Enable students to acquire new hands-on software experience using the modular teaching assistance system

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Abstract: As long as learning management systems (LMS) are offering a predefined set of functionalities and could be not flexible enough for changes and improvements. Especially, it could be difficult to enable usage of a new software tool, which is required only by a special teaching curriculum and when change requests are relevant only for a particular course of study. Thus, incorporating innovative technologies into existing learning platforms could be a very challenging task. However, this problem can be addressed through the latest IT technologies in combination with innovative teaching methodologies. In this work, students are supported in acquiring better hands-on experience using real software in real scenarios. It is done in a way that such scenarios and tools are directly embedded into a teaching curriculum. The introduced modular teaching assistance system helps to simplify installation, configure, and data wrangling phases and enables students to focus on primary tasks, which is solving scenario problems, rather than spend valuable time and deal with software as such. On one hand, the system takes care of various problems with installation and configuration for students, on the other hand, the system is modular and enables adaptation of an innovative teaching experience by being flexible and extensible by design.

Keywords: Teaching; CEMIS; Teaching Platform; Software

1 Introduction

Digitization and Industry 4.0 are both buzzwords that have been used for almost a whole decade [KW21]. In addition, the digital transformation processes continue to force companies in looking for new ways to reconfigure and redesign their business strategies [Sc17]. In this context, companies often ask themselves how they have to implement the technological change in order to remain successful with their products and services without jeopardizing their economic success. With a view to further future topics, the implementation of sustainability aspects in the business strategy are essential. Reducing CO_2 consumption not only takes place on a product level (e.g. *What materials should be use for production or how it should be manufactured, packed and shipped?*). With regard to the business strategy and operational processes, sustainability is a company wide reconfiguration task.

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At this point research and education comes into foreground and have an important impact for the mediation of a sustainable mindset for companies in times of the ongoing digital transformation. At the University of Oldenburg, different sustainability related courses are offered and addressed to students with different academic backgrounds (e.g. Business Informatics or Sustainability Economics and Management). *Teaching sustainability in universities is challenged by the rapidly changing requirements and standards in the field of sustainability [...]* [Ra17]. The Covid-19 pandemic showed, that digitization in companies and at the educational institutions is not yet completed and far away from being implemented in a way, which will fulfill requirements. A number of steps must be performed to adapt teaching processes for new circumstances, which includes a teaching of practical skills as well as teaching an ability to combine theory and practice to work with real software tools and real scenarios [Ga20]. The requirements to switch to working at home with the necessary processes and equipment (e.g. workstation, video conference systems, working place, etc.) is a challenge for all involved participants. The changeover from presence teaching and face-to-face meetings to digital online teaching requires more advanced and innovative concepts, methodologies and tools in order to support self-study of the students and facilitate the teaching of practical knowledge [KB21]. For this reason, the entry barriers to use any required software tool must be kept as low as possible for the students.

In this paper, we look at the challenge for students who must be enabled to obtain not only theoretical knowledge but also practical knowledge. As an example, sustainability course materials will be used. For this reason, we developed a software tool to support students in the context of self-learning. Within the course *Sustainability Informatics* at the University of Oldenburg research oriented teaching methods will be used to empower students hands-on experience research intentions. One of the teaching core tasks inside the course is to set up a sustainability report. This will be also the use case of this research contribution. For that reason, sustainability data needs to be analyzed and Key Performance Indicators (KPIs) have to be set up. Usually, multiple software tools and systems will be used for this purpose and must be installed. This could be a time-consuming and frustrating experience for students in case something does not work (e.g. the installation process fails). Also, students could have the different technical knowledge and need to be supported in different ways. Our provided solution takes up this problem.

The modular teaching assistance system using for teaching hands-on experience offers a centralized infrastructure.

The rest of the paper is structured as follows: Section 2 describes existing online teaching platforms and the research-oriented teaching approach in the course *Sustainability Informatics*. Section 3 characterize challenges in teaching hands-on experience. The following section 4 shows our provided solution and the architecture of the software tool. Section 5 discusses the use of the tool based on a constructed use case. Finally, section 6 concludes the paper.

2 Online Teaching Platforms and Research-oriented Teaching Methodologies

2.1 Online Teaching Platforms

There are a whole set of software systems, which are used in teaching and for teaching. For instance, such systems could offer students virtualized laboratories to run experiments [DDI17] odor support generic online-teaching processes. E-Learning platforms such as Moodle[4a], Stud.IP[4b], Canvas[4c], Open EdX[4d], Oppia[4e], ELMS Learning Network[4f] and many others are primary used to deliver content to the student and establish teacher-to-student communication. Such platforms are also known as a learning management system. This kind of platforms are sophisticated and provide a huge set of features and functionalities, which are designed to address a teaching process as a whole. Following Elabnody theories, several features of LMS support students (or further users) in their learning paths: tracking and reporting, assessment and testing tools, communication and collaboration or mobile learning [El16]. Despite being very sophisticated such platforms are centrally managed and offer multiple predefined set of features for online teaching experience.

As long as these platforms offer a predefined set of functionalities, they are not flexible enough for changes and improvements. Especially, it could be difficult, when change requests are only relevant for a particular teaching curriculum. Thus, it could be a challenging task to incorporate the teaching of innovative technologies into existing learning platforms. This problem can be addressed using technology or teaching methodologies, see the section 2.2. For instance, for teaching in-memory database and their applications in real-world driven applications various approaches such as bachelor or master theses, seminars, projects groups were performed [Dm16]. There are also teaching curricula, which require the usage of specialized software tools as such. For instance, using virtual laboratories to simulate experiments in natural sciences could be a helpful resource to facilitate knowledge acquisition by students [DDI17, Al14]. In the case of LMS, despite existing functionalities that could be extended via diverse plugins and modules, even this couldn't be a proper solution to the problem, as long as such changes are applied to the whole teaching system at once and influence all participants, which is not always desirable and sometimes even not possible.

The introduced in the paper modular teaching assistance systems help students to acquire hands-on experience and flattens the learning curve by taking care of installation, configuration, and data wrangling phases. The system offers to each student a personalized workspace[5] with an extensible number of software modules to be used (e.g. database, tools to create dashboards, etc.). The solution also enables to adapt teaching curriculum for a

[4] (a) https://moodle.org/ (b) https://studip.de/ (c) https://github.com/instructure/canvas-lms (d) https://open.edx.org/ (e) https://github.com/oppia/oppia (f) https://github.com/elmsln/elmsln

[5] This particular workspace consists of multiple modules and could be seen as a personalized sandbox for individual experiments

new software tool, because the modularity of the teaching assistance systems is part of its architecture.

2.2 Research-oriented Teaching Methodologies

The purpose of higher education at universities is to support and sensitize the students thinking and labor in academic behaviors. Educational institutions such as universities have the responsibilities to guarantee the highest standards of scholarships and in particular, the conceptual development of innovative, modern research methods. This may help students to bring their research methods and skills such as scientific research, writing, spelling and teamwork as a process in mind by using new approaches [Ra17]. This reflects also Humboldt's idea of a modern and future oriented university. At the University of Oldenburg different research oriented teaching programs such as FLIF+ [6] tries to increase the standards of student self-oriented education by connecting research and learning concepts. Following this point of view, research oriented teaching and learning can be seen as an enabler to support students and also teachers in gaining scientific knowledge and also teaching hands-on experience. In times of a global pandemic, flexible learning methodologies as described in [ASAEKB21]and the strengthening of students self-responsibility could be a key factor.

Within the course *Sustainability Informatics* a research oriented and flexible teaching approach as described in [WHP20] will be used. On the basis of the overarching task of preparing a sustainability report, the students formulate independently own research questions, conduct and evaluate the findings and finally present the findings in a manner they prefer. Our developed software tool supports the students during their work and causes that the students are able to concentrate on the essentials - the analysing, interpretation and presentation of findings.

3 Challenges in Teaching Hands-On Experience

As it was mentioned earlier, to support students in getting their own hands-on experience the real tools and real scenarios (or simplified versions of such) should be integrated into a teaching curriculum. The primary student learning objective in such cases is not only to get familiar with a particular software tool, but also apply acquired theoretically knowledge. In most of the tutorials for getting such type of hands-on experience the very first step would be to install and configure the required software tool and get yourself familiar with it. Of course, an ideal case would be to use pre-installed software, which utilizes hardware located in a laboratory room. However, this particular option is not always feasible and may even not be applicable, for instance in the case of an online course. Thus, the very first step

[6] FLIF+ in German stays for *Forschungsbasiertes Lernen im Fokus Plus*. URL - https://uol.de/forschen-at-studium

should be simplified as much as possible, to help students to overcome initial problems on a learning curve much easier. In addition, students can concentrate on their essential steps of the research oriented learning procedures. A process of a software installation could be simplified and even sometimes automated (e.g. using software tools such as Vagrant[7], Docker[8] or any other available virtualization approach). These virtualization tools are also useful for teaching a number of subject in computer engineering curricula (e.g. computer networking, operating systems, etc.) [Ci21, Hu19]. However, as long this particular step on the way to get a hands-on-experiments represents a clear "blocker" it is crucial to accomplish this step as fast as possible without much straggle on the side of a student. The problem with any installation gets even worse, when a particular teaching curriculum requires multiple software tools and systems to be used. As long as the installation should be conducted by the student, it could lead to a frustrating experience. Thus, instead of spend his/her time on a task, students could struggle with the installation process of a new software tool. There are a number of ways how to overcome or at least minimize aforementioned problems – (a) provide very detailed installation and configuration instruction; (b) automate installation and configuration; (c) use cloud-based or comparable 3rd party services; (d) user own dedicated infrastructure. Fig. 1 provides a relative comparison between given 4 variants with respect to user friendliness and control over provided tools for teaching hands-on-experience.

When variant (a) is applied, it should be mentioned that maintaining all these instructions, manuals, and setup tutorials from year to year could be a tedious task. That leads to additional workloads for teaching staff. This overhead happens due to software changes and updates. Students usually do not have a homogeneous hardware and software setup of their hardware, which is supposed to be used in this particular variant. It also must be noticed, that adding new software tools to the existing curriculum may lead to unforeseeable complications on the side of the student's hardware.

Variant (b) could help to overcome issues of the variant (a), but still got own pre-requisites. There are two main pre-requisites – hardware setup that fits and basic knowledge of bash/command-line scripting. The last is crucial, because it is usually not possible to test and automate all possible variants, and instructions for script adjustments are provided.

Variant (c) could solve all issues of the (a) and (b), but major drawbacks of this particular variant are the following – request official contractors to offer 3rd party solutions and in case of community or academy licensing, it could be that some parts of the tools and systems used within the study will be deprecated/removed by the vendor without any notifications. Basically, with variant (c) one has less control over the infrastructure in comparison to the (a) and (b). The variant (d) could all aforementioned issues but requires that "technical complexity" of the installation and configuration will be hidden from the students and they will be offered only access to required tools upon request. Besides this variant solves issues of the variants (a), (b), and (c), it also allows instructors to maintain technical complexity for the students. For instance, in the case when a database instance should be used with

[7] https://www.vagrantup.com/
[8] https://www.docker.com/

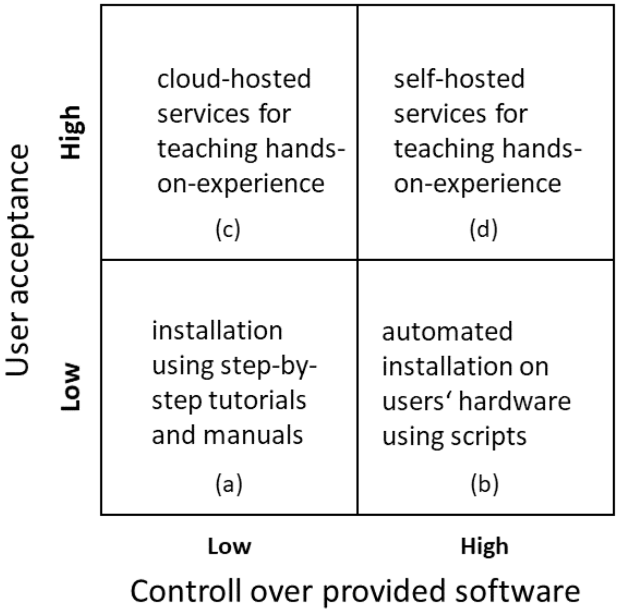

Fig. 1: Provides a comparison between 4 given variants ((a), (b), (c) and (d)) with respect to the user acceptance and control over provided software for teaching an hands-on-experience

particular data inside it, this data could be pre-imported, which will allow students to directly start working with data and overcome typical strangles with a data import process.

This contribution implement the variant (d) for the course *Sustainability Informatics*. It demonstrates how it is implemented and how the solution can be extended with new tools. The work also demonstrates, how such solution helps to maintain complexity of the hands-on-expertise exercises of a particular curriculum.

4 Architecture and Implementation

The *mta-system* (**m**odular **t**eaching **a**ssistance **system**) consists of 4 main components – mta backend, reverse proxy, local Docker Images registry and personalized workspaces. The mta backend is responsible for communication with user, creation of services in form of predefined Docker containers. The crucial part of the mta backend is called *integration utilities*. They are responsible for creation of individualized services and configuration of the reverse proxy. The reserve proxy is responsible for managing incoming HTTP/HTTPS requests for reach offered services and proxy these request towards requested service. The Docker Images Local Registry is basically a collection of pre-created Docker images, which are used as base to create user specific Docker containers upon request. The workspace of a user consists of a number of encapsulated services individually run for each user. Usually, one Docker container is created for each user and services. However, it also could be that one Docker container is shared by multiple users. It order to save resources on the server, running containers will be stopped at some point and users will have to “start” them manually in order to resume their work on the task. This process is also handled by the backend part of the mta-system. The architecture of the system showed on Fig. 2. The latest version of the source code of the mta-system can be found in the public git-repository[9]. The mta-system is modular by design. It means that a new service in form of a Docker container can be easily added and hosted by the system.

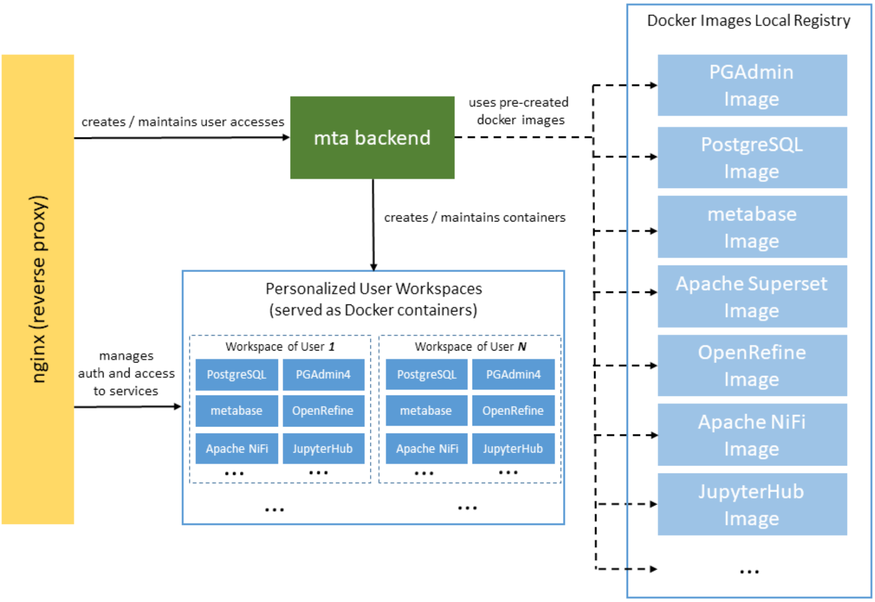

Fig. 2: Demonstrate the architecture of the hands-on experience teaching assistance system for students. It uses *nginx* as a reverse proxy to manage HTTPS inquiries to various services (e.g. *metabase*). The mta-system uses special Docker images to create user-specific services based on them, it also manages user access and running containers[9]

However, the drawback of such an approach is that only online-based tools and services could be used to get hands-on experience. This leads to the point that in some cases tools with a limited number of features could be used, which could be acceptable, as long as such tools are normally dedicated to demonstrate and teach core principles, rather than provide a detailed introduction of a particular technology.

The system works as follows: students register themselves in the modular teaching assistance

[9] The mta-system implementation can be found here - `https://github.com/vdmitriyev/mta-system`

system. After registration was successfully completed, access to various services should be provided. Theses services are offered and accessed via the mta-system. The typically user view on the system in shown on Fig. 3.

Fig. 3: Demonstrate how a particular service (e.g. OpenRefine) could be accessed in the user interface. Typically, the user interface of the system provides credentials, access links and further required instructions

However, not all services are accessible and visible to the students at once. It is not always necessary, because not all services are used at the same time. Thus, services could be accessed on demand. Demand for a particular service could be coupled with a teaching curriculum. For instance, it could be that a database with a dataset should be immediately accessed by students to start working on a use case, but a visualization tool could be developed later on when the first parts of the use case would be completed.

5 Use Case and Discussion

One of the given tasks in the course *Sustainablity Informatics* is to analyze material flows. The mta-system used the freely availed implementation of the web-based Sankey diagram called "SankeyMATIC (BETA)'. Fig 4 shows an example of a diagram with a flow of a household budge. The "Sankey diagram" solution is deploy with a Docker container and encapsulated into a service on the mta-system to be delivered upon request to each student individually.

Besides using web-based Sankey diagram, other use cases may require an import of a dataset into a database for further analysis using SQL. For this purpose, the PGAdmin4[10] tool was used by students to import required data. Beside that, the mta-system provided a specialized data import feature out of the box, to reduce the import overheads. Such feature could be useful, if an import of a data should not be a part of a teaching assignment. The mta-system offered a DBMS (e.g. PostgreSQL) to store required datasets to each student as well. As long as databases do not usualy offer visualization capabilities, further visualization software (e.g. Sankey Diagram, business intelligence visualization tools like Apache Superset) were offed to students via the mta-system. This allows students to design and visualize desired

[10] pgAdmin 4 is a management tool for PostgreSQL database- https://www.pgadmin.org/

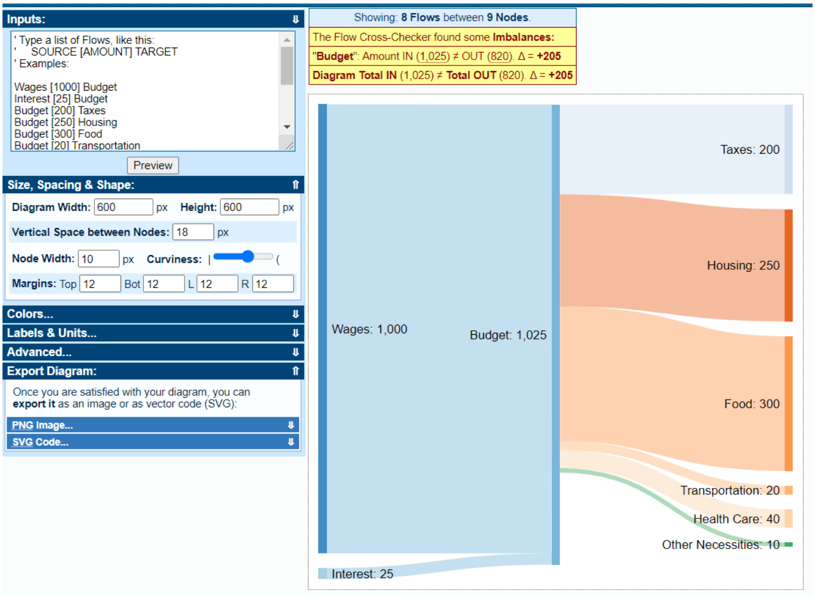

Fig. 4: Shows the web-based implementation of the “sankey diagram”. The diagram shows an example of a household budge flow. The “sankey diagram” solution is deploy using the special Docker image and served via the mta-system as a service

reports and dashboards, using any given data. For advanced classes, which may require programming experience, hosted within JupyterHub an interpreter of a Python programming language and a predefined dataset (e.g. machine-readable sustainability report) was offered. It let students to run simple analysis and create simple prediction model (e.g. estimate predefined key performance indicators (KPIs) for a particular sustainability report and dashboard).

It also has to be mentioned, that the mta-system offers an interface to maintain individualized workspaces. It allows students to start/stop offered within the system services, which leads to better utilization of the server resources (e.g. services that are not used by a student will be stopped after a while, but could be always be resumed).

In general, students that participated in offered to them assignments and used the mta-system for this purpose performed slightly better during the final examination in comparison to other students, who didn’t use this option. It was measured by comparing the final scores of the students who used the mta-system with other of the students. However, it has to be mentioned that it happened due to the deeper understanding of the theoretical foundation and deeper involvement in teaching process. Which was possible due to practical assignments. Usage of the system was optional because instructions to care out installation locally (on own PCs) for a required software tool were provided as well. Nevertheless, the usage of the mta-system allowed to simplify an overall hands-on software experience process for students and helped teaching faculty members to gain more control over this process.

6 Conclusion and Outlook

As it was mentioned in the work most of the learning management systems offer a predefined set of functionalities. Extending functionality of such systems only for a particular teaching curriculum could sometimes be not feasible. For instance, because required changes could only be relevant for a particular study course. In this work, the mta-system was introduced, which supports students in acquiring better hands-on experience using real software in real scenarios. The mta-system was directly integrated into a teaching curriculum, as an additional software tool and not as a replacement for LMS. The introduced modular teaching assistance system helps to simplify installation, configure, and data wrangling for students. It also simplifies software tools support process, which is usually carried out by teaching faculty member. On one hand, the system overtakes problems with installation and configuration, on the other hand, the system was designed to be modular and to enable adaptation of an innovative teaching experience. The mta-system is modular by design, thus a new tool required by a teaching curriculum could be potentially integrated and used. For example, another tool that can be potentially integrated is stplanr [LE18]. stplanr is a package for sustainable transport planning with R and its geo-visualization could be potentially enabled for further development from students on the mta-system. The system will be further developed and used in other teaching curricula. Also, further software tools will be adapted to be used in container-driven individualized workspaces.

Bibliography

[Al14] Ali, Numan; Ullah, Sehat; Rabbi, Ihsan; Alam, Aftab: The Effect of Multimodal Virtual Chemistry Laboratory on Students' Learning Improvement. In (De Paolis, Lucio Tommaso; Mongelli, Antonio, eds): Augmented and Virtual Reality. Springer International Publishing, Cham, pp. 65–76, 2014.

[ASAEKB21] Ait Si Ahmad, Hana; El Kharki, Khadija; Berrada, Khalid: Agility of the Post COVID-19 Strategic Plan on Distance Learning at Cadi Ayyad University. An Opportunity Towards a Total Digital Transformation of the University. In (Agrati, Laura Sara; Burgos, Daniel; Ducange, Pietro; Limone, Pierpaolo; Perla, Loredana; Picerno, Pietro; Raviolo, Paolo; Stracke, Christian M., eds): Bridges and Mediation in Higher Distance Education. Springer International Publishing, Cham, pp. 199–213, 2021.

[Ci21] Cisternino, Antonio; Ducange, Pietro; Tonellotto, Nicola; Vallati, Carlo: Leveraging Cloud Infrastructures for Teaching Advanced Computer Engineering Classes. In (Agrati, L.; Burgos, D.; Ducange, P.; Limone, P.; Perla, L.; Picerno, L.; Raviolo, P.; Stracke, Ch., eds): Bridges and Mediation in Higher Distance Education. Springer International Publishing, Cham, pp. 256–270, 2021.

[DDI17] Daineko, Yevgeniya; Dmitriyev, Viktor; Ipalakova, Madina: Using virtual laboratories in teaching natural sciences: An example of physics courses in university. Computer Applications in Engineering Education, 25(1):39–47, 2017.

[Dm16] Dmitriyev, Viktor; Wagner vom Berg, Benjamin; Stamer, Daniel; Sandau, Alexander; Giesen, Nils; Siewert, Jens; Marx Gómez, Jorge: Teaching In-Memory Computing and Big Data Related Skills at University. In: Multikonferenz Wirtschaftsinformatik (MKWI) 2016 (Brand II). volume 2, pp. 729 – 740, 2016. SBN 978-3-86360-132-4 (Druckausgabe, Gesamtwerk).

[El16] Elabnody, M.: A Survey Of Top 10 Open Source Learning Management Systems. International Journal of Scientific & Technology Research, 5:7–11, 2016.

[Ga20] Gamage, Kelum AA; Wijesuriya, Dilani I; Ekanayake, Sakunthala Y; Rennie, Allan EW; Lambert, Chris G; Gunawardhana, Nanda: Online Delivery of Teaching and Laboratory Practices: Continuity of University Programmes during COVID-19 Pandemic. Education Sciences, 10(10):291, 2020.

[Hu19] Huang, Albert: Teaching, learning, and assessment with virtualization technology. Journal of Educational Technology Systems, 47(4):523–538, 2019.

[KB21] Kővári, Edit; Bak, Gerda: University Students' Online Social Presence and Digital Competencies in the COVID-19 Virus Situation. In (Agrati, Laura Sara; Burgos, Daniel; Ducange, Pietro; Limone, Pierpaolo; Perla, Loredana; Picerno, Pietro; Raviolo, Paolo; Stracke, Christian M., eds): Bridges and Mediation in Higher Distance Education. Springer International Publishing, Cham, pp. 158–169, 2021.

[KW21] Kagermann, Henning; Wahlster, Wolfgang: Digitalisierung der Produktion: Zehn Jahre Industrie 4.0. In: Frankfurter Allgemeine Zeitung. 29-03-2021.

[LE18] Lovelace, Robin; Ellison, Richard: stplanr: A Package for Transport Planning. The R Journal, 10(2):7–23, 2018.

[Ra17] Rapp, Barbara; Solsbach, Andreas; Gizli, Volkan; Janßen, Christian: Teaching ICT-based Sustainability Reporting by Using a Research-oriented Teaching Concept. In (Daniel, Nukpezah; Mensah, Adelina; Ofori, Benjamin; Rapp, Barbara; Marx Gómez, Jorge, eds): Dialogue on Sustainability and Environmental Management. Shaker Verlag, Düren, pp. 1–8, 2017.

[Sc17] Schallmo, Daniel; Rusnjak, Andreas; Anzengruber, Johanna; Werani, Thomas; Jünger, Michael, eds. Digitale Transformation von Geschäftsmodellen: Grundlagen, Instrumente und Best Practices. Springer Fachmedien Wiesbaden, Wiesbaden, 2017.

[WHP20] Wulf, Carmen; Haberstroh, Susanne; Petersen, Maren, eds. Forschendes Lernen: Theorie, Empirie, Praxis. Springer Fachmedien Wiesbaden, Wiesbaden, 2020.