Self-regulated learning builds on the concept of specific skills that good self-regulators have that can be learned by other learners and taught by educators.

Self-regulated learning (SRL) is generally considered to be guided by *Metacognition*, i.e., to review and think about one's thinking, and a *motivation to learn* while employing *strategic actions*, such as planning and monitoring, to reach a certain goal [11, 100]. Good self-regulated learners are usually aware of their academic strengths and weaknesses. They know and can employ various methods to encounter academic challenges appropriately.

Panadero has recently published a literature review on the various SRL models developed throughout the past forty years [95]. He identifies that most of the models have their validity and share several aspects, such as factors to success, and rarely any model is superior to another one. We will, therefore, refrain from presenting a singular model in detail in this work. Overall, most models contain a sequenced, iterative learning progress, mainly consisting of the following three stages:

- **Perception & Preparation**: Learners attempt to understand the task and structure their approach to a solution by identifying suitable methods.
- **Performance & Control**: Learners apply their chosen methods to solve the problems. While doing so, they control their performance, e.g., against fellow students from their cohort, to measure how well they are performing.
- **Reflection & Adaption**: Students review their methods, results, and performance to reflect on whether the chosen procedure was appropriate for the given scenario. They further adapt for future scenarios or follow-up tasks. The reflection phase can already happen while working on a certain problem, ideally enhancing the method applied until finishing the task.

Panadero [95] further outlines three main conclusions that can be taken from the contextualization and review of the previously developed models for SRL:

1. **SRL as a framework** helps to contextualize and connect crucial variables required for success in SRL strategies and scenarios.
2. Using **SRL to improve student learning** has been validated in various empirical studies.
3. **Effects of SRL interventions** strongly differ between students' levels of education, whereby the wrong intervention for the wrong group of students can have detrimental effects.

Face-to-face education offers the benefit of increased student-teacher interaction, where a teacher can easily observe whether and how a task was solved. As such an observation is more complicated in online-only education scenarios, alternatives must be explored. Therefore, self-regulated learning as a student skill to better master the challenges posed during their lifetime as learners has proven beneficial. As the skills required to become a successful self-regulator can be taught, different interventions to enhance learner self-regulation have to be evaluated in any online education program. However, as outlined by previous research [26, 95], appropriate use of SRL interventions requires close consideration of the context and level of education among the learners. Hence, we refrain from providing a specific guideline in this report, as that requires a more in-depth assessment, which is beyond the scope of the manuscript at hand.

3.2. Deeper Learning

Deeper learning describes a new approach enabling learners to engage deeply with knowledge by processing it through instructional—guided and self-regulated—co-creation processes. One core goal of Deeper Learning is to enable learners acquiring the skills, which are required for participation in the 21^{st} century. The application of skills is focused on real-world scenarios. A common understanding of the **21**st

century skills covers the "*four C's*", as established and promoted by the *Partnership for 21st Century Learning*. These fundamental skills to obtain cover *Critical Thinking*, *Communication*, *Collaboration*, and *Creativity* [9]. Training these skills is deeply incorporated into the pedagogical foundations of the Deeper Learning approach.

The (German) Deeper Learning teaching model considers three phases of educational interaction [132]:

(1) **Instruction & Appropriation:** In this phase, learners are supposed to understand and appropriate the central subject-specific concepts. Through instructional processes either guided by the expertise of an educator or supported digitally, learners acquire central technical terms and elementary knowledge. The possibility to adjust this phase according to the learner's knowledge is a fundamental advantage of the Deeper Learning concepts. While learners with little previous knowledge are required to appropriate additional information, other learners e.g., can skip initial learning videos to reduce their effort.

(2) **Co-Construction & Co-Creation:** Once the required knowledge is initially acquired, this phase of learning prioritizes to work with it in a creative and constructive way. This phase is crucial for acquiring the "4C" competencies. Learners are challenged to apply their knowledge in a problem-solving way. Usually, learners work cooperatively and self-regulated in small teams. Principles such as "*Voice & Choice*" are applied by requiring learners to make certain decisions as part of the educational process. Thereby, they experience self-efficacy and their different personalities are strengthened. The educator's role changes in this phase from being an instructor, to a consultant who is observing the process and supports on individual problems.

(3) **Authentic Performance** : Finally, a phase of assessment completes the Deeper Learning teaching model. As learners have previously worked on authentic scenarios in a self-regulated way, authentic assessments are conducted. Therefore, presentations of the learned content or actual application in real-world scenarios are prioritized. Examples of such authentic performances could be an invention, a performance, a publication, or an exhibition for an authentic target group.

Investigation of the Deeper Learning teaching model shows that best practices are more complex than the singular selection of one teaching method to design a learning experience for a single session [24]. As the contextualization of appropriate education methods and blueprints for educational sessions using Deeper Learning strategies is beyond the scope of this work, we want to guide the interested reader to a few other resources of fellow researchers and educators describing their experience with the teaching model.

Sliwka and Klopsch outline several examples and guidelines to successfully incorporate Deeper Learning concepts in schools in their book *Deeper Learning in der Schule: Pädagogik des digitalen Zeitalters* [133]. The authors present a model of Deeper Learning adapted to the German cultural and school context, improving traditional practices with opportunities of the 21^{st} century following principles, ideas, and guidelines of Deeper Learning.

Other researchers have previously explicitly studied concrete applications of Deeper Learning, particularly for higher education contexts, sometimes including blended learning scenarios. In 2014, Czerkawski published a review of previous publications on Deeper Learning, contextualizing that the implementation of Deeper learning is necessary but difficult to achieve [24]. In 2008, Sitthiworachart and Joy successfully developed and assessed a peer assessment tool to support active and deeper learning [131]. In 2011, Serby replaced a law course that used to be taught in a traditional way with an online collaborative learning experience [116]. Serby's research suggests that the interactions with peers resulted in successful deeper learning, as intended, particularly with the second phase of the teaching model. Klemmer first applied peer assessment in MOOCs in 2013 and found that peer grades correlated highly with staff-assigned grades [67]. In 2020, Staubitz has examined the results of a variety of peer assessments in several MOOC scenarios with quite encouraging results [135]. In 2016, Makani et al. studied core skills that reinforce deeper learning by performing a structured literature review [81]. The authors derive a framework connecting deeper learning to e-learning, highlighting that conversation is the core phenomenon promoting deeper learning.

3.3. Computational Thinking

Computational thinking in teaching describes a tool-set of methods that can be used to formulate, analyze, and process problems so that an algorithmic logic can solve them. Computational thinking is based on thought processes such as *abstraction* to help understand and assess challenging and complex problems. Particularly in the 21^{st} century, where an increasing amount of problems is solved by the use of algorithmic tools and computers, computational thinking is considered to be the "*fifth C*" of digital century competencies [130].

Computational thinking can be considered as a repetitive process building on the "*Three A's*", as contextualized by *Repenning et al.* [106]:

Abstraction: By decomposing a problem into its components. This can, e.g., be done by attempting to formulate questions or deriving visual representations and relationships between the different components. Often, this includes *Decomposition* of the problem identifying the relevant variables and pieces of data required.

Automation: Building on the previously derived abstraction(s), the solution is expressed in a non-ambiguous way such that a computer can interpret it. Often, techniques for this stage attempt to incorporate simple, binary checks such as *if ..., then ....* The *algorithms* created in this way provide a possible solution to the problem.

Analysis (*Execution & Evaluation*): covers executing the proposed solution with a computer or machine to represent how each instruction influences the results visually.

Upon completion of an initial round of phases in the model, it can be reiterated. I.e., the previous abstraction can be revised, or the algorithm used for automation can be improved. Furthermore, depending on the problem, in a final phase of abstraction, it can be attempted to further abstract the (working) algorithm for use in additional scenarios outside of the initial challenge.

Recent developments around artificial intelligence show that posing problems to machines becomes increasingly accessible to laypersons, e.g., by using ChatGPT. However, various publications show that *prompt engineering*, the skill to formulate a problem in a specific way such that the machine is enabled to provide the best possible solution, is in itself an evergrowing field of research that requires skills by professionals in different practices [51, 85, 128, 168]. Therefore, appropriate ways of thinking to adapt problem formulation to given circumstances, such as practiced in computational thinking, have to be considered essential for participation in the ongoing digital transformation more than ever.

3.4. Problem-Based Learning

Problem-based learning (PBL), or problem-oriented learning, describes an educational strategy in which students are tasked with open-ended questions or problems requiring them to work self-organized, often in small teams, to derive solutions. Problem-based learning was initially developed by Barrows and Tamblyn for medical education [8]. Incorporating PBL into educational situations enhances learners' critical thinking abilities and their ability to retrieve and review literature. Furthermore, it provides a context that encourages teamwork. Similar to other more student-focused methods outlined earlier in *deeper learning*, or SRL, educators serve as *facilitators* in PBL scenarios. As such, their task is to help building students' confidence when working on challenging problems through appropriate guidance, monitoring, and supervision of learners' work and progress. Problem-based learning is a form that closely resembles and unifies principles employed in *constructivist* learning scenarios.

A common approach to problem-based learning is the are the 7-steps the have been outlined by the University of Maastricht [79], guiding the team that is working on the problem [171]:

Step 1 **Understanding**: The participants identify any unfamiliar terms that might have been used in the scenario description. They investigate and research these, discussing their findings and ensuring that the group has a common understanding.

Step 2 **Definition**: The participants present their views on the intention of the problem and potential aspects to be considered. In a discussion involving the entire group, a problem definition is derived.

Step 3 **Brainstorming**: Based on previous knowledge, students discuss potential ideas, solutions, and explanations for the problem. In this step, the group strongly benefits from a diverse pool of participants who contribute different experiences.

Step 4 **Review**: In this step, participants review their results from Steps 2 and 3, arranging potential explanations for the problem at hand. Still, no research on the problem has been performed.

Step 5 **Objectives**: Based on potential solutions and explanations to the problem, the group discusses and decides which particularly interesting questions are and which actual solutions they want to derive for the problem. The group defines learning objectives for the following phase.

Step 6 **Private Study**: For the first time in the PBL process, group participants start investigating the problem using publicly available resources such as the internet or libraries. Each participant researches solutions and answers to the learning objectives individually.

Step 7 **Sharing**: In the final phase, the group meets to share the outcome of the individual studies. Due to the different contexts of the participating learners, different answers to the same questions will likely highlight different aspects. Therefore, an appropriate group discussion ensures that every learner has shared the results from their study.

Regarding the application of problem-based learning strategies for digital contexts, a few previous works from fellow researchers list possible tools, ideas, and blueprints. Only some authors (in online and offline contexts) have compared collaborative problem-based learning to individual problem-based learning. They derive that group discussions are a crucial part of promoting critical thinking and reflection during PBL scenarios, and hence, collaborative PBL with teams of students outperforms individual student PBL challenges [6, 115]. In 2018, Hussin et al. reviewed previous literature on online tools for PBL scenarios [56]. They present and divide the previously used tools into the groups of tools for *instruction*, *content development*, *social interaction*, and *personal and professional* contexts. From those categories, they observed *social* and *instructional* tools to be most used in the previous studies. On the openHPI platform Staubitz has conducted ground-breaking research on the application of PBL scenarios in MOOCs [135].

4. The Context of openHPI: A short History

In 2008, Stephen Downes and George Siemens, two Canadian researchers and educators, conceived a new learning theory, which they called *connectivism*. To test and promote it, they created an online learning course at a Canadian online university and opened up the course to a world wide audience. Dave Cormier, one of their friends and colleagues, coined the term Massive Open Online Course (MOOC) [91].

In 2011, Sebastian Thrun and Peter Norvig from Stanford University/Google, decided to provide their class on Artificial Intelligence online and free for everybody. In the same year, two other Stanford professors Jennifer Widom and Andrew Ng did the same with their classes on Databases and Machine Learning.

In 2012, Daphne Koller and Andrew Ng started the Coursera MOOC platform while Sebastian Thrun started the Udacity MOOC platform. Shortly after that, MIT and Harvard University launched their own MOOC platform: edX [92]. As the Canadian and the US MOOCs hardly had anything in common except for being offered online and having an abundance of participants, the terms cMOOC (for connectivist MOOCs) and xMOOC (for extension school MOOCs) emerged to distinguish these concepts. In the following, we will use the term MOOC for both: the general concept of massive open online courses, and the particular flavor of xMOOCs. The first course on the openHPI platform was delivered in September 2012. openHPI, therefore, claims to be the first MOOC platform in Europe. The platform was developed and operated by the chair of Internet-technologies and -systems of Prof. Dr. Christoph Meinel with support from the enterprise systems chair of Prof. Hasso Plattner at the Hasso Plattner Institute (HPI) in Potsdam, Germany. Its purpose is to deliver high-quality courses, derived from the HPI's offline curriculum, in a digestible form to a broader public and contribute to the world's *digital enlightenment*. The platform's thematic focus is on IT and Innovation/Design Thinking topics. It currently sports more than 340.000 registered users and more than 1.2 million course enrollments. Since 2012, about 160 publicly available courses have been offered on the platform free of charge. Generally, the courses on openHPI are conducted in a semi-synchronous way. Materials are released weekly. Deadlines for exams are also on a weekly basis within these limitations. Synchronous elements, such as live sessions, etc. can be added via external tools. The main content delivery formats are video and text. Assessments can be conducted as multiple-choice quizzes, peer assessments, team exercises with peer assessment, or via suitable LTI[1] tools. The

[1]Learning Tools Interoperability (LTI) is a standardized interface to connect specialized online learning tools to learning management systems.

courses are highly interactive and participants can discuss with peers and the teaching team. In contrast to genuine *self-paced* courses, where participants can access the material anytime without limitations, the term *event-based* delineates the way courses are generally delivered on openHPI. Basically, a course is a social event in which thousands of participants gather to learn together.

Early in 2013, SAP[2] approached the HPI as they were interested to use the openHPI software to offer courses of their own. Only a few months later, openSAP was released as the first enterprise MOOC platform worldwide and was an immediate success. More European MOOC platforms, such as Iversity(Germany), OpenupEd(Netherlands/EU), FUN MOOC (France), MiriadaX (Spain) were established now by other providers as well.

In 2014, openHPI celebrated the 100,000th course enrollment, the FutureLearn platform was established by the UK's Open University [21] and the EPFL in Lausanne hosted the first European MOOC Stakeholder Summit (EMOOCs).

In 2015, the mooc.house platform was launched by the HPI as a more cost efficient alternative for smaller partners. In this year, openHPI also offered the first courses including auto-graded programming exercises with CodeOcean, team tasks and peer assessments on both the openHPI and openSAP platforms.

In 2016,the HPI started a very fruitful collaboration with the World Health Organization (WHO), which resulted in the launch of OpenWHO in 2017. Furthermore, an online proctoring system was integrated with the openHPI platform and the first courses with online proctored exams were offered on openHPI. Finally, openHPI started to offer the first programming courses particularly targeting K-12 schools. Starting, with a small pilot of 16 pupils in one school, the school editions of a Python and a Java programming course have since been offered regularly once a year until today and nowadays reach an audience of 1000 to 6000 learners [147].

In 2017, the European MOOC Consortium (EMC) was started by the European MOOC platforms FutureLearn (UK), FUN (France), MiríadaX (Spain), EduOpen (Italy), and OpenupEd (Netherlands). Back then, together they offered about a thousand MOOCs and represented a network of 250 higher education partners [70]. openHPI joined the EMC in 2022.

In 2018, openHPI celebrated the 500.000th enrollment, while globally more than 100 million learners were enrolled on all platforms in aggregate [127].

2019 saw the launch of Lernen.cloud, another e-learning platform based on the openHPI software and the eGov-Campus and the KI-Campus consortia asked the HPI to join and provide the openHPI e-learning platform as the technological basis for these projects. Both projects required, however, that the platform's code base had to be published under an open source license. In 2020, both KI-Campus and eGov-Campus platforms were launched as new members of the openHPI platform family. In the process of the launch, H5P[3] was added as an additional peripheral tool to enhance the courses with more interactive exercises. Significantly more important, however, was the spreading of the Covid-19 pandemic, which forced universities,

[2]A large German software company

[3]https://h5p.org/

schools, and many other institutions to either go remote or even into lockdown within a few weeks. For many MOOC platforms this boosted the enrollment numbers, e.g. in April 2020 more learners enrolled in courses on Coursera, edX, and FutureLearn in one month than throughout the whole of 2019 [126]. On OpenWHO, the enrollment numbers sky-rocketed during the first few months of the pandemic. Since it was launched in 2016, OpenWHO was steadily growing and successfully delivering learning materials throughout several crises, such as the Ebola outbreak in West-Africa or the Zika virus in South America. By March 2020, about 30,000 learners were enrolled. With the start of Covid-19 as a global crisis, up to 50,000 new enrollments were registered—each day. In June 2020, the platform had passed the five millions enrollments benchmark. By the end of 2023, the eight million enrollment benchmark was passed.

2021 saw the birth of the MOOChub as an association of various MOOC portals, operators of online learning platforms, universities, and university-related associations in German speaking countries with the aim of using synergies and standardizing interfaces in online teaching [166]. The openHPI research group, developed standardized metadata formats for the MOOChub, which later on also have been used in several other contexts. openHPI celebrated the 1.000.000th enrollment and welcomed two new partners to the openHPI platform family, the KommunalCampus and *Industrial-Upskilling* by RWTH Aachen, both platforms have been launched in early 2022. In June 2021, EMOOCS and ACM Learning@Scale were hosted by the openHPI team as a double — owed to the Covid-19 situation — pure virtual conference. In December, the HPI officially announced the availability of the platform's source code under the AGPL license.

2022 signified openHPI's tenth anniversary and the platform received a cosmetic makeover. A particular achievement in 2022 is openHPI's membership in the European MOOC Consortium (EMC).

In April 2023, Prof. Dr. Christoph Meinel, till then CEO and Director of the Hasso Plattner Institute and head of its Internet Technologies and Systems group, head of openHPI and the openHPI research group, retired and moved on to launch the German University of Digital Science, a new fully digital university.

More than ten years of experience with designing, implementing, and executing online courses on this platform, our research on user interaction and learning experience in these courses, as well as the collaboration, requirements, and discussions with the different platform partners, and last but not least our general experience with higher education and online learning, provided us with the expertise we need to write the report at hand.

5. Educational Formats Suitable for Teaching in Online Contexts

Traditional, face-to-face education employs lectures, seminars, group or team[1] tasks, and assignments as foundations for learning success. Many scholars have developed guides and handbooks to help educators by providing them with a list of tools or methodologies they can apply in their classrooms. One well-known example from a German-speaking community is Leisen [74], who developed more than 40 different tools to apply in language education. Didactic principles for these educational formats are well-researched in face-to-face instruction but have been challenged, e.g., with hybrid education during the COVID-19 pandemic. Many educational concepts have yet to be successfully applied to online education [25].

We derive various educational formats suitable for online teaching contexts from our experience in the past ten years of online course development, enriched by related work. We generally divided these formats into the two phases of **Knowledge Provision**, by an educator to learners, and *Knowledge Development*, which can occur by learners independently or while supervised or instructed by an educator. In face-to-face teaching scenarios, learners will (re-) engage with the content when summarizing content or writing down notes (by hand). Such repetition of the content is missing in online educational contexts as most learners cannot be convinced to write down additional notes or summarize content. Therefore, particularly in online learning contexts, follow-up learning challenges that force the learners to engage with the content are required to help settle knowledge. In this phase of Knowledge Development, educators are ideally only consultants supervising the learner's work. Thereby, connections between educational activities as we categorized in *Knowledge Development* and the phase of *Co-Construction & Creation* of the Deeper Learning model can be observed. While the challenge of deriving an *Authentic Performance* from the learning session remains, these educational formats can help provide first ideas for activities in Deeper Learning teaching sessions.

Into the category of **Knowledge Provision**, we classify formats that serve for sole *Presentation* of content or *Examples* that help to expand on a subject's theory. Examples cover (pre-recorded) *Videos* used to provide fundamental information, or *Simulations* or *Educational Games* to enhance the understanding for the learned content.

[1] We use the term groups for loosely coupled participants, while we use the term teams for more tightly coupled participants. Groups of students can be formed for a variety of reasons, teams are in most cases directly assigned to a certain task or project. In terms of size, a group can consist of two students up to all students in a class or even more as e.g. in a school orchestra. Teams, however, are generally smaller. Our recommendation is two to ten, depending on the task or project their assigned to.

Into the category of **Knowledge Development**, we classify *Individual Exercises* and *Group or Team Projects*, that learners are supposed to work on, to derive and develop new knowledge by themselves. Such exercises that learners (in groups or teams) have to fulfill often cover skills that shall be developed. Examples for that can be tasks such as writing an *Essay*, or performing a *Media Analysis*. More importantly, however, both of the examples provide a structure to a certain element of work and can thereby can be used to structure education, independent of the respective content. Furthermore, we classify *Debates*, into the category of knowledge development as they help to reiterate content within a classroom scenario, thereby ensuring understanding of the content.

In the remainder of this chapter, we highlight various educational formats suitable for online contexts derived from our experience during the provision of hundreds of MOOCs across more than ten years on the online education platform openHPI [84]. Many of the formats were derived from face-to-face foundations, adapted for online education. This list and the discussion of this work shall serve as a first stepping-stone for teachers and educators new to online contexts. Furthermore, we start a discussion on new formats, to be developed with an *online-first perspective* and didactic approaches particularly evaluated for, e.g., video-conferencing sessions.

Knowledge Provision

- **Presentations**, e.g.
  - Videos
  - Animations
  - Interactive Videos
  - Audio-Based Content
  - Text-Based Content
- **Examples** and **Demonstrations**, e.g.
  - Simulation
  - Reactions
  - Educational Games

Knowledge Development

- **Individual Exercises**, e.g.
  - Media Analysis
  - Essay
  - *Discipline-Specific Exercises*, e.g.
    - Coding Problem
    - Photography Challenge
    - Project Assessment
    - ...
- **Group or Team Projects**, e.g.
  - Essay
  - Survey
  - Experiment
  - Jigsaw
  - Hackathon
  - Study Challenge
  - *Discipline-Specific Projects*, e.g.
    - Software Development
    - Designing a Building
    - Developing a Business Plan
    - ...
- **Debates**, e.g.
  - Panel Discussion
  - Fishbowl Discussion
  - Inside-Outside Circle
  - Forum Discussion

5.1. Presentations

Active presentation of knowledge is often the foundation for further teaching and learning. Traditional lectures in lecture halls can be transformed into various formats in online education. For any of those formats, though, teaching content has to be specifically created, as researchers have repeatedly assessed that recording traditional lectures and presenting them as videos online does not solve the problems that online education is facing [68]. The following paragraphs present the educational formats for presenting new content to learners, which we have observed or used in the past years.

Videos, ideally short and concise, form the basis of any successful online course. Learning videos scale unrestrictedly and provide the advantage that they can be consumed asynchronously [34]. This enables students to self-direct their engagement with the module content according to their schedule and learning behavior. From a didactic perspective, educational content must be more strictly structured than when presented in a full 90-minute university lecture [157]. Videos should ideally be 8 - 12 minutes long [105], contain engaging content presentation, and be self-contained so students can pause their learning without interrupting a particular lesson.

Educational videos provide strong flexibility regarding concrete implementation. Previous research has already investigated and identified that different video concepts can be used to derive slightly altered learning outcomes or to provide a particular focus for a learner [40, 62, 154, 165]. Santos-Espino et al. [112] have studied over 100 online courses, characterizing them into seven styles. He particularly derived: *Talking Head*, *Live Lecture*, *Interview*, *Slides*, *Screen-cast*, *Virtual Whiteboard*, and *Documentary*. His research further showed that different formats are often used together, such as the *Talking Head with Slides*, one of the most common video types in online education. Reutemann [107] came to a similar result when she examined the videos in 448 MOOCs on four different MOOC Platforms. In her study, she identified 10 different styles, which in most cases can be mapped to or form subcategories of the styles that have been identified by Santos-Espino et al. E.g. while Santos-Espino only lists *Live Lectures*, Reutemann differentiates between *Classroom with students* and *Classroom without students*, etc. Additionally to the recorded videos, she also lists *Animations*, which we will cover separately in the next paragraph.

Animations are usually video-based excerpts closely highlighting specific topics. One primary differentiation between an animation and a traditional video is the amount of preparation required for an animation. Animations usually interlace computer-generated videos with explanations as audio content alongside the video. The computer-generated videos are usually daunting to prepare and often hardly feasible in a single course. Instead, incorporating external animations can increase interactivity and engagement provided and generated within an (online) course. With the rise of generative AI, the production time and costs for such videos likely can be reduced significantly in the near future. There are already several comparably easy to use tools that allow to create simple animations for e.g. trailer, such as Renderforest[2], Powtoon[3], or Animoto[4] among others.

Interactive Videos incorporate some form of user feedback into the video playback. This increases attention rates by the learners throughout the video [65, 104]. In interactive videos learners can e.g. options to click on more complex graphics on the slides to explain specific areas in more detail, they can be used to interlace the content presentation much more substantially with short assessments, e.g., multiple-choice tests, to ensure the learners remain attentive or questions encouraging the learners to think about a given problem individually, before the lecturer gives away the actual solution. Furthermore, interactive videos can be used to provide interactive stories with multiple possible outcomes, at the cost of a much higher production effort. At specific points in the video, the learner can decide which decision the person in the video should take. While this can make for exciting integration in case-study-like scenarios. A more common approach would be to challenge learners with specific tasks and, based on the answer, choose to (re-) play a specific part of the educational content.

Audio-Based Content, such as Podcasts, can solve many challenges that videos are facing, such as availability in rural areas with weak(er) internet connections. Furthermore, even in developed countries with appropriate internet connections, audio-based content can be consumed, e.g., on a commute or by learners with visual impairments [37, 63]. Like videos, learners can consume podcasts asynchronously, which scales freely. Educators have to consider, however, that not all content is fit for audio-based education, and content for podcasts should be developed with an audio-first approach in mind, e.g., by not relying on learners looking at any graphics [13].

Text-Based Content can be an appropriate addition to videos in cases in which educators want to provide, e.g., background information for learners' self-studies. Most traditional lectures in higher education employ textbooks to allow and foster self-study among students. This approach works equally well in online education. However, the online context enables additional approaches as e.g., (excerpts from) textbooks can be provided via the learning platform to the learners—given that the lecturer or the university has the appropriate copyrights. We, previously, have successfully used additional text-based content in MOOCs as referenced books for learners needing to catch up or in the form of links to external resources, such as news articles to provide real-world examples. In many cases, offering such additional content encouraged learners to share their own (collected) resources, such as helpful articles, write-ups, or blog posts, with educators and fellow learners.

An approach to reduce costs and effort in creating such materials and at the same time provide meaningful assessments, can be to ask the students to create videos, animated videos, podcasts, or additional texts as deliverables in a course. The best results can then be integrated in the course's next iteration. At the HPI we even went

[2]https://www.renderforest.com/#Videos
[3]https://www.powtoon.com/
[4]https://animoto.com/

a step further and very successfully asked students to produce complete courses for the learning platform in an on-site seminar.

5.2. Examples and Demonstrations

Demonstrations complement many of the instructional delivery formats. In these, teachers or learners present practical examples. Demonstrations have become a common form of teaching across various domains and subjects. Examples can be used to deepen and consolidate previously discussed theoretical content. In particular, examples can further be suitable as ”ice-breakers” at the beginning of a learning unit to spark learners’ curiosity and interest in a specific topic or to touch on a new topic and motivate learners to deal with it in greater depth.

Simulations offer a way of imparting knowledge in a digital context. Simulations are used to recreate real scenarios or systems in practice. The starting point is reproducing the scenario or system in a model. Experiments or training sessions are carried out on this model by exposing it to different influencing variables, such as operating inputs or environmental influences. In this way, knowledge about the system can be gained. Virtual reality (VR) is very suitable for simulations, allowing learners to interact in digital space. Previous research particularly highlights the advantages of simulations to train analytical thinking skills among students [12]. In a current meta-analysis of more than 100 studies, Chernikova et al. highlight simulations’ overall large positive effects in higher education [15]. One major field of study in which simulations have proven effective across many studies is the medical field, allowing young practitioners to improve their skills without directly impacting patients [73].

Reactions are materials that contain not only their original content but also some sort of comment (or reaction) by a third party. This could be, e.g. the lecturer or a student but also the author at a later point of time or someone completely unrelated to the class and the content. Well known examples from the scientific perspective are *comment* papers, that react and comment on another, previous publication. From a leisure-activity perspective, so-called game walk-throughs in which players record themselves while playing a game and commenting their actions can be considered a reaction. Another example are extras on DVDs where actors or directors comment particular scenes in the movie. Reactions are suitable for showing, consuming, evaluating, and integrating external content into a teaching program [80]. Reactions offer a relatively informal approach to consuming content from third-party creators [75, 80]. Thus, the experiences of third parties can be integrated and reflected in a course. Reactions can be particularly suitable for preparing oneself or a group for a debate or appropriately training in observing, addressing, and critiquing other comments.

Educational Games describe video games that present educational content to their players. Building on gamification, educational games combine an educational challenge with (multiple) aspects of gamification, such as improving scores, comparing high scores with peers, or introducing involving stories, indulging the player to play more and thus learn more. Often, educational games are built around a specific challenge and thus require a relatively high initial preparation effort. Once an educational game has been developed, it can be easily reused for different students and learners. In previous literature, educational games have often greatly improved learning outcomes, enhanced learner motivation if used appropriately, and student engagement [174]. However, throughout all categories, various researchers highlight that the success of an educational game is closely connected to its quality [174], thereby laying utmost importance on carefully selecting if and which game(s) to include as an unfitting or bad quality game will not show the expected results.

Similar to the presentations the creation of educational games, reactions, or simulations can be offered—depending on the course subject—as tasks for the students' assessment and thus contribute to the long-term quality of the course material.

5.3. Debates

Debates create opportunities for learners to take and share different points of view. They are particularly engaging as participants actively help to design the study session. As an educational format, debates further help increase peer presence, thereby strongly increasing participants' motivation. Therefore, debates should regularly be interlaced with traditional educational formats.

Panel Discussions are a prospective approach to the challenge of scaling group discussions. A group of selected discussants discusses in a plenary session observed by a larger group of participants. During the discussion, various topics from the previous lecture content or additional content on the perimeter of the lecture can be explored. Presenting content, which has previously been developed in (smaller) groups during another session, in the panel discussion is particularly effective. Thereby, the observers will retain a closer interest in the discussion, as their thoughts and arguments from the earlier preparation are discussed and included in the dialogue.

Fishbowl Discussions generally feature two circles of participants and are a particular form of a panel discussion. Learners from the outer circle can be dynamically interchanged with the discussants in the inner circle. The inner circle of participants drives the active discussion. Participants in the outer circle are tasked with closely observing the discussion in the inner circle and thinking of new and additional arguments that could be added [172]. Participants from the outer circle can switch with participants from the inner circle at any time and thereby start contributing to the debate themselves. This format contrasts plenary and panel discussions in which most learners only passively follow the discussion [86].

Inside-Outside Circle is a discussion format that employs two classes of participants - similar to Fishbowl discussions. Instead of the outer circle only being tasked with listening and having to take action to join the discussion, the discussion is always happening exactly between one participant from the Inside and one from the Outside Circle for all participants[162, 169]. Compare Figure 5.1 for a conceptual representation of this discussion format. Active inclusion of the participants in the outside circle strongly increases the motivation for all participants, instead of only those choosing to join the inner circle for the discussion.

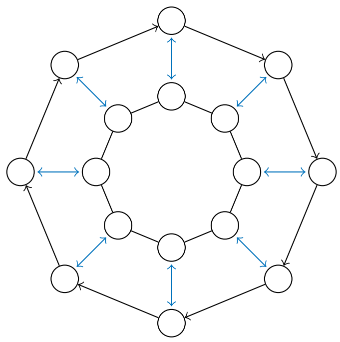

Figure 5.1.: Exemplary illustration of the Inside-Outside Circle Discussion Format. Discussions happen between participants in the inner and outer circle (*blue*). At certain points in time, the circles can be rotated to allow for different pairings of discussants.

Forum Discussions provide slightly less engaging but far more scalable solutions to the problem of interactivity. Learners can asynchronously read and reply to forum posts of other learners, hence further practicing online etiquette [5]. Instructors can keep the discussions moving forward. Teacher guidance in discussion forums is often seen as essential to ensure that no questions are left behind and discussion etiquette is maintained [108]. Educators can use forums as specific exercises, e.g., by assigning each student a separate task that they are to execute and post the results in the forum, or by having the forum as an additional activity throughout the lecture period. Such a forum can help students as it is a single point of contact for any open questions. In the context of openHPI, we have quite successfully encouraged participation in the forums by using quizzes to trigger forum interaction, either by asking somewhat ambiguous questions that encouraged students to discuss certain aspects of a topic in more depth or by actively triggering certain discussions asking the students to figure something out or commenting on an opinion, etc. and using the quiz to bluntly ask *if* and *how* they participated in that specific discussion. [141]

5.4. Individual Exercises

Exercises describe an educational format used for further student knowledge development. Individual exercises are tasks that are posed by a teacher toward a student. In theory, these tasks could be assigned to a group or team of students. Generally, however, for the tasks we list, we expect them to have a limited workload associated with them, such that a single learner working on the task individually should be more appropriate. Usually, exercises will be tasked to be worked on within a dedicated time frame. Generally, we expect the time frame for an individual or group exercise to cover a singular educational session, e.g., 1.5 hours. Team Projects (c.f. Section 5.5) cover tasks and challenges expecting a higher time commitment by a team of students.

Media Analysis can be one task to evaluate a learner's critical thinking skills. During a media analysis, a particular form of media is supposed to be evaluated in qualitative and quantitative aspects. This methodology helps develop media literacy and understand how media influences individuals, culture, and society. Learners are tasked with understanding and critically reflecting on media content. A contextual analysis is usually applied to draw insights from the overall respective environment. Further, different types of media (examples) can be compared and discussed in aspects such as ethical considerations, core message, and background of the piece of media. Results can be aggregated in manuscripts, reports, or presentations.

Essays are an essential teaching form that supports student learning and assessment. Essays provide tremendous flexibility, as they can be written and crafted based on any topic of choice [35]. Thereby, essays can easily be applied to have students derive further knowledge by consulting relevant literature, or students could be tasked to write an essay based on a discussion performed in the classroom. Through essay writing, students can consolidate their knowledge of a topic, develop critical thinking skills, and train in analyzing a topic. Applying essays encourages students to explore the given topic in depth, present their thoughts coherently, and support arguments with evidence and reasoning. Essays can further be used to have students explore different critical perspectives on a specific topic and can be used as preparation for a debate. As a versatile form of instruction, essays promote not only the transmission of knowledge but also the development of skills that are important both in the academic world and beyond.

Discipline-Specific Exercises can contain a variety of exercise types. Each discipline and field of study features specific tasks and exercises that learners must work on to obtain the skills required in, e.g., industry in the specific practice. Such discipline-specific challenges can range from, e.g., photography assignments in art study courses, potentially including follow-up inclusion of the photograph into a larger artwork. Similar skills, such as analyzing and assessing projects in management study programs, could be of essential interest. Our experience from running courses on openHPI, which mainly featured courses on IT topics, is exceptionally distinct for exercises that include coding.

Coding Problems are an easy and quick way to help learners appropriately grasp coding concepts covered in the respective lectures. Coding problems can vary in size and difficulty to enable application for the different levels of knowledge that could be present, particularly in online education courses. Providing the learners with coding problems challenges them to apply the knowledge they were previously presented with. Only upon application of the skills, it becomes apparent whether a learner has genuinely understood the underlying concepts and problems. Practicing coding usually requires local development environments to be configured and used by students. This can be a severe task for students so that online development environments can be provided. These often use so-called auto-grader systems to assess the code that learners have provided and compare that code against possible solutions for the problems [23, 117].

5.5. Team Projects

Projects provide a frame for a team of students to work on deriving new knowledge on a specific topic in a self-guided way. The lecturer often only provides students with a topic or question they should research using public sources on the internet, academic manuscripts, or available books. Contrasting to exercises, team projects are expected to provide tasks that require a more significant workload and, therefore, should be distributed among a more tightly coupled group of students: a team. Team Projects can be solvable within a singular exercise session but can also span a longer duration, up to run alongside an entire lecture series. The outcome of projects could be a (graded) presentation or a write-up of a topic. Team projects can have various deliverables, which we highlight in Section 5.6. Projects can further differ in their (team-) size, enabling flexible usage for various scenarios. Generally, many educational formats for projects can be combined to achieve projects fitting for a specific educational use case, study setting, or field of study.

Essays can be used in team-based projects identically to individual exercises as outlined previously (c.f. Section 5.4). For essays as a task in a team-based project, the educator can target different learning challenges. The topic to be worked on can be larger, requiring more, e.g., literature research that should be distributed to different people. Alternatively, the time in which learners are supposed to work on the essay could be reduced, thereby increasing the amount of coordination needed between team members to target such transversal skills. We will pick up the topic of soft skills, future skills, and transversal skills later in the report (Section 6.3.1 and 6.3.2). If the topic allows, in team projects with a longer duration, particularly for more advanced students, it is an alternative to ask for a manuscript to be submitted as a student paper to a conference.

Surveys can be used to practice qualitative and quantitative scientific approaches. A group of learners can be provided with a specific topic or field of interest. They either have to develop their own study methodology for their research question or follow the outline and question proposed by the educator. The learner's task is planning, coordinating, and performing the survey appropriately. Regarding survey design, learners can choose between quantitative approaches, e.g., online survey tools and an appropriate assessment and analysis of the findings, or qualitative approaches, such as expert interviews or focus groups.

Experiments are an alternative project method to practice appropriate scientific approaches. Throughout various fields of study, experiments can be performed. Conceptually, experiments are very similar to surveys judged by their approach to an educational concept. Learners are presented with a task for which they are required to select an appropriate experimental setup. Depending on the time frame, the project could solely cover planning and preparing the experiment, including conducting the experiment and follow-up analysis of the results. From a motivational point of view, conducting the experiment in the end will increase motivation rates, as this is usually the particularly interesting part. Furthermore, from a didactical perspective, conducting the actual experiment puts theory into practice and refines a different skill set among learners.

Jigsaw Jigsaw is a cooperative learning strategy based on group dynamics and social interactions. It enhances listening, commitment to the group, interdependence, and teamwork [66, 173]. In Jigsaw strategies, different groups of students get assigned different tasks. Upon initial work on each task, groups are mixed, so now students formerly working on different tasks are assigned to one group. With each student having prepared their part of the task in advance, the preparation of the final goal can be achieved easily. Just as in a jigsaw puzzle, each piece, in essence, each student's part, is essential for a complete understanding of the final subject. Many researchers have already evaluated the Jigsaw method for an online context. For example, Larsari et al. investigated the effect of the flipped-jigsaw learning classroom on primary students' autonomy and engagement in an e-learning context. They confirmed its effectiveness compared to traditional (face-to-face) classes [69].

Hackathon is a particular type of project used in educational contexts. Stemming from programming, Hackathons are usually ultra-short projects that often only last for 24 or 48 hours. During the runtime, (small) project teams often attempt to push the development of a solution to a given problem as far as possible. Such project results often include Minimum Viable Products (MVPs) as prototypes for, e.g., web applications. However, Hackathons could similarly be used to develop various other project results, such as concept (-papers), project plans, or process definitions [102, 103].

Sprints describe a concept from the agile project methods introduced by SCRUM [31]. Similar to hackathons, sprints are a methodology that can be applied to set a time box in which participants focus on a given topic or task. Sprints are often expected to cover two to three weeks, in which availability from all participants is required. Sprints are longer than Hackathons, so they allow for a slightly stronger focus on future skills such as *Project Management* or *Communication* during the Sprint runtime.

Study Challenges finally are expected to be of longer runtime. Often, such projects could be expected to span an entire semester or multiple months. The increased runtime of these projects can be used in different ways. Either, student activity is not as intensive as in the other project methods, as the workload can be spaced over a longer period to achieve similar results. Alternatively, the project task and scope can be increased as a larger workload can be expected by students. Similar to the Sprints, longer project runtimes facilitate practicing future skills further, as coordination between the team and stakeholders is becoming increasingly important.

Discipline-Specific Projects provide a context for unique tasks and challenges for a specific practice. Examples could be designing a building in architectural studies or developing a business plan in business administration studies. Independent of the actual project to be worked on, this educational format, in its variety, provided learners with subject-specific skills that will be needed in real-world work contexts in their later professional lives.

Software Development is one specific project from the discipline of digital engineering. Similar to the *Coding Problems* presented alongside educational formats for individual exercises (c.f. Section 5.4), software development requires learners to build some (part of) an IT system themselves. Software Development Projects, however, expand on the previously mentioned Coding Problems, as they provide learners with an actual real-world challenge for a specific system. Depending on the educational context, different requirements for the system can already be provided by the educator or can be left open for the learners to decide on. While Coding Problems primarily require (small) code artifacts as a solution, Software Development requires appropriate planning at the beginning of the project before preparing some documentation on the system that has been developed once the project comes to a close.

The approaches listed above also can be combined in several ways e.g. to structure larger team projects. Instead of simply assigning a group of students with the task of researching a certain phenomenon and writing a scientific manuscript, the project could be started with a subgroup of the students designing an *experiment* while another subgroup prepares a *survey*. The results are the combined with the *jigsaw* method. Finally, the whole group convenes in a *book sprint*[5] evaluate and present the results in a scientific paper, which in the best case can then be submitted as a student paper to a conference.

5.6. Deliverables

Education can generally be divided into multiple phases. Initially, educators provide content in order to teach their learners something. Often, fundamentals on a specific topic are initially provisioned by the educator. Various educational formats often accompany this teaching process to allow interactive educational scenarios with a large variety of content to be presented. Later, educators can pose different challenges to learners, allowing them to develop further knowledge. Finally, educators must assess their students to give them marks or points based on their performance. While such assessment might consist of observing learner behavior during, e.g., classroom discussions or of learner's activity in projects, assessment can also occur based on **Deliverables** provided by the learner. Later in this report, in Section 7.2, we map potential learning assessment methods derived from the different educational formats. The following paragraphs present different formats of deliverables that learners could provide as an outcome of any of the previous forms of education. These deliverables can be assessed by the educator or any teaching assistants, automatically or manually, as we will highlight later.

[5] A book sprint can be considered as a particular form of sprint.

Essays and Reports are the subordinate elements from a group of text-based *Deliverables*. Usually, learners will be required to submit text in a specific form, such as an essay or report, if it describes the outcome or progress of a certain project. Text-based deliverables can provide much insight into learner knowledge, as they allow learners to express their understanding and further identify content in a specific field. For team-based projects, it has to be considered, how, if applicable and required, the individual performance of learners can be assessed from a joint report. Individual contributions could, e.g., be identified by using taxonomies such as the CRediT framework for author contributions [2].

Video-Based Materials can be another approach to deliver gradable results to an educator. It can be of interest to offer alternative assessment methods to learners other than text-based deliverables. In certain contexts, using videos can drastically help the understandability of an argument. One example is a depiction of a finalized software project in which the application's usability could be presented in a video. In contrast, in text-based delivery methods, such usability would have to be expressed through many screenshots. Furthermore, Video-based methods can be used to have learners (pre-)record videos of presentations to make them available to other learners in asynchronous learning contexts.

Audio-Based Materials can supplement any other type of deliverable. They could be used in scenarios where learners have little access to higher technology, such as video-recording software, and still want to provide empathy and a more personal note with their deliverables. Alongside asynchronous study programs, audio-based materials could be provided in a podcast-like form from students to students to accompany the lecture series with personal remarks, further interpretations, or more practical examples.

Presentation (Slides) In the semi-synchronous online education context, (live) presentations by students can be a suitable method for assessment. The deliverable that could be provided to other students in order to allow revisiting the content could be presentation slides, or recorded videos (*video-based materials*) of the presentation. Providing or requesting presentation slides from and to learners allows the cohort to (re-) use the material, such as, e.g., to remix the material for use in *Reactions* or *Media Analyses*.

Showcases describe the outcomes of previously mentioned discipline-specific exercises. While, e.g., in a fashion study course, this could be a design for a new piece of clothing, or in larger projects, the finished piece of clothing, other disciplines require different showcases. Showcases, therefore, can be considered the pieces that record a student's performance and that they would be interested to show, e.g., to prospective employers to prove their subject-specific skills. Examples of showcases could be project plans, models or plans of a building, data sets, process descriptions, definitions, mathematical proofs, and many more.

(Code) Artifacts are the pieces of showcase from the discipline of IT education. They prove that a learner can work on a specific topic and develop a solution to the posed problem. In larger project contexts, the code artifacts could cover configuration files and documentation for more extensive server systems or software projects.

6. Educational Objectives and Softskills Supported in the Formats

In the previous chapters and sections, we presented an overview of different educational methods that can be used online. Besides the methodological overview, however, the impact of the different methods must be evaluated. The impact of the methods can be measured through different lenses. Is a method *fun* to use by the educator or learner? Does the method teach the expected (soft-) skills? Can this method be altered to achieve deep(er) sensitization for a particular aspect of a topic?

To assess those and similar questions, we map the presented educational formats to different frameworks derived and contextualized in the past years. In Section 6.1, we present a mapping of the applicability of the different formats to learning success based on educational objectives as used in Bloom's taxonomy [77]. In Section 6.2, we present a mapping of different levels of cognitive engagement as proposed by Wylie and Chi in their ICAP framework [17] to the educational methods. Following, we question the applicability of certain methods to practice and learn specific soft- and transversal skills. Based on the ESCO Framework by the European Union, we present a mapping of the educational formats towards different skills according to ESCO [29] in Section 6.3.1. In Section 6.3.2, we cover the mapping towards different transversal skills categorized in the ESCO framework [48].

6.1. Bloom's Taxonomy of Learning Objectives

Bloom's taxonomy of learning objectives is a classification system for learning objectives developed initially in the 1960s [10] and refined by Anderson et al. in 2001 [77]. The taxonomy categorizes learning objectives into a hierarchical structure and helps teachers to formulate clear and measurable learning objectives. The original taxonomy covers the three domains of *cognitive*, *affective*, and *psychomotor* aspects of learning. Of particular interest in this assessment is evaluating the cognitive level of learning that can be provided according to Bloom's taxonomy. The taxonomy provides learning across six levels:

- **Remembering** covers fundamental knowledge about and understanding of facts, information, and concepts. Students can acquire knowledge by repeating, memorizing, and understanding information.
- **Understanding** involves comprehending the meaning of concepts and information. Skills on the level cover explaining, translating, and interpreting information to draw connections between content.

- **Applying** involves using concepts and knowledge to implement and solve real-life situations or problems. Students apply previously understood knowledge to new situations.
- **Analyzing** covers features and skills required to break down information and differentiate between contexts. Students must understand how different aspects of a topic are connected and can identify these connections in scenarios to derive patterns and structures. Analysis of a problem further covers the ability to break down problems into their components.
- **Evaluating** drives students to make judgments about situations, problems, or solutions by checking, critiquing, and recommending. The ability to evaluate proves the students' in-depth understanding of a particular topic.
- **Creating** requires students to combine (their) existing knowledge across different domains, situations, or problems to generate new approaches to problems or new solutions on their own. This synthesis of previously achieved knowledge in a particular domain depicts the upper end of learning as categorized by Krathwohl et al. and is the most complicated mental function of the taxonomy.

Theoretically, all educational formats can be used to achieve learning across all taxonomy levels. However, advances in education over the past century have shown that different kinds of educational concepts and study challenges provide particular learning effects on different levels of the taxonomy. In the past, various scholars have provided different mappings of learning approaches to levels in the taxonomy. One recent study has been conducted by Nkhoma et al., who measured how well the fit of various methods towards the proposed cognitive learning levels was [94].

Table 6.1 highlights our mapping of the earlier proposed educational formats to the levels of cognitive learning as highlighted in Bloom's taxonomy. For each method, we evaluated, based on related work and our own experience from our courses, how well it is suitable to provide educational objectives respective to the taxonomy. Furthermore, we enriched our assessment by assessing how well an educational format can be used to generate **Motivation** among learners. In the Table, we employ colored highlighting to visualize the mapping. Colored in **Dark Blue** are educational formats that can be **applied** to cover educational objectives on the respective level. Colored in **Lighter Blue** are those methods that can only be **partly applied** to fulfill the respective educational objectives.

Table 6.1.: Mapping of presented educational formats to their support of educational objectives according to Bloom and Anderson. Additionally highlighted is, whether a format can be particularly used to generate *Motivation* among the learners. Color-Coded is, whether an educational format can be **Applied** or **Partly Applied** to achieve the corresponding level of education.

Educational Format	*Motivation*	*Taxonomy of Educational Objectives* RE	UN	AP	AN	EV	CR
Presentations, e.g.,							
Videos	Partly Applied	Applied	Applied	Partly Applied	Partly Applied		
Animations	Applied	Applied	Applied	Applied	Partly Applied		
Interactive Videos	Applied	Applied	Applied	Applied	Applied	Partly Applied	
Audio-Based Content		Applied	Applied	Partly Applied	Partly Applied	Partly Applied	
Text-Based Content		Applied	Applied	Partly Applied			
Examples and Demonstrations, e.g.,							
Simulation	Applied	Partly Applied	Applied	Applied	Applied	Partly Applied	Partly Applied
Reactions	Partly Applied		Partly Applied	Applied	Applied	Applied	Partly Applied
Educational Games	Applied	Partly Applied	Partly Applied	Applied	Applied	Partly Applied	Partly Applied
Debates, e.g.,							
Panel Discussions	Partly Applied	Partly Applied	Partly Applied	Applied	Applied	Applied	Applied
Fishbowl Discussions	Applied	Partly Applied	Partly Applied	Applied	Applied	Applied	Applied
Inside-Outside Circle	Applied	Partly Applied	Partly Applied	Applied	Applied	Applied	Applied
Forum Discussions		Partly Applied	Applied	Applied	Partly Applied		
Individual Exercises, e.g.,							
Media Analysis			Partly Applied	Applied	Applied	Applied	Partly Applied
Essay		Partly Applied	Applied	Applied	Applied	Partly Applied	
**Coding Problems*	Partly Applied	Partly Applied	Partly Applied	Applied	Applied	Partly Applied	Applied
Group Projects, e.g.,							
Essay		Partly Applied	Applied	Applied	Applied	Applied	Partly Applied
Survey	Partly Applied		Partly Applied	Applied	Applied	Applied	Partly Applied
Experiment	Applied		Partly Applied	Applied	Applied	Applied	Partly Applied
Jigsaw	Partly Applied	Partly Applied	Applied	Applied	Applied	Partly Applied	Partly Applied
Hackathon	Applied		Partly Applied	Applied	Applied	Applied	Applied
Study Challenge		Partly Applied	Partly Applied	Applied	Applied	Applied	Partly Applied
**Software Development*		Partly Applied	Applied	Applied	Applied	Applied	Applied
Deliverables, e.g.,							
Essays and Reports		Partly Applied	Applied	Applied	Applied	Applied	Partly Applied
Video-Based Materials	Partly Applied	Partly Applied	Partly Applied	Applied	Applied	Applied	Partly Applied
Audio-Based Materials		Partly Applied	Applied	Applied	Applied	Applied	
Presentation (Slides)		Partly Applied	Partly Applied	Partly Applied	Partly Applied	Partly Applied	Partly Applied
Showcase	Applied		Partly Applied	Applied	Applied	Applied	Applied
*(Code) *Artifacts*				Applied	Applied	Applied	Applied

* *Discipline-Specific Exercise, Project or Deliverable*

6.2. ICAP Framework for Cognitive Engagement

In 2014, Chi and Wylie published the ICAP framework [17] following an earlier publication of a preliminary version of the framework in 2009 [16]. The ICAP framework engages with educational methods and their potential impact on learning success by investigating the processes of cognitive engagement linked to the different tasks. Chi and Wylie present a framework that contextualizes and connects student engagement in terms of overt behavior to underlying knowledge-change processes occurring inside the student's mind and to the corresponding levels of learning achieved by the respective student.

One example of contextualization of an educational method derived from the framework covers the educational concept of taking notes in a lecture context or from a video. Chi and Wylie categorize this task as an Active task, in which the task triggers *integrative* thought-changing processes, as taking notes integrates new knowledge into previous knowledge, potentially building mental schemes of (inter-)connections between content. The authors expect that building on notes taken during lectures, learners have achieved the cognitive outcome of being able to *apply* their knowledge to similar other scenarios, thereby providing a *shallow* understanding of the topic.

Chi and Wylie further hypothesize that the levels of learning achieved in the different modes can be ordered to where *Interactive* modes of engagement achieve the highest levels of learning, followed by *Constructive*, *Active* and *Passive* modes of learning ($I > C > A > P$). The authors present empirical evidence from various laboratory and classroom studies validating their ICAP hypothesis in their manuscript.

While Bloom's taxonomy assesses *if* learning *has occurred*, essentially at the end of the learning process in a given stage, the ICAP framework assesses *how* learning occurs. The ICAP framework description further highlights that a singular classroom activity can result in different levels of learning, depending on the associated task. They provide an example for the activity of *listening to a lecture*, which can result in different levels of cognitive engagement depending on how the associated tasks are formulated [17]:

Passive: (Solely) listening to the lecture, concentrated on the instructor

Active: Repeating or rehearsing lecture content; copying and verifying solution steps; taking verbatim notes

Constructive: Deriving concept-maps; asking questions; reflecting out-loud

Interactive: Arguing about the content in small groups

In Table 6.2, we present a mapping of the educational formats introduced earlier to the levels of cognitive engagement as defined in the ICAP framework. As outlined, the level of cognitive engagement is strongly determined by the detailed description of the task associated with the respective education method. However, some education methods are more likely to induce specific tasks. Further, with the differentiation between different educational methods, some of the tasks associated with the above example are explicitly associated with different educational methods.

Table 6.2.: Mapping of presented educational formats to the dimensions of cognitive engagement particularly triggered according to the ICAP framework [17]. Color-Coded is, whether an educational format **Supports** or **Partly Supports** engagement on the respective level.

Educational Format	*Cognitive Engagement* **Passive**	**Active**	**Constructive**	**Interactive**
Presentations, e.g.,				
Videos	Supports			
Animations	Supports	Supports	Partly Supports	
Interactive Videos		Supports	Partly Supports	
Audio-Based Content	Supports			
Text-Based Content	Supports	Partly Supports		
Examples & Demonstrations, e.g.,				
Simulation		Supports	Supports	Partly Supports
Reactions		Supports	Partly Supports	
Educational Games		Supports	Partly Supports	Partly Supports
Debates, e.g.,				
Panel Discussions		Partly Supports	Partly Supports	Partly Supports
Fishbowl Discussions		Partly Supports	Partly Supports	Supports
Inside-Outside Circle		Supports	Supports	Partly Supports
Forum Discussions	Partly Supports	Partly Supports	Supports	Partly Supports
Individual Exercises, e.g.,				
Media Analysis			Supports	
Essay			Supports	
**Coding Problems*			Supports	
Group Projects, e.g.,				
Essay			Supports	Partly Supports
Survey			Supports	Partly Supports
Experiment			Supports	Partly Supports
Jigsaw		Partly Supports	Partly Supports	Partly Supports
Hackathon			Supports	Partly Supports
Study Challenge	Partly Supports	Partly Supports	Supports	Supports
**Software Development*		Partly Supports	Supports	Partly Supports

* *Discipline-Specific Exercise, Project or Deliverable*

Therefore, the *Interactive* mode of listening to a lecture, which was exemplarily described as group discussions in [17], is considered a *Debate* in this report. Thereby, we induce that most Debates and Discussions will usually be triggering *Interactive* modes of cognitive engagement.

6.3. The ESCO Framework by the European Commission

ESCO (European Skills, Competencies and Occupation) is a framework created and hosted by the European Commission. It categorizes and characterizes the different occupations in the European Union (EU) and standardizes the vocabulary on competences that have to be mastered for a successful career in those jobs. The framework follows a holistic approach to connect the occupations with the relevant competencies and skills.

The purpose of the framework is the standardization of vocabularies to enable the European citizens to easily move between the member states and to simplify job applications in different states. Technically, ESCO is an extension to UNESCO's *International Standard for the Classification of Occupation* (ISCED) and aligned with US O*NET including a mapping between these two frameworks.

The work on ESCO started as early as 2008, while the first version was published in 2017. The *European Qualification Framework* (EQF) served as a blueprint and first bedrock for ESCO [83]. Frequent updates are representing current developments in the labor market. As of January 2024, ESCO lists 3008 occupations and 13,890 competences. ESCO is divided into the categories "Occupations" and "Skills" to organize this huge amount of data. In our context, we will only take a deeper look into "Skills"-sub-categories, namely, "T" - *transversal skills and competences*, "S" - *skills*, "K" - *knowledge*, and "L" - *language skills and knowledge*.

Assessing these sub-categories reveals that neither "K-knowledge" nor "L - language skills and knowledge", along with their respective items, meet our needs. "K-knowledge" deals with the topics of domains like "chemistry" is part of "natural sciences, mathematics and statistics" but does not give any information about skills. On the other hand, "L - language skills and knowledge" only allows to specify a certain language but currently does not allow to specify the language level a learner can achieve or is required to have.

"S - skills" includes eight sub-level categories (see below) with 308 items in total with unambiguous short-codes (there are more without short-codes). The category "T - transversal skills and competences", in contrast, has 24 items under six subcategories (see below). As for the skills, these are only the unambiguously coded items not counting the items without short codes.

6.3.1. Cross-sector skills and transversal skills according to ESCO

ESCO distinguishes between "sector specific skills and competences" and "cross-sector skills and competences". Both categories are listed under "S - skills" as well as under "T - transversal skills and competences". Both, transversal and cross-sector skills can be seen as skills and competencies that are not limited to a single narrow field of occupation. Many competencies and skills that are listed under these tags are regarded as so-called "soft skills". However, this categorization is not always a match, as also so-called "hard skills" can fall under this categorization if they are required for more than one occupation. Furthermore, the definition of "soft skills" is not undisputed and its usage is subject to ongoing discussions.

A discussion paper published by the German Stifterverband and McKinsey introduces the term "future skills" [61] instead, which is better suited in this context. In this publication, "future skills" are defined as "skills that will be of increasing importance for work and/or social participation in the next 5 years'. It provides a framework that organizes these skills into three categories: technological skills, basic digital skills, and classic skills. While only experts in certain fields are required to have the respective technological skills, the basic digital and classic skills are recommended for basically everybody as they will be required for handling daily life in society and profession. Examples of such skills are digital literacy, digital social interaction, digital collaboration, agile work as well as problem-solving skills, creativity, and entrepreneurial thinking.

As the following examples from the ESCO framework show, many of the mentioned skills can also be found there, but not necessarily in the way that the "future skills" framework describes them. So some adaptation is required.

ESCO Skills [1] [29]

S1 **Communication, Collaboration and Creativity**: Interaction with other people, developing solutions interactively

S2 **Information Skills**: Collecting, storing and using information, such as by performing studies and investigations

S3 **Assisting and Caring**: Providing assistive support to people and ensuring compliance to rules, standards or laws

S4 **Management Skills**: Managing people and organizations, developing strategies, controlling resources, supervision of teams

S5 **Working with Computers**: Installation and administration of ICT software, and collaboratively creating content

S6 **Handling and Moving**: Sorting, managing and fabricating goods and materials by hand

S7 **Constructing**: Building or repairing interior or exterior structures

S8 **Working with Machinery and Specialized Equipment**: Controlling and operating vehicles, machinery, precision instruments or equipment

[1]Webpage ESCO Skills: `http://data.europa.eu/esco/skill/335228d2-297d-4e0e-a6ee-bc6a8dc110d9`, Status: Released, *Last Accessed: Jan, 9th 2024.*

Table 6.3.: Mapping of presented educational formats to the **Skills** (S) used in the **ESCO Framework** by the European Commission. Color-Coded is, whether an educational format can be **Used** or **Partly Used** to train the respective skill.

Educational Format	*ESCO Skills* S1	S2	S3	S4	S5	S6	S7	S8
Presentations, e.g.,								
Videos		Partly Used						
Animations	Partly Used	Partly Used						
Interactive Videos	Partly Used	Partly Used						
Audio-Based Content		Partly Used						
Text-Based Content		Partly Used						
Examples & Demonstrations, e.g.,								
Simulation	Partly Used	Partly Used			Partly Used			
Reactions	Used	Partly Used						
Educational Games	Used		Partly Used					
Debates, e.g.,								
Panel Discussions	Used			Partly Used				
Fishbowl Discussions	Used			Partly Used				
Inside-Outside Circle	Used			Partly Used				
Forum Discussions	Used			Partly Used	Partly Used			
Individual Exercises, e.g.,								
Media Analysis	Partly Used	Used						
Essay		Used						
**Coding Problems*		Partly Used			Used			
Group Projects, e.g.,								
Essay	Partly Used	Partly Used		Partly Used				
Survey	Partly Used	Used			Partly Used			
Experiment	Partly Used	Used		Partly Used	Partly Used			Partly Used
Jigsaw	Partly Used		Partly Used	Partly Used				
Hackathon	Partly Used				Used			
Study Challenge	Used	Partly Used	Partly Used	Used	Partly Used			
**Software Development*	Used		Partly Used	Partly Used	Used			

* *Discipline-Specific Exercise, Project or Deliverable*

6.3.2. Transversal Skills

ESCO Transversal [2] [48]

T1 **Core Skills**: Fundamental skills to understand, speak and write languages, work with number and use digital tools

T2 **Thinking Skills**: Mental processes of deriving solutions to problems, evaluating and analyzing information

T3 **Self-Management Skills**: Ability to act reflectively, accept feedback and adapt to change

[2]Webpage ESCO Transversal Skills and Competencies: `http://data.europa.eu/esco/skill/04a13491-b58c-4d33-8b59-8fad0d55fe9e`, Status: Released, *Last Accessed: Jan, 9th 2024.*

T4 **Social and Communication Skills**: Interact productively with others, effective communication of ideas, empathy for others needs, coordination of different objectives, leadership

T5 **Physical and Manual Skills**: Ability to perform activities requiring manual dexterity such as bodily strength, carrying out activities in hazardous environments or requiring endurance and stamina

T6 **Life Skills**: Skills that facilitate active citizenship in the areas of health, environment, culture, finance, and general knowledge

Table 6.4.: Mapping of presented educational formats to the **Transversal Competencies** (T) used in the **ESCO Framework** by the European Commission. Color-Coded is, whether an educational format can be **Used** or **Partly Used** to train the respective skill.

	ESCO Transversal Competencies					
Educational Format	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Presentations, e.g.,						
Videos	Partly Used		Partly Used			
Animations	Partly Used	Partly Used	Partly Used			
Interactive Videos	Partly Used	Partly Used	Partly Used			
Audio-Based Content	Partly Used		Partly Used			
Text-Based Content	Partly Used		Partly Used			
Examples & Demonstrations, e.g.,						
Simulation	Partly Used	Used	Partly Used			
Reactions	Partly Used	Partly Used		Partly Used		
Educational Games	Partly Used	Used		Partly Used		
Debates, e.g.,						
Panel Discussions		Partly Used	Partly Used	Used		Partly Used
Fishbowl Discussions		Partly Used	Partly Used	Used		Partly Used
Inside-Outside Circle		Partly Used	Partly Used	Used		Partly Used
Forum Discussions	Partly Used	Partly Used	Partly Used	Used		Partly Used
Individual Exercises, e.g.,						
Media Analysis	Used	Used	Used			
Essay	Used	Used	Used			Partly Used
**Coding Problems*	Used	Used	Used			
Group Projects, e.g.,						
Essay	Partly Used	Used	Partly Used	Partly Used		Partly Used
Survey	Partly Used	Partly Used	Partly Used	Used		Partly Used
Experiment		Used	Partly Used	Partly Used	Partly Used	Partly Used
Jigsaw	Used	Partly Used	Partly Used	Used		
Hackathon	Partly Used	Used		Partly Used		Partly Used
Study Challenge	Partly Used	Used	Partly Used	Used		Partly Used
**Software Development*	Used	Used	Partly Used	Partly Used		

* *Discipline-Specific Exercise, Project or Deliverable*

7. Applicability of Educational Formats to Online Contexts

Previously, we have proposed and assessed various educational formats regarding their didactic approach and how fit they are to promote knowledge on a certain cognitive level, or for a specific transversal skill. This chapter touches on applicability of the specific educational formats to real world scenarios in online education. Therefore, we initially highlight, how well a certain format is fit for a specific group size, particularly differentiating between synchronous and asynchronous implementation of the format. Later, in Sections 7.3.1 and 7.3.2, we highlight, how well an implementation of the format is able to scale and which degree of interactivity it provides. While scalability is often a question of technical feasibility or workload, interactivity is important as it impacts aspects such as learner engagement and therefore crucially defines how well an educational concept will be perceived. Finally, in Section 7.4, we highlight few exemplary real world examples of previous reports on application of the respective format in practice. These reports can be referred to for more in-depth ideas on implementation and considerations for each educational format.

7.1. Group Sizes in Courses and Classrooms

The proposed educational formats can be differentiated based on *how* they can be applied in real-world contexts. Generally, in online education contexts, we differentiate between **synchronous** and **asynchronous** sessions. While the majority of traditional MOOCs are based on on asynchronous learning elements, such as pre-recorded videos, more complex educational programs, require also synchronous sessions. Traditional face-to-face learning scenarios such as in higher education institutions, schools or professional learning in classroom sessions usually employ synchronous sessions.

Educational formats that can be used in asynchronous learning contexts usually rely on pre-recorded videos, or describe tasks that learners can solve individually. When considering synchronous learning sessions, a differentiation between the number of learners present in the session has to be performed. We differentiate between:

- **Group Meetings** with a maximum of ten students
- **Class Meetings** with up to 40 students
- **Town-halls** with multiple hundreds of students

Table 7.1.: Mapping of educational formats to whether they are possible to be implemented in *synchronous* or *asynchronous* sessions. For synchronous sessions, we further differentiate between the size of the participant group to be integrated into the session. A **Dark Blue** color indicates a **good fit**, while **Light Blue** indicates a **partly fit** between respective implementation form for a given educational format.

	Synchronous Sessions			
Educational Format	**Team Meetings**	**Class Meetings**	**Town-halls**	**Asynchronous Learning**
Presentations, e.g.,				
Videos	good fit	good fit	good fit	good fit
Animations	good fit	good fit	good fit	good fit
Interactive Videos	good fit	good fit	good fit	good fit
Audio-Based Content	good fit	good fit	good fit	good fit
Text-Based Content	good fit	good fit	good fit	good fit
Examples & Demonstrations, e.g.,				
Simulation	good fit	good fit	partly fit	good fit
Reactions	good fit	good fit	good fit	good fit
Educational Games	good fit	good fit	partly fit	good fit
Debates, e.g.,				
Panel Discussions	good fit	good fit	partly fit	
Fishbowl Discussions	good fit	good fit		
Inside-Outside Circle	good fit	partly fit		
Forum Discussions				good fit
Individual Exercises, e.g.,				
Media Analysis	good fit	partly fit		good fit
Essay	good fit	partly fit		good fit
**Coding Problems*	good fit	good fit	good fit	good fit
Group Projects, e.g.,				
Essay	good fit	good fit	partly fit	good fit
Survey	good fit	good fit		partly fit
Experiment	good fit	good fit		partly fit
Jigsaw		good fit		
Hackathon	good fit	good fit		partly fit
Study Challenge	good fit	good fit		good fit
**Software Development*	good fit	good fit		good fit

* *Discipline-Specific Exercise, Project or Deliverable*

Table 7.1 presents the mapping between the different educational formats and the corresponding possibilities for implementation in synchronous, asynchronous sessions and with dependencies on upper limits of students that can participate simultaneously. Overarching, we observe that educational formats, which primarily depend on frontal presentation of a specific topic, such as videos, animations, or text-based content can be consumed asynchronously, but also be presented in synchronous sessions to large-scale audiences. Similar observations apply to the educational formats for examples and demonstrations. Based on technical limits of respective applications, however, we consider them slightly less applicable to synchronous *Town-hall* sessions, as the amount of participants could be challenging for certain IT systems.

Debate formats are—due to their nature—not feasible in asynchronous learning sessions. Similarly, large-scale synchronous sessions can pose challenges to debates, due to the sole complexity of coordinating such large groups of learners at once.

Individual exercises and longer-running projects allow to be worked on asynchronously, thereby providing flexibility to educators and learners alike. Similarly, while most of these methods can prove beneficial to be performed in synchronous sessions, they also fall victim to problems of coordination with larger amounts of participants.

7.2. Assessment of Learner Performance

Assessing the performance of learners always has been a tricky business. Teachers have to ensure that they assess what they actually have been teaching. Often additional skills are assessed, intentionally or unintentionally, as a by-catch. Many assessment types focus on content that has been learned by heart rather than the application of the learned principles, which in turn often leads to so-called bulimic learning among the students. Similarly, many assessments only show that a student deals well with this particular type of assessment instead of showing that he or she actually masters the content. A more recent challenge are the emerging generative AI tools such as ChatGPT, etc., which are rendering many classical examination models obsolete.

On top of that, in the context of online learning, the assessment of the learner performance comes with additional challenges, such as a more difficult identity verification, additional challenges in the proctoring of exams, additional challenges to ensure an environment that prevents cheating attempts.

Finally, depending on the type of the online course, the assessment tools have to allow scalability. This is particularly important as the maximum number of users that can be assessed without some sort of technical support by a single teacher is very low. Once that the technical support is available, however, in most cases scalability is endless and only limited by technical resources, which generally can be scaled much faster and cheaper than human resources. A very simple example is a multiple choice quiz. If a teacher has to grade the results manually, although this will be done much faster than grading any other form of assessment, the amount of students the teacher can grade is limited. Teaching assistants could be added, but they are not always that easy to recruit and also are comparatively expensive. If the multiple choice quiz is offered as an online exam, the grading can be easily automated. Once that is done, it no more matters if the work of a hundred, a thousand, or hundred thousands of learners has to be graded. At max, the available machinery needs a little boost, which in times of cloud computing, virtual machines and containers can be done more or less on the fly.

Next to automation, outsourcing the grading to the learners is a possible alternative. In the following we briefly outline several variants of automating or outsourcing assessments. Finally, we provide a quick introduction to online proctoring. Assessment in digital learning is an extensive field, deserving a report on its own. We, therefore, decided not to go in too much detail here and to provide a separate report on assessment methods later.

7.2.1. Automating Assessment

Multiple Choice, Multiple Answer Quizzes (MCQ) The easiest and, therefore, most common automated assessment form are multiple-choice or multiple-answer exams. Basically, a question is shown together with a set of answers and the students have to select the correct ones. The difference between multiple choice and multiple answer is that in one case only one correct answer is possible, in the other case multiple correct answers are possible. As this difference is marginal for the given context, both will be referred to as MCQs.

These exams are highly scalable and come as an integrated feature with most Learning Management Systems (LMS). Depending on the tools that are integrated to the LMS, these questions can be parameterized to complicate cheating or added to question banks to ease re-use. To all those who have been students themselves or have dealt with students as teachers, it probably does not need to be mentioned that students also know that teachers like to re-use questions to reduce their workload and therefore spare no effort to get hold of last years questions.

The downside of MCQs is that they only cover a subset, the lower four levels [45], of Bloom and Anderson/Krathwohl's learning taxonomy. Furthermore, creating demanding MCQs that do not only test if students can reproduce the knowledge provided by the lectures (levels 1 and 2) but also test if they can apply their knowledge or analyze given data (levels 3 and 4) is challenging.

Drag & Drop, Connect the Dots, etc. There are a few formats that extend MCQs by providing a more pleasant and interactive user interface for more complex MCQs. Best known are *fill in the gaps*, *drag & drop*, *connect the dots*, *drag the words*, *mark the words*, etc. as provided e.g. by the H5P library[1]. Using these exercises can certainly help to enhance the learning content with some interactivity, however, many of these libraries are JavaScript-based, which might allow creative learners to find the solution in the website's source code.

Coding Exercises Particularly on the beginner's level, coding exercises can be highly formalized and, therefore, allow a comparatively simple automation of the grading. Several auto-graders for coding exercises exist. CodeOcean, e.g., is such a tool that has been developed at the Hasso Plattner Institute. CodeOcean is completely browser based and the code and the according tests are executed on a server. This comes with several challenges for the security of the environment and the scalability but on the other hand also provides a simple point of entry for the learners, who can learn coding right away without having to install complex software first (see e.g., [78, 118, 120, 122, 124, 137, 138, 146, 148, 149, 158, 159, 160, 161]). Other

[1] https://h5p.org/content-types-and-applications

auto-graders are e.g., *Praktomat* by the KIT[2], *Jack* by Uni Duisburg-Essen, or more recently also *JupyterHub*. Most of the listed auto-graders are open source projects and their code is available on GitHub. Operating such systems securely, however requires a certain degree of professional skills.

Math Exercises Similar to coding exercises, there are several approaches to automatically grade math exercises. One of them is the MatLab Grader[3] a commercial tool by MathWorks.

AI-based Assessment So far, implementing automated assessment for complex or even creative tasks is not yet possible. The verge of AI, however, offers the opportunity to auto-assess everything, so solutions to auto-assess such tasks are also on the horizon.

Learning Tools Interoperability (LTI) Interface Most of the listed tools can be connected to a wide variety of LMS via the LTI Interface. LTI is a standard that is supported by basically all relevant LMS and a wide variety of tools (not only auto-graders), which allows to flexibly combine the tools with many different LMS.

7.2.2. Outsourcing Assessment

The alternative to automating the assessment in terms of scalability is outsourcing the assessment.

Peer Assessment The most appropriate form for the scalable outsourcing of assessment is the so-called peer assessment. Peer assessment solves the scalability issue by outsourcing the assessment from the instructors to the participants instead of automating this task. Additionally, it inherently pushes all exercises to the *Evaluating* level of Bloom's taxonomy, as the participants have to assess (or evaluate) the work of their peers. Albeit, it possibly can be used for exercises and tasks on all levels of Bloom's taxonomy. It is recommended, however, to focus on the top three levels, as it comes with a certain overhead. Basically, the learners are grading each other. The more learners there are, the more graders are available. It works particularly well for team assignments as individuals can assess the work of other teams, so the number of reviews that have to be written by each learner is low while the number of reviews that are received by a team is high. The higher the number of received reviews, the more accurate is the overall result as outliers can be eliminated. Peer assessment requires a certain level of maturity of the learners and, therefore, works particularly well in the life-long learning context. However, peer assessment also has been employed successfully in the school context and with regular university students. Some results of our work in the context of peer assessment can be found in the following publications [32, 59, 135, 139, 140, 141, 143, 144, 145, 147, 150].

[2]Karlsruhe Institut of Technology
[3]https://de.mathworks.com/products/matlab-grader.html

Assessment by External Experts Next to the "internal" outsourcing via peer assessment, the grading can also be outsourced to "external", paid experts via marketplaces such as e.g. Amazon Mechanical Turk[4]. However, this approach requires a large amount of quality assessment to make sure that the assessors have a sufficient qualification. While peer assessment adds an extra quality to the given exercise for the learners as they can experience the work of other learners and the learning experience is lifted to one of the higher levels in Bloom's taxonomy, outsourcing the grading to paid experts does not add any inherent quality to the task. Therefore, peer assessment will still be a valid approach when AI-based evaluation for complex and creative tasks has reached a certain level of maturity. Paid outsourcing of the grading, however, will become obsolete.

7.2.3. Online Proctoring

Several assessment models require a certain level of surveillance. The classic on-campus approach is to put all students into a large lecture hall or similar and have several teaching assistants check the room for illegal activities of the examined. For particularly large exams, an additional ID check will be required, while for smaller classes it might be sufficient that the teacher knows their students.

The equivalent in an online learning setting are several online-proctoring solutions on the market. There are three basically different models in use.

1. live proctoring,
2. record-and-review proctoring,
3. fully automated proctoring.

Live proctoring The proctor monitors the learner while she or he is writing the exam. This approach allows interaction between proctor and learner, but is generally inflexible as time slots have to be scheduled and it is the most expensive solution.

Record-and-Review proctoring The learner is recorded while taking the exam and the proctor watches the recording later on. A little more flexible than live proctoring and also a little less expensive as the proctor often watches several videos in parallel.

Fully automated proctoring No more humans are involved. Proctoring is reduced to a certain set of rules and automated face recognition.

Modern proctoring solutions all come with some level of automation and AI support for the proctors. A wide variety of solutions and providers is offering their services world wide. Particularly, in the European context an important aspect in this context is the the provider's GDPR (General Data Protection Regulation) compatibility.

[4]https://www.mturk.com/

7.3. Assessment of Scalability and Interactivity

Table 7.2 presents an overview of the results of our assessment for the degree of scalability and interaction provided by the educational formats. Both factors depend on the implementation of the respective educational format. For some, the actual implementation is intuitive. An example are videos. Small learning videos can be distributed using any video platform of choice. However, other methods developed for online education building on best practices from face-to-face teaching, such as discussion methodologies such as the *Inside-Outside Circle* might require more complex system to be put into practice. To use online educational methods to their fullest, they must be scalable across many learners. **Scalability** can be regarded as one of the critical factors to decide for, or against any educational method. Depending on the context, am educator has to decide, which methods to implement. Depending on their goals, these can be choosen to be fully scalable, such as videos, animations and (digital) educational games. Alternatively, when less scalability is required, educators can choose methods such as different discussion formats, or even projects such as Hackathons or study challenges that require a high moderation effort.

On the other hand, however, the entire study or learning program has to remain interactive for learners. As highlighted earlier, interactivity is considered one of the keys to the success of online educational programs, as only interactivity will keep learners engaged [110]. In the following two sections we highlight few aspects of our assessment of both Scalability (Section 7.3.1) and Interactivity (Section 7.3.2).

7.3.1. Scalability of the Educational Formats

Some proposed education methods, such as videos, animations, or reactions, rely on (prerecorded) videos. Like text-based educational formats or podcasts, these are effortlessly scalable from hundreds to thousands of participants. Any content that happens *live*, such as educators presenting examples, e.g., in the context of physics education can be live-streamed and recorded to allow scalability for learners who were not able to join live. The challenge of presenting the respective content is easily solved via video platforms such as YouTube or dedicated online education platforms such as Coursera or edX. Any prerecorded videos are asynchronously consumable, providing complete flexibility to the learner and their schedule.

Live sessions, on the other hand, to perform panel discussions, etc., must be closely aligned with the learners' schedules. Aligning specific time slots is particularly challenging when multiple time zones and possibly continents are involved, which, however, is essential to consider for international online courses[89]

The proposed discussion formats pursue different twists on traditional classroom discussions, allowing for considerable flexibility. Only sub-groups of the entire cohort of learners must be active synchronously. An example of this is a panel discussion which was previously prepared in small groups, but for the actual discussion, the time slot only needs to be aligned between the panelists. This does allow for a – to some extent – increased scalability and better accessibility for, e.g., shy learners. However, with too many participants, Panel or Fishbowl discussions are not manage-

Table 7.2.: Mapping of educational formats to whether they **Provide** or **Partially Provide** features of **Scalability** and high degrees of **Interaction**.

Educational Format	Scalability	Interaction	Resources and Examples
Presentations, e.g.,			
Videos	Provide		[34, 40, 105, 129]
Animations	Provide		[62, 109]
Interactive Videos	Provide	Partially Provide	[65, 104]
Audio-Based Content	Provide	Partially Provide	[37, 63, 97, 156]
Text-Based Content	Provide		[60, 111]
Examples & Demonstrations, e.g.,			
Simulation	Partially Provide	Provide	[12, 15, 73]
Reactions	Provide	Partially Provide	[75, 80]
Educational Games	Provide	Partially Provide	[1, 174]
Debates, e.g.,			
Panel Discussions	Partially Provide	Partially Provide	[72]
Fishbowl Discussions	Partially Provide	Provide	[7, 44, 50, 172]
Inside-Outside Circle	Partially Provide	Provide	[162, 169]
Forum Discussions	Provide	Provide	[5, 57, 58, 108, 176]
Individual Exercises, e.g.,			
Media Analysis	Provide	Partially Provide	[80, 155]
Essay	Partially Provide		[35]
**Coding Problems*	Provide		[23, 117]
Group Projects, e.g.,			
Essay	Partially Provide		[35]
Survey		Provide	
Experiment		Partially Provide	
Jigsaw	Partially Provide	Provide	[4, 66, 69, 173]
Hackathon		Provide	[102, 103]
Study Challenge		Provide	
**Software Development*		Provide	

* *Discipline-Specific Exercise, Project or Deliverable*

able anymore. As an alternative, forum discussions do not require a synchronous exchange and can be scaled (almost) endlessly, allowing all students to participate and train their discussion skills. In large courses, it is important to provide a certain house-keeping in the discussions. Threads need to be closed if they contain inappropriate content or if there are too many duplicates on the same topic. This requires an amount of effort that should not be underestimated. Depending on the employed software, the teaching team can be supported by the learners, if e.g. a reporting mechanism is available for inappropriate posts.

Regarding individual exercises and team projects, scalability is often primarily limited by the amount of topics available. If, however, an educator is fine with multiple students elaborating on the same topics, particularly individual assignments can scale without limits. However, as highlighted earlier in Section 7.2, while the task and exercise can scale, the assessment has to be considered alongside that. In team projects, scalability often depends on issues such as timing of collaborative work. If the student groups are large enough such that each student can work together with a team in their timezone, or synchronous collaboration is not required, then project based tasks can scale well. Another factor that does not scale particularly well in the context of team assignments or project work, is guidance. As shown by Vygotsky [125] learners can achieve more if they are guided by someone more experienced. If the teams are properly matched, some of this guidance can occur within the team. Often, however, providing appropriate help can become a time-consuming process for a teacher, thus severely limiting the scalability of particularly project-based methods.

For our subject-specific projects and exercises, such as coding problems and software development, assessment can be automated by using so-called auto-graders. These software environments allow students to submit their program code, which is then evaluated against metrics and tests to derive a score for the respective student. While we have already scaled programming exercises across large-scale online courses with more than 100 code assessments per second in peak times, the infrastructure required for that has to be closely evaluated [119, 121]. Furthermore, the use of auto-graders limits the size and the extent of a coding project as it has to stay within boundaries of the predefined tests and, therefore, also often restricts the creativity of the learners. This topic will also be handled in more detailed in the follow-up report on assessment methods.

7.3.2. Interactivity of the Educational Formats

Interaction is one of the crucial aspects of student motivation and learning success. While not all education methods are interactive, variations between the methods can enhance how the learner perceives interactivity [30]. Usually, interactivity is divided into learner-instructor, learner-learner, and learner-content interactivity [43, 157]. Learner-Instructor interactivity, covers how approachable and connected the educator appears from the perspective of a student. Learner-learner interactivity primarily focuses on aspects of not being alone, being integrated into a cohort of like-minded peers and following the lecture(s) in a (distributed) group. Finally, learner-content interactivity covers, how engaging the educator's teaching content is. Such perceived interactivity in content can often already be achieved by integrating different content formats inside an educational scenario. Within an online course context, all three interaction types help increasing learner engagement. Table 7.2, therefore, groups the assessment for all three under the term **Interaction**.

Interactive videos integrate decisions, small challenges and potentially even character development into video-based education. While traditional videos, even if applied appropriately for online contexts, with short duration for small learning nuggets, still fail to provide a feeling of interactivity as the watcher is only passively consuming, interactive videos allow to integrate the learner into the content by providing thought-provoking or reiterative questions, or posing entire decisions to them. If, however, traditional short videos have to be used, e.g., because of limitations in time for creation of a (new) course, time-anchored peer comments can increase interactivity and social presence [71]. On the other hand, podcasts and audio-based content can help to increase perceived learner-content interactivity, as they allow learning in moments where video consumption is impossible [64]. Such opportunities for using learning scenarios outside traditional classroom contexts can help to increase perceived interactivity.

Content that allows learners to explore on their own, such as providing simulations to the learners obviously increases interactivity within a course tremendously. Media Analyses and Reactions enhance interaction when employed as tasks for students, analyzing each others', the educators', or external content. This approach can provide actual learner-learner and learner-teacher interaction.

Furthermore, all forms of debates and discussions (strongly) provide interactivity between learners and potentially even teacher-learner interactivity, if the teacher is able to participate in these activities. Discussions further help to generate a sense of peer presence for learners. Such peer presence is fundamental for motivation to keep being engaged within a course [164, 176]. With increased peer presence as particularly available during the discussions among learners, participants' motivation is strongly increased. Therefore, discussion sessions should regularly be interlaced with traditional educational formats. Panels provide an excellent opportunity for every learner to feel engaged in the discussion, particularly when they help derive the arguments. More engaging forms of discussions, such as the Fishbowl or Inside-Outside Circle unfortunately lack *good* scalability, or at least scalability is complicated, if not supported by appropriate technical tools. Instead, forum discussions provide the best of both worlds. By eliminating any synchronicity in the method, forum discussions can scale freely while allowing every student to interact and discuss with their peers.

Finally, projects in which groups of learners work together are inherently the most interactive education method, particularly as they provide a sense of peer presence and interactivity throughout a longer period of engagement. Within projects, students can dive deep into teamwork with other students. Student-to-student interaction is one of the significant advantages of participation in project work.

7.4. Real-World Experiences using the Formats

Alongside Table 7.2 and the previous sections highlighting few pieces of related literature on the different problems, in this section we provide an overview of real-world implementations of some of the educational formats covered in this report. Our proposed formats for enhancing digital education only provide an actual benefit if they are applicable and implementable in practical scenarios. Many of the proposed formats have — in some variation — been applied in our MOOCs on openHPI[5] in the past years. We successfully included carefully selected aspects of gamification and *gameful* learning [42], prepared and provided audio-podcasts alongside the MOOCs [63, 64], integrated live streams [154] allowing learners to ask open questions directly to the presenter, and many more.

[5]Website: `open.hpi.de`

The various video-based formats are used across a variety of platforms. We previously highlighted Santos-Espino et al. [112] who provided a good overview of the question, *"how"* a video can be designed. Some of the methods for video design, particularly interviews and animations and the impact derived by the inclusion has been analyzed in one of our courses with approximately 1.500 participants [62]. Besides educational platforms such as openHPI, fellow researchers have already shown that the field of educational live streams on platforms such as Twitch is very popular [14, 41, 153].

As highlighted earlier, discussion formats are somewhat limited in regard to scalability. Panel Discussions, scale best, but leave relatively little room for interaction during the discussion. The interaction and thereby the perceived impact that each individual has on the study outcome is generated by the preparation of the discussion in smaller groups. For those means, individual learning rooms for smaller groups, so-called *collab(oration) spaces*, have previously been used successfully on our education platform [20, 142, 163]. Fishbowl Discussions provide a good experience for students' perceived interactivity and learning success [44, 50]. Regarding scalability, fishbowl discussions enhance traditional discussions and have been (successfully) performed with up to 70 participants by Hertling et al. [50]. Video-conferencing platforms or dedicated tools often allow for a far larger audience, so these could provide a foundation to scale fishbowl discussions even more. However, how and if the observed effects prevail during the scaling of the method to hundreds of students, remains to be researched.

A discussion forum deployed and used alongside a course is the most capable tool for scalable interaction among learners, their peers, and teachers. Related research highlights insights from up to 1000 participants in discussion forums, which positively impacts social presence [176] and can help achieve higher learning outcomes [5, 18]. With our education platform, we already observed multiple thousand participants in discussion forums, while maintaining the positive impacts described previously [57, 58, 136]. Project-based learning approaches have been employed in many courses on openHPI as well as on our partner platform openSAP. In the beginning, the participants have only been able to work on these projects individually. The interaction with the fellow learners was restricted to the later phase when the participants were asked to grade each other in a peer assessment. Such projects have been embedded in courses on a wide variety of subjects and the tasks that had to be solved as well as the digital artifacts that had to be delivered varied widely. The projects ranged from the area of Design Thinking were the deliverables often were texts, presentations, or videos to programming courses where the deliverables consisted of code and lab-reports.

Later on, team-based projects received the focus. The tasks and deliverables, were similarly broad as for the individual projects. Aside provision of the educational content, particularly to enable more complex educational formats such as exercises and projects, an educational platform is required to provide a toolbox for (collaborative) work. Primarily, learners require a way to share data, such as files and video clips among them, e.g., for their delivery of any deliverable during the course of an educational program. Furthermore, learners require tools to enable teamwork, such as video chats and collaborative document editing. Various of such technical features to support learner success have been developed and extensively examined in the context of openHPI [135].

8. Summary and Discussion

In the report at hand, we have outlined several learning theories and their benefits and shortcomings, particularly in the context of online education and MOOCs. Furthermore, we have listed several learning strategies, such as self-regulated learning, deeper learning, or problem-based learning. We then proceeded to delve into the subsequent tier to examine several formats, such as presentations, exercises, debates, or team projects for their applicability in online contexts and had a look at the educational objectives and soft skills that are supported in these formats with a particular focus on scalability and interactivity. We further embedded these formats in well-accepted frameworks, such as Bloom's taxonomy and its revision by Anderson and Krathwol, or the ICAP framework developed by Chi and Wylie more recently. Finally, we have provided some real-world experience examples in the context of the openHPI MOOC platform.

We are aware that it is close to impossible to show a development or chronology of teaching methods and we are aware that the methods we have listed are far from being complete. Still, we are very confident that the given overview will be a very helpful resource for educators on all educational levels, who want—or have to—switch from in person training to online or hybrid formats. Online learning enables learners who are living in remote areas or cannot attend synchronous on-campus classes for other reasons, such as a job, or children, or elderly relatives that need to be attended to complete their studies. Furthermore, it can contribute to reduce traffic and it allows students to live in cities that are more affordable than the typical university towns. Finally, the Covid-19 pandemic, Russia's invasion of the Ukraine, or an increase of severe weather conditions due to climate change, to mention just a few, have shown that these scenarios will be more likely in the near future and educators around the world should be prepared for situations where face-to-face classes are simply not possible.

Discussions with several teachers revealed that, particularly for younger learners, the lack of physical activity is one particular shortcoming of pure online learning. Including physical activities in online classes is not infeasible per se, however. Depending on the subject, learners can be encouraged to perform many experiments at home as long as they are not dangerous and do not involve explicit laboratory equipment. With the ubiquity of modern communication technology, they could e.g., film these experiments for documentation. Alternatively, motion detection technologies as known from several gaming environments could be employed in some contexts. However, such technologies usually require specific hardware, the acquisition of which should be considered carefully as it implies additional costs for the learners, which might then increase the social gap.

Teachers also pointed out that younger learners often lack the skills to learn self-reliantly. Control mechanisms are required to make sure that they actually have completed the given tasks etc. This issue is getting less important with an increasing age, responsibility, and particularly intrinsic motivation of more mature learners, such as students and particularly life-long learners who also bring a certain work experience. Finally, a certain extrinsic motivation introduced by (even minimal) tuition fees also helps to reduce the need for such controls. Next to tests or exams, control mechanisms as introduced via team tasks can deliver good results if they are designed properly.

Handwritten notes are often considered to be an important factor for the long-term retention of content in the brain as these notes require a certain cognitive processing. In pure online learning contexts it is hard to motivate learners to manually copy or summarize texts. Instead project-based approaches alone or (better) in teams can help to overcome this shortcoming of digitalization.

Another issue to be considered is that, so far, most digitalization efforts in the context of education are targeting only the aspect of scalability, while other aspects keep being untouched—the old methods are re-implemented with modern tools. In many other areas of society, however, digitalization completely disrupts whatever used to be there before leaving no stone unturned. Focusing on scalability, is a good start. The question is: is it sufficient? Shouldn't we try to achieve more?

About 2000 years ago, the Greek philosopher Plutarch already realized that learning is not (only) filling a brain with concepts and knowledge:

> For the mind does not require filling like a bottle, but rather, like wood, it only requires kindling to create in it an impulse to think independently and an ardent desire for the truth. [101]

Many online learning offers so far, however are rather resembling the Nuremberg Funnel [47] than a box of matches to be lit. Particularly, early approaches to implement teaching machines built on the behaviorist theories of Pavlov, Thorndike, Watson, or Skinner, as they were easy to automate. These concepts re-emerged more recently in the form of gamification. To make online learning an appropriate equivalent of face-to-face education, we have to overcome these simplistic approaches and need to focus on the collaborative potential of online learning. Technology often used to be seen rather as an obstacle than a helper for collaboration. Indeed, face-to-face meetings do not have connectivity issues, participants in face-to-face meetings tend to be more focused, etc. However, without remote meetings and without communication and collaboration technology, collaboration would always be restricted to a small circle of local participants and many of today's achievements, such as home office or regular meetings in distributed projects, would not be possible at all. While the usage of digital technologies in pre-schools and K-12 environments is debatable (and heavily debated, see e.g. [170] and [82]), the advantages for certain groups of undergraduate and, particularly, graduate students are by far outrivalling the disadvantages. Furthermore, we should not necessarily try to copy offline approaches to online learning but rethink the processes from an online first approach.

Particularly in the area of computer science education, there are many examples in online learning, or, more general, e-learning that at least attempt to light a fire in the learners and follow the theories by Dewey, Piaget, Vygotsky, Lave and Wenger, or Bruner. To mention just a few, the work of Seymour Papert and Cynthia Solomon on the *Logo* Programming language and the *Turtle bots*, the work of Sugata Mitra on the *Hole in the wall*, *Granny Cloud*, or *SOLE* projects or the work of the early connectivist MOOC creators Stephen Downes and George Siemens.

Despite all the obvious advantages of digitalization in education, it always has to be considered very carefully why a certain aspect of education should be digitalized and where traditional materials are suited better. Recent studies, e.g. have shown that pupils are actually learning better reading in books than on tablets [22, 28, 53, 54]. The desolate usage of many smart-boards in schools is just one example showing that new technology alone is never the solution and always needs to be embedded in an educational concept that comes along with a training strategy for the teachers. In the worst (and unfortunately very common) case, digital technology is seen as a means to reduce costs (which it generally does not).

If implemented properly, however, digitalization and educational technology can support significantly new approaches in learning and teaching that otherwise would not be possible. The scalability of learning and teaching as it was proven by MOOC platforms, such as openHPI, edX, Coursera, or FutureLearn throughout the last decade or the liberation from geographic restrictions as provided by the digital communication tools that have developed in a very positive way due to the requirements of the pandemic and their ubiquitous use in academia and industry ever since, or the rapid development of many online collaboration tools are only few examples for successful developments.

9. Vision of a Digital University

The learning from operating an e-learning platform for many different partners with a wide variety of offers and requirements and, particularly, actively using this platform for our own course offers on openHPI, provided the basis to take the next step in starting a new fully digital university. This new university combines the concept of free and open courses for everybody with traditional formalized degree-based Masters and MBAs. In July/August 2023, the establishment of the German University of Digital Science (German UDS) transpired through the amalgamation of the two distinct yet closely aligned concepts of the two founders Prof. Dr. Christoph Meinel and Prof. Dr. Mike Friedrichsen, envisioning the inception of a novel fully online university. The spirit and research underpinning of openHPI's development will form one of the pillars of the German UDS. Central to this transition are not technological solutions, but the adoption of the overarching concept of lifelong learning presented in stackable formats—a concept made very tangible by Anant Agarwal, the founder of edX, through the metaphor "Lego towers instead of ivory towers"[1]. This paradigm involves courses capable of functioning autonomously or serving as modular components contributing to broader certification entities, including micro-credentials, micro-degrees, or comprehensive higher education degrees.

The German UDS as a comprehensive digital institution will continue the legacy of openHPI as a valued member in the global e-learning research community. In order to establish the brand identity of the German UDS and broaden the prospective students' perspectives, segments of the course programs will be presented as openly accessible MOOCs. Concurrently, specific components of the programs will be structured as micro-credentials, aiming to deliver compact, adaptable, and stackable programs geared towards the re- and upskilling of the workforce. The main offer of the German UDS, however, goes beyond informal and semi-formal programs, such as MOOCs, micro-credentials, and micro-degrees: To start with, it is planned to offer three Master's programs and an MBA program. Bachelors and PhD programs will follow later.

The realization of the German UDS' vision as a fully online university and its capacity to achieve the overarching objective of offering substantial solutions to the challenges faced by not only German society but also numerous global communities

[1] Fireside chat with Carlos Delgado Kloos at EMOOCs2023. The concept of Lego Towers vs. Ivory Towers refers to the idea that we not only need few excellence institutions, but have to provide a proper higher education for the broad public. With the ongoing digitalization unqualified jobs will become rarer while the need for a qualified work force increases. One approach to get there is to provide small stackable, so-called micro-credentials, which can combined—just like Lego bricks—to larger blocks, so-called micro-degrees, and finally to full-fledged bachelors or master degrees.

in coping with the escalating pace of digitalization across various domains remains contingent upon future developments. Next to addressing the growing demand for a well-educated workforce, the broader ambition is to actively contribute to the establishment of more stable, democratic societies. Only time will reveal the extent to which the German UDS can effectively contribute to these multifaceted societal challenges, but whatever the actual impact will be, it will provide valuable insights and best-practices how to address these challenges now and in the future.

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A. Glossary

A

Agarwal, Anant. Founder of edX. Professor of Electrical Engineering and Computer Science at MIT.

Anderson, Lorin Willard. American educator and psychologist. Revised Bloom's taxonomy with Krathwol.

Andragogy the method and practice of teaching adult learners. See also pedagogy.

Animation film-making technique to create moving images or drawings out of still images. Animations can be created analogous or computer-generated.

B

Behaviorism learning theory hypothesizing that behavior can be trained by methods of punishment and positive reinforcement. See also Skinner, Watson, Pavlov, and Thorndike.

Bloom's taxonomy A hierarchical classification system for learning objectives, named after Benjamin Bloom. First published in 1956 and in its revised version (by Anderson and Krathwol) still widely used.

Bruner, Jerome. American psychologist and cognitive scientist.

C

Carnegie-Mellon private research university in Pittsburgh, Pennsylvania.

ChatGPT A generative ChatBot by OpenAI.

Chomsky, Noam. American linguist and philosopher. Declined the behaviorist learning theory and criticized the work of Skinner. One of the founders of cognitive science and cognitivism.

Cognitivism focuses on conceptualizing the student's learning process. Hypothesizes that the learning process is dependent on what the learner already knows and how new information is integrated into the existing schemata.

Computational Thinking formulate problems in a way that they could be executed by a computer.

Connectivism framework developed by George Siemens and Stephen Downes to understand learning in the digital age. Learning is no more necessarily a process that happens within a humans mind and body, but can happen any across any technological networks.

Constructionism educational theory building on constructivism.

Constructivism epistemological theory that learning doesn't happen by passively receiving information but by constructing new understanding through active experience and discussion.

Coursera MOOC platform founded by Stanford professors Daphne Koller and Andre Ng.

COVID-19 pandemic world wide virus epidemic causing lock-downs and many other disruptions in everyday life from December 2019 until about 2023.

D

Deeper Learning enabling students to develop skills to apply their learning in life and career. Robust academic content is only part of the picture. Analytic reasoning, skills to solve complex problems and teamwork are at least as important.

Dewey, John. American educational reformer.

Downes, Stephen. Canadian philosopher and educator.

E

Educational games Games explicitly developed for a certain educational context or to train a certain skill. Educational games often miss the point of being fun to play and, therefore, should be chosen very carefully. The development of educational games for a certain skill can become quite costly. For both reasons, "regular, off-the shelf, games" are often preferred over special educational games if possible.

edX MOOC platform founded as a joint operation between MIT and Harvard University.

EMOOCs European MOOC Stakeholder Summit.

Empiricism Epistemological concept that claims that knowledge can only be gained by sensory experience. The human mind of a newborn child is a blank slate and will develop new thoughts only by experience. Empiricism is a fundamental part of the scientific method: all hypotheses and theories must be tested against observations of the natural world.

Epistemology Branch of philosophy concerned with knowledge.

ESCO framework The ESCO classification identifies and categorizes skills, competences, and occupations relevant for the EU labor market and education and training. It systematically shows the relationships between the different concepts[1].

Essays Short textual assignments.

F

Friedrichsen, Mike. German media scientist. Founder of German UDS.

FutureLearn British MOOC platform started as a joint operation between Open University UK and BBC.

G

Gamification The application of game elements such as badges, leader-boards, etc. in non-game contexts. Gamification basically builds on positive reinforcement and, therefore, should be employed very critically.

Game-based learning Learning and teaching methodology that employs games to train skills or transfer knowledge.

Gameful learning Covers both gamification and game-based learning.

[1]https://esco.ec.europa.eu/en

German University of Digital Science (German UDS). New fully digital private university in Germany.

Granny Cloud The Granny Cloud initiative operated between 2009 and 2022. It comprised an independent team of volunteers that reached out to children with limited educational resources around the globe, in a variety of settings, and provided them with the opportunity to experience worlds far removed from their own[2].

H

HPI Hasso Plattner Institute. Research institute and faculty of digital engineering at the University of Potsdam.

Hole in the wall Educational experiment and initiative by Sugata Mitra that provided less-privileged children an opportunity to interact with computers, in a self-organized way. The computers were installed in the wall of a building, similar to e.g. a cash machine, . The first installation was setup in a slum in New Delhi. The children were able to interact with the computers on their own[3].

I

ICAP framework The ICAP framework defines cognitive engagement activities on the basis of students' engagement behaviors and proposes that they can be categorized and differentiated into the modes: Interactive(highest), Constructive, Active, and Passive (smallest). The ICAP hypothesis predicts that learning will increase as students become more engaged with the material[4].

Instructivism Knowledge is transferred directly from the (active) instructor to the (passive) learner.

Interactive video Videos including interactive elements as e.g. quizzes or prompts to contemplate about something before the instructor provides the solution. More elaborate interactive elements include decisions, which lead to different results based on the given answer.

Interactivity In the context of e-learning interactivity is often defined as learners interacting with the content. In such cases the content is often presented in forms

[2]https://thegrannycloud.org/
[3]https://www.edutopia.org/blog/self-organized-learning-sugata-mitra
[4]You can download the full paper here: https://www.tandfonline.com/-doi/abs/10.1080/00461520.2014.965823

that allow digital interaction such as clicking on buttons or drag & drop. The Oxford dictionary provides a more general and in our opinion more suitable definition: "The process of people or things working together and influencing each other." Inter-human interaction can be differentiated in learner-teacher (e.g. a learner asks a question in the forum and a teacher answers), learner-learner (e.g. peer assessment), and teacher-teacher (e.g. two teachers discuss a certain topic in a video) interaction.

K - L

Krathwol American psychologist and educational researcher. Revised Bloom's taxonomy with Anderson.

Lave, Jean. American social anthropologist.

Lock-down Closing of schools, businesses, areas, or even complete cities during e.g. a pandemic situation. During the Covid-19 pandemic, countries handled many things differently. At some point, however, schools were closed for significant time frames in most countries.

Logo programming language Created end of the 1960s. It is a general purpose programming language, which is best known for its Turtle graphics (see Turtle graphics. See also Cynthia Solomon, Seymour Papert).

M

Media analysis refers to analyzing different types of media in terms of certain contents but also in terms of specifics that are typical for a certain medium. Furthermore, it can deal with monetization and marketing strategies, etc.

Meinel, Christoph. German computer scientist. Founder of German UDS.

MIT Massachusetts Institute of Technology

Mitra, Sugata. Indian computer scientist and education expert.

MOOCs Massive Open Online Courses. Started in Canada around 2008 by Siemens and Downes to proof their connectivist learning theory. Hyped around 2012 by the NY Times and other media. Courses that are offered online by renowned universities (originally) free of charge and open for anyone to join.

O

OpenCourseWare (OCW) Courses created by universities and freely distributed on the Internet. A prominent example is MIT OpenCourseWare. OpenCourseWare can be considered to be one of the predecessors of MOOCs.

Open Educational Resources (OER) Learning materials that are licensed in a way that the end user is free to own, share, and modify them legally.

openHPI The MOOC platform of the Hasso Plattner Institute.

Open Learning Initiative The OpenCourseWare offer bey the Carnegie-Mellon university.

P

Pavlov, Ivan. Russian researcher. Best known for his experiments with bells, dogs, and food.

Papert, Seymour. American computer scientist and educator.

Pedagogy , the method and practice of teaching children. See also andragogy.

Piaget, Jean. Swiss psychologist and epistemologist.

Positive reinforcement see Reinforcement.

Problem-based learning (PBL) student-centered approach to learning. Instead of "being instructed" students learn by actively solving an open-ended problem. Skills such as team collaboration, communication, creativity are at least as important as the actual expertise in a certain topic area to successfully deliver a solution.

Problem-oriented learning see Problem-based learning.

Prompting The art of writing instructions for generative AI tools.

R

Rationalism epistemological theory that sees reason as the source of knowledge. Rationalists claim that knowledge is primarily innate and the intellect can derive logical truths without having to experiment and prove the hypotheses as the the empiricists claim.

Reactions Comments on given artifacts, such as texts or videos, etc. E.g. commented literature, game walk-throughs, etc.

Reinforcement Central element of behaviorism. Desired behavior is rewarded with food, praise, chocolate, gamification badges, etc. (positive reinforcement) or the absence of punishment or unpleasant reactions (negative reinforcement). Undesired behavior is punished with the removal of pleasant stimuli, such as "no TV tonight" (negative punishment) or the application of unpleasant consequences, such as noise or beating.

S

Scalability In the context of e-learning, scalability is the ability to provide the same, or at least a similar, learning experience to 10 learners as to 10.000 learners.

Self-Regulated Learning Learners set their own goals and also monitor and regulate the progress in achieving their objectives.

Siemens, George. Canadian psychologist and together with Stephen Downes inventor of the connectivist learning theory.

Simulations Imitation of a process that exists, or could exist, in the real world.

Skinner, Burrhus Frederic. American psychologist and behaviorist. Articulated the reinforcement theory.

SOLE Educational model developed by Sugata Mitra. SOLE emphasizes minimally invasive methods of teaching. Students are encourage to use collaborative skills, and active problem solving techniques.

Solomon, Cynthia. American computer scientist and educator.

T

Tele-TASK Video recording system and video portal. Predecessor of openHPI.

Thorndike, Edward Lee. American psychologist and behaviorist.

Turtle graphics A vector graphics engine in which the cursor is visualized by a small turtle figure. The turtle can be programmed to move forward, turn around etc. The turtle also has a pen, which can have different widths, colors, etc. Next to the virtual turtles, there were also actual turtle shaped robots which were used in educational contexts. (see also Cynthia Solomon, Seymour Papert, Logo)

U - Z

Virtual reality (VR) Simulated experience using pose tracking and 3D headsets to allow the user to immerse in a virtual world.

Vygotsky, Lev. Soviet psychologist.

Watson, John Broadus. American psychologist who established behaviorism as a psychological school.

Wenger, Etienne. Swiss educational theorist and practitioner.

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