Co-funded by the Erasmus+ Programme of the European Union

STEAM UPGRADE

Upgrading pre- and in-service teachers' digital skills with online STEAM hands-on training modules

IO6 User guidelines for digital skills upgrading in STEAM teaching

Janika Leoste, Maire Tuul, Sirly Väät, Kristóf Fenyvesi, Luis Pastor, Peter Galambos, Éva Kovács, Frode Skarstein, Branko Andjic

PROJECT PARTNERS

Tallinn University
University of Jyväskylä – Finnish Institute for Educational Research
JKU Linz School of Education
University of Stavanger
Universidad Rey Juan Carlos
MaxWhere
craftbot

1. The structure of the digital resources of the STEAM UPGRADE on-line training modules

Digital resources are indispensable for a modern teacher as they are needed to support up-to-date teaching and learning methods (Hendricks, 2019)[1]. However, a lot of teachers still don't benefit from using them because digital resources are not a part of their everyday classroom practices (Wang, Tigelaar & Admiraal, 2019)[2].

Compared to the worksheets and quizzes that are designed for paper mediums, digital resources offer richer experiences for students. Modern digital educational resources are mostly interactive, making it possible for the resource to "react" to students' actions by either choosing the correct teaching path, providing students with feedback, or carrying out actions that are usually done by a human teacher. Besides being interactive, educational resources quite often include various types of elements with the purpose of providing students with optimal learning experience. It is possible to include videos (for example, to demonstrate how wolverines live in their natural habitat), audio (for example, to demonstrate a correct pronunciation of French words), quizzes (allowing students to enter their responses) – but an educational resource can also include many different types of elements at once. Read more about properly designing interactive educational resources here: ctl.wiley.com/creating-interactive-content. Advanced interactive resources can even provide teachers with automatic feedback about student progress. There are several online environments for creating and using interactive learning resources, for example H5P (h5p.org), GeoGebra (www.geogebra.org) or LiveWorksheets (www.liveworksheets.com/worksheets/en).

Whenever you want to share some digital resources with other people (for example, with students or with other teachers), you would need to find the right strategy for doing this.

Copyright. First of all, you would need to be sure if you are allowed to share the resource with other people at all. This is easy to decide with self-created documents that do not contain works of

[1] Hendricks, G. P. (2019). Connectivism As a Learning Theory and Its Relation to Open Distance Education. Progressio: South African Journal for Open and Distance Learning Practice, 41(1), no. 1, Dec. 2019. https://doi.org/10.25159/2663-5895/4773

[2] Wang, J., Tigelaar, E. H. D., Admiraal, W. (2019). Connecting rural schools to quality education: Rural teachers' use of digital educational resources. Computers & Education, 101, 68-76. https://www.researchgate.net/publication/344853008_Rural_teachers%27_sharing_of_digital_educational_resources_From_motivation_to_behavior

other authors (for example, all the pictures are made, and all the text is written by yourself). However, if the shared resource is made by other people or includes works of other people, you would need to either ask for their written permission (this is something you can do when you personally know the authors), or check and fulfill the copyright license conditions. These conditions may include various limitations or duties. For example, you could only produce a limited number of copies of the work, use the work in only some certain areas or during a certain timeframe – or you might be obligated to pay a certain amount of money to the authors or their representatives. In some countries, the law allows you to use otherwise copyrighted work for non-commercial purposes in educational establishments.

Sharing. Let's get back to the process of sharing a digital educational resource with others, assuming that the copyright part is taken care of. A digital educational resource can be a file in your computer, such as a Microsoft Word document or PowerPoint presentation. These types of files can be easily shared as email attachments. Read about sending e-mail attachments with Gmail: support.google.com/mail/answer/6584. Read about sending e-mail attachments with iPhone: support.apple.com/guide/iphone/add-email-attachments-iph8580f163b/ios. It is impractical and sometimes even impossible to send resources (such as movies or interactive worksheets) with an email. Also, there are other scenarios[3] where it would be more feasible to share educational resources as hyperlinks, instead of email attachments. In these cases you should have the resource available on the Internet (for example as a Youtube video or H5P quiz) and you would only need its hyperlink that can be shared either through email, Facebook messenger, or through some other channels. For example, read about sharing H5P content: documentation.h5p.com/content/1290705800772641378, and about sharing Google Drive documents: support.google.com/docs/answer/2494822.

Over time when you have built up a reasonable number of resources, you would perhaps like to share your works through a dedicated repository, instead of emailing the resources one-by-one to your students or colleagues. Repositories can improve access to your digital learning resources and allow you to disseminate your work beyond the direct boundaries of your classes or schools. Setting up a repository allows students to more easily access learning materials but also enables your colleagues to both learn from and contribute to your resources. Starting a simple repository is quite easy. First of all, in many educational platforms you can use your own account as a repository of your resources. But creating a separate repository on your webpage is also easy. For example, to create a H5P repository you would only need to (1) use the H5P authoring tool h5p.org/testdrive-h5p; (2) add a plugin h5p.org/getting-started to your existing publishing system – WordPress, Moodle or Drupal; and (3) add materials.

STEAM Upgrade includes 3 online training modules, each for one of the following groups: pre- and inservice teachers of early childhood, primary education, and secondary education. These materials are available in the following languages and links:
In Estonian: https://www.geogebra.org/m/bdamvpxt
In Finnish: https://www.geogebra.org/m/eygxvzqj
In Norwegian: https://www.geogebra.org/m/ka6cxbhb
In Spanish: https://www.geogebra.org/m/ctscyjjj

---

[3] See Garg, S. (2021). Email Attachments vs File Links?
https://medium.com/cloudfiles/email-attachments-or-file-links-6d40895b2de2

In German: https://www.geogebra.org/m/axux2rh4
In English: https://www.geogebra.org/m/mpznnga7

Each module consists of four activities, each following a pre-established structure. Passing one training module will take approximately 50 hours (12 hours per activity), equaling 2 credits. These hours include familiarizing oneself with the materials and additional resources, solving the activity, filling in the SELFIE questionnaire[4], and analyzing one's learning results. These activities should be carried out during at least four weeks in order to have enough time to test the newly acquired skills in real-life situations at school (with students, colleagues or peers). The structure of activities employs the micro-learning learning strategy that aims at quickly closing various skill and knowledge gaps. Micro-learning offers a flexible, targeted way to help people develop the knowledge, skills and competences they need for their personal and professional development[5].

Each training activity is divided into several sections (see below), allowing learners to appropriate the learning contents in up to 45 minutes. The design of the sections takes into account the "Tell, Show, Ask, Do" didactical method outlined by Merrill (2002)[6] that is based on the idea that effective technology learning requires learners to (a) become engaged in solving real-world problems; (b) use existing knowledge as a cornerstone for constructing new knowledge; (c) demonstrate new knowledge; (d) apply new knowledge; and (e) integrate new knowledge to their overall knowledge base. To this end, the sections include texts or slides ("Tell"), videos, animations or images ("Show"), interactive question sets or educational learning apps ("Ask"), and instructions for hands-on activities that could involve building prototypes, collecting and analyzing data, searching for information on internet, presenting results, or playing games that make use of VR or AR technologies. These elements are presented as usage instructions for STEAM kits and virtual environments, hands on examples for integration, self-assessment tasks, or virtual laboratory workspace, and are realized through Google Drive and MaxWhere, connected by a challenging story.

A typical learning activity is made of the following sections:

- General information. This includes title, links to the material in the GeoGebra or Google Drive format, abstract, keywords and a resource list. The purpose of this section is to provide trainees with quick information about the selected training activity, its purposes and requirements.

- Explanation of the background of the topic and its importance. This section helps trainees to recognize and understand the context of the learning material and to validate its usefulness.

- Description of the activity, including solution for the activity (including text, video or image). This section helps trainees to familiarize themselves with the activity and to see how the successful performance of the activity would look like.

---

[4] SELFIE (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies) is a free tool designed to help schools embed digital technologies into teaching, learning and assessment. European Union. SELFIE. https://education.ec.europa.eu/selfie

[5] European Union. A European approach to micro-credentials. https://education.ec.europa.eu/education-levels/higher-education/micro-credentials

[6] Merrill, M. D. (2002). First Principles of Instruction. *Educational Technology Research and Development*, 50(3), 43-59.

- Suggestions for enhancing the activity (including text, video or image). Here are some examples on how to make the activity more engaging to students or how to adapt the activity to various needs of different student groups.

- Recommendations for using the activity with learners with special needs (including text, video or image).

- Knowledge test that includes several multiple choice questions about the topic and activity. The purpose of this activity is to let trainees (and later students) to assess their learning outcomes.

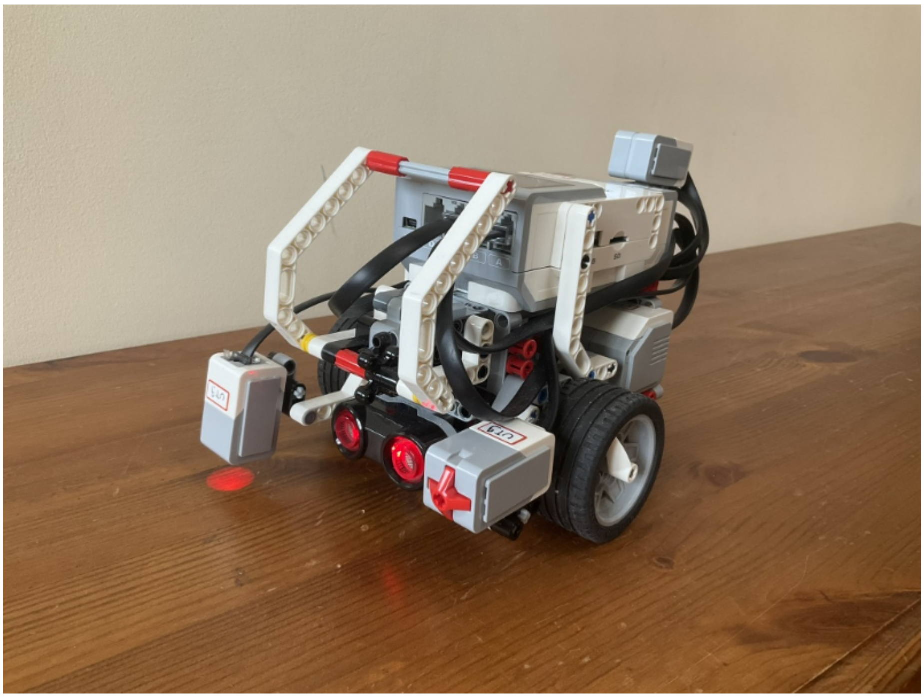
- Suggestions for conducting an alternative activity (including text, video and image). The purpose of this section is to help teachers understand alternative approaches to the activity and demonstrate how to replace one tool with another.

- Guidelines for conducting a related workshop (including text, video and image). Here it is described what is needed for conducting a workshop related to the activity, including planning, resource list, etc.

- References, credentials and license information. Here the used literature is listed and information about authors and usage conditions is provided.

Table 1. A section structure example.

Section structure	***Example***
Title	A prototype of the **self-driving bus**. Based on the LEGO Mindstorms EV3 robot *The topic here is the self-driving bus and we use a LEGO set to prototype it.*
Geogebra link	https://www.geogebra.org/m/gj7ft2qh

Image	
Abstract	This activity gives an overview of using the distance sensor of the LEGO Mindstorms EV3 robot. The aim of the activity is to build a self-driving bus prototype by using the LEGO Mindstorms EV3 robot, and to help understand the underlying principles (on the very primitive level) that guide the behavior of self-driving buses.
Keywords	Self-driving bus, LEGO Mindstorms EV3, prototype, robot
The resource list	One LEGO Mindstorms EV3 robot for each team (2-4 members) of students; one controlling device (iPad, Android tablet, Windows 10 PC or Macintosh computer) for each student team, with the LEGO EV3 Classroom app installed.
The background and importance of the topic	Self-driving buses are a specialized form of self-driving cars. The first experiments with self-driving cars date back to the 1920s, but the very first semi-automatic car was developed in 1977, in Japan. …..
The activity description	In this activity we are using the LEGO Mindstorms EV3 robot to imitate a self-driving last-mile bus that drives from one destination to another and back (for example, from the school to the railway station and back)....
The activity solution	The program is formed of three logical blocks that are started simultaneously when the program is run. When you build the

	program, follow the example and place all three blocks to the same program page. When executing the example program…
Enhancing the Activity	Try modifying the program to make it more interesting or meaningful to your purposes. Make use of other sensors and robot features (e.g., try line following, change the color of the robot's LED lights, let the robot show an image or make different sounds).
The Knowledge Test	When was the idea of self-driving cars first introduced? in 1920s in 1550s in 2012
For special needs' learners	Students who are sensitive to sounds could use headphones to turn down the sound of the robot. Students who are sensitive to colors could use LEGO bricks of their favorite color and/or LED lights. Students who are sensitive to flashing lights (epilepsy) should be able to use constant light. To support students with vision problems, it should be ensured that the room is adequately lit.
Alternative activity	
Conducting a Workshop	This STEAM learning activity workshop is addressed to familiarize pre- and in-service secondary school teachers with Educational Robots (ER) as didactic tools. In particular, this activity introduces hardware and software ER related concepts to teachers without any previous robotics experience, providing them with some examples and discussions about actual classroom activities.
References, project credentials and license information	Gibson, J. (2022). Autonomous Buses Will Revolutionize Public Transportation, but at What Cost? *GoGoCharters*, gogocharters.com/blog/autonomous-buses-will-revolutionize-public-transportation-cost/ LEGO EV3 Classroom app. https://education.lego.com/en-us/downloads/mindstorms-ev3/software#downloads Line Detection with LEGO Mindstorms EV3. https://education.lego.com/en-us/lessons/mindstorms-ev3/line-detection#continue

2. Setting up the infrastructure of STEAM labs for universities

The importance of science, mathematics, engineering and technology, as one of the central aims of modern education, became acknowledged in the 1990s when the approach of grouping these academic disciplines together was introduced as SMET. A decade later, the acronym was supplemented with the letter "A" that represents either agriculture, architecture, aerospace – but most commonly, art. As of today, the STEAM approach in education is seen as a way of guiding students to study professions that, on the one hand, are useful for the society, but, on the other hand, require skills and knowledge that are closely related to STEAM disciplines. For this end, the STEAM approach in education aims at integrating different disciplines in a meaningful way, preparing students for their future professions. The STEAM approach is being promoted by various stakeholders. For instance, producers of educational technology have developed learning materials and teacher guidelines to use their products for STEAM teaching and learning. One of the examples here is the LEGO Academy that uses constructionist learning[7], gamification[8], and design thinking[9] in the lesson plans it provides.

Although STEAM is a promising approach in education, it is not as widespread as it could be. It is difficult to integrate technology, art or science with other disciplines due to dense syllabi, lack of allocated paid lesson time, and the time consuming nature of STEAM teaching (due to using problem learning, project learning, discovery based learning, and other modern learning approaches). In addition, the current assessment models for student learning are not useful in indicating whether and how STEAM teaching increases student learning-outcomes in related disciplines – however, teachers are not encouraged to use more relevant assessment models. For teachers, it is important to see the benefits of using STEAM methods in the teaching process before they start considering STEAM teaching as part of their everyday routines. To understand these benefits, more paid time is needed, during which teachers could experiment with methods and become convinced about their usefulness. However, it is difficult for the school management to provide such time due to dense syllabi and tight budgets. The fact that STEAM teaching relies on novel technologies, presents new challenges. Implementing new STEAM methods requires teachers to have sufficient digital competence, learn new products and adapt learning material to the specific needs of their students. In addition, teachers would need mentoring and supportive communities, both in their organization and in their region. University-provided teacher professional development programs are one of the ways for providing teachers with such support.

STEAM teaching is also restricted by the cost of needed technological devices. STEAM learning is often based on learning individually or in groups, meaning that the number of sets required for teaching STEAM is high. For instance, there are up to 30 students in a class in Estonia, 25 students in Spain, 30 students in Norway, meaning that providing one class with necessary kits requires buying, servicing, and storing up to 15 kits. In plain English this means a one-time cost of 1500 EUR

---

[7] Papert, S., & Harel, I., (1991). Constructionism. Ablex Publishing Corporation. http://www.papert.org/articles/SituatingConstructionism.html

[8] Hamari, J. (2019). Gamification. Blackwell Pub, In The Blackwell Encyclopedia of Sociology, Malden. https://doi.org/10.1002/9781405165518.wbeos1321

[9]

1. Razzouk, R., Shute, V., (2012). What Is Design Thinking and Why Is It Important? Review of Educational Research, 82(3), 330-348. https://doi.org/10.3102/0034654312457429

for the kits (100 € per one kit), plus additional salary for the person servicing and maintaining the kits, and additional costs for the storage room. In addition, the use of STEAM kits requires computers or tablets, meaning that the lessons should either take place at computer classrooms (putting additional time pressure on the teacher) or that there is an additional financial need for required computers or tablets.

Despite the existing problems, the field is developing rapidly, with new StartUp companies providing more affordable solutions (e.g., the Edison robot that has similar sensors to the LEGO Mindstorms robots but is 10 times cheaper; or the Makey-Makey inventor's kit with a price range about 10 times cheaper compared to the Little Bits kit). This abundance on the one hand makes it possible for the schools to choose their favorites from hundreds of STEAM constructors, toys, robotics and electronics kits – while, on the other hand, it presents a challenge of choosing a suitable STEAM teaching tool that does not age quickly and would be supported for years to come.

Shared STEAM laboratories

We have shortly covered the reasons why STEAM teaching and learning can be obstructed or downright impossible at regular school or kindergarten. For instance, the cost of implementation, administrative problems (lack of suitable rooms, reservation system, training or support structure), low motivation of teachers due to inability to connect STEAM teaching with their teaching routine, their low digital competence and lack of training to use new devices). In the countries where there are universities focused on providing teacher education and in-service training, it is possible to conduct STEAM lessons outside schools and kindergartens, at the universities' shared STEAM laboratories that promote the growth of interest towards STEAM teaching, teachers' digital competence, and help teachers to become familiarized with STEAM learning in a risk-free manner. Such use of the universities' STEAM laboratories empowers school-university partnerships and creates ground for evidence-based educational innovation. Next, we provide some guidelines for universities (but also other stakeholders like municipalities) that should facilitate establishment of new STEAM laboratories. We will also provide some examples of the universities' shared STEAM laboratories in different countries.

Setting up a STEAM laboratory

The first step is to choose a room with enough space for conducting STEAM workshops for a whole class of students or for a regular group of teacher-students (about 30 people). The room should have moveable furniture and its interior should be waterproof to ensure that a wide range of different STEAM experiments can be conducted. The room or a corridor adjacent to it should have enough floor space for testing robots or other moving systems. The lightning, audio and video systems in the room should make it possible to conduct hybrid distance-learning lessons if needed, allowing broadcasting hands-on activities in detail, making it possible to conduct hybrid teamwork. In addition, it should be possible to use a great number of tablets and laptops in the room (i.e., it should have a good wireless Internet connection and enough charging outlets). As the number of the possible STEAM approaches is high then there should be a well-organized storage room near the laboratory. An example of a possible laboratory setup is provided in Figure 1.

Figure 1. Tallinn University Eduspace laboratory.

Choosing STEAM tools for the laboratory can be challenging. It is not possible to rely fully on the international experience as the availability of STEAM tools varies in different countries. The first step should be clarifying which STEAM kits are already available (even if not yet used) at the schools and kindergartens of the region that the laboratory should service. Some advice about this topic can be gathered from the bigger distributors of educational technology, but also from policymakers (e.g., to understand if the state or municipality has conducted or is planning tenders for acquiring some STEAM tools). For example, in Tallinn (Estonia) the municipality provided all kindergartens with affordable Bee-Bot, Blue-Bot and Ozobot robots in 2018.

Even when ready, the laboratory needs to be updated continuously, as the devices expire and get replaced with new ones. This also means that with restricted budgets and expensive emerging technologies it can be necessary to limit the number of kits (e.g., the VR sets are currently evolving rapidly, bringing down their prices and enhancing their functionality each year).

Efficient use of the laboratory

The next step is to start the laboratory efficiently. A STEAM laboratory needs a digital reservation system and rules for making reservations. It is necessary to make it possible that besides using STEAM tools in the laboratory, the tools can be lent out so that teachers and students could participate in training courses from home or they would be able to learn at their own pace. Different use scenarios for STEAM tools must be defined – for instance, a professor conducting a lesson, conduction of an in-service training, a basic-school teacher visiting the laboratory with their students, independent learning by a student or a teacher, etc. It is important to ensure that the laboratory is actively used, to justify the cost of STEAM tools that expire relatively quickly.

The laboratory should provide support for its users, taking into consideration the needs of learners: some of the learners do not need support at all, some need initial guidance, while some may need full-time support. There should be one or several laboratory assistants to cover these needs, preparing STEAM tools for conducting lessons, helping people use devices, and managing the reservation system.

In order to ensure the maximal use of the STEAM laboratory, it may be necessary to develop new STEAM in-service training courses that thrive to deliver the content in as short time period as possible (see also Leoste et al., 2022[10]).

On-line training modules and STEAM laboratory

The online modules, developed through the STEAM Upgrade project, are well suited for integrating syllabus, conducting in-service teacher trainings, and independent learning. As previously mentioned, using the modules requires STEAM kits that are located at the universities' laboratories or at schools or kindergartens. Independent learner needs to arrange either room reservation or STEAM kit lending with the STEAM laboratory of the relevant organization. However, as STEAM education leans heavily on collaboration, then we encourage teachers to form smaller or greater learning communities where they collaboratively increase their digital competence by solving the online modules of the STEAM Upgrade project.

Project partners' STEAM laboratories

Tallinn University EDUSPACE

In Tallinn University, the EDUSPACE laboratory was unveiled in autumn, 2020. At its homepage, eduspace.tlu.ee/en, there is a collection of more than 100 STEAM tools, grouped by both age of users and usage categories (Figure 2).

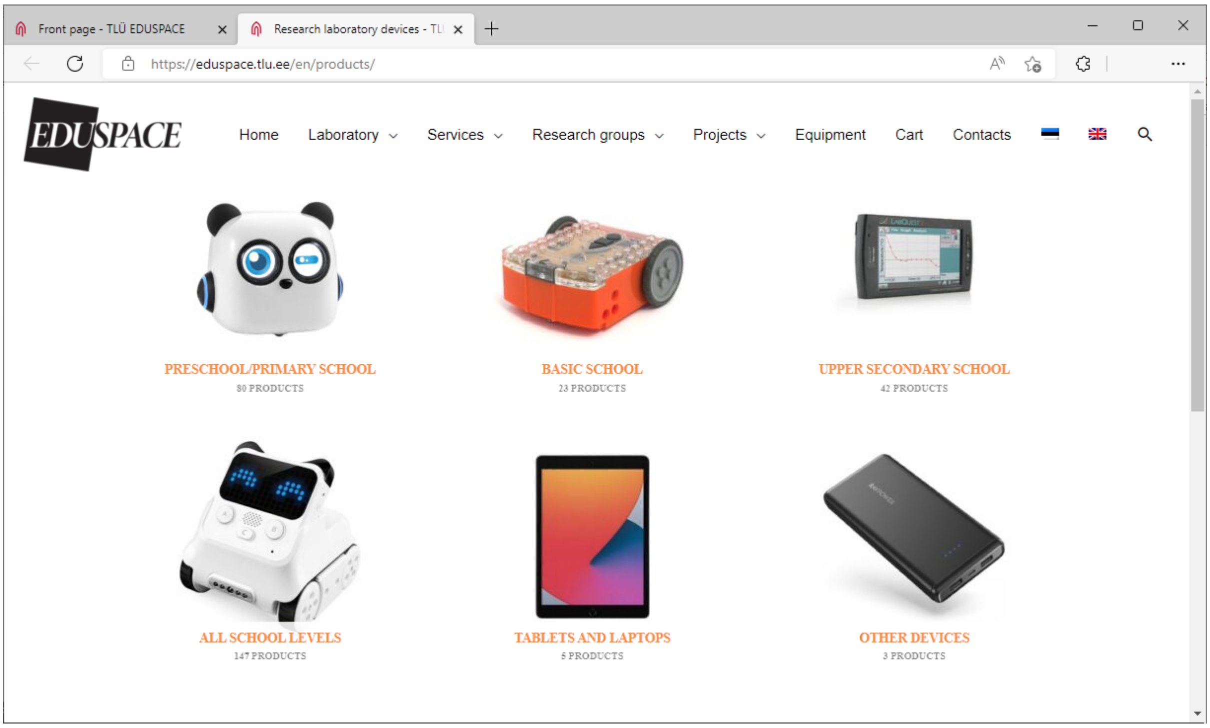


Figure 2. EDUSPACE laboratory's STEAM tool collection.

[10] Leoste, J., Lavicza, Z., Fenyvesi, K., Tuul, M., & Õun, T. (2022). Enhancing Digital Skills of Early Childhood Teachers Through Online Science, Technology, Engineering, Art, Math Training Programs in Estonia. Frontiers in Education, 7. https://www.frontiersin.org/articles/10.3389/feduc.2022.894142

In addition, the page features a public reservation system for reserving the laboratory, devices for on-site use or for use in other locations, reserving help from labor assistants for using STEAM tools (Figure 3).

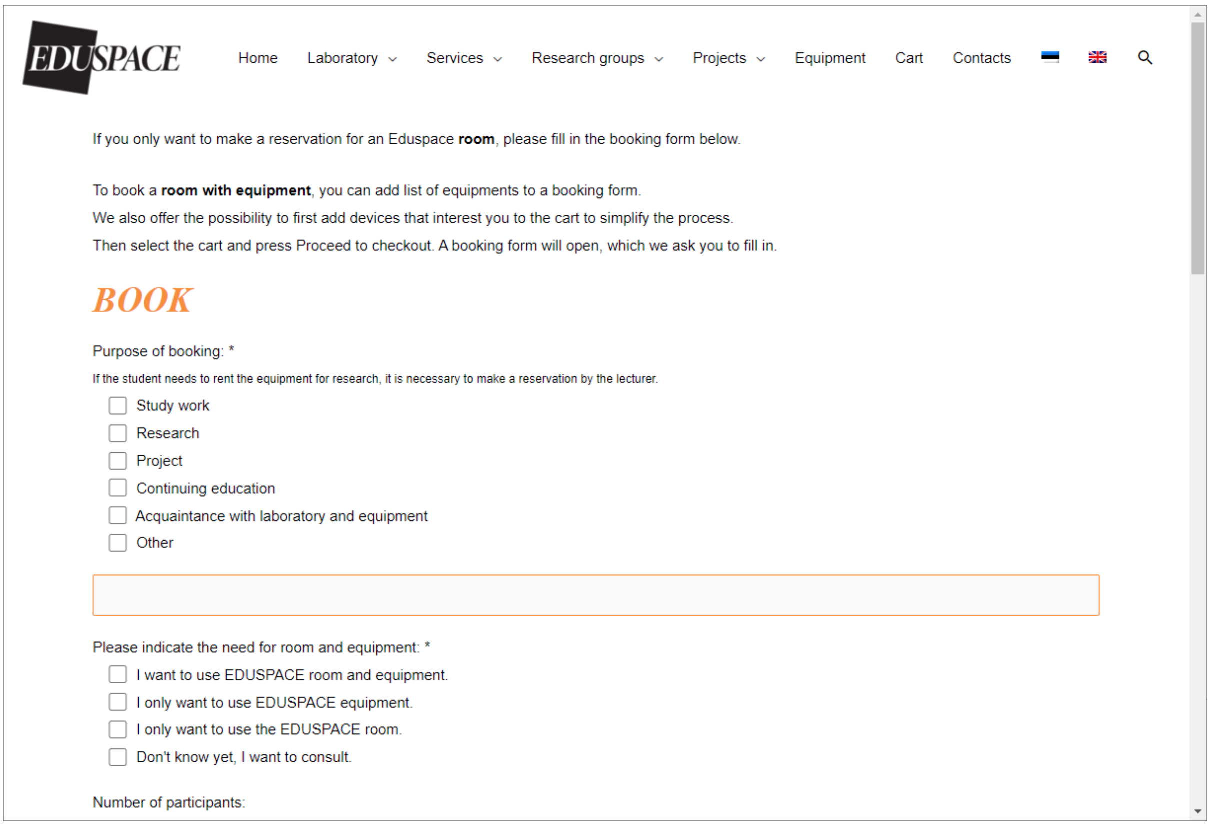


Figure 3. The reservation system of EDUSPACE laboratory.

The laboratory is used for regular teaching and learning. For example, for the third year it is used for conducting a training course "STEAM integrated learning for kindergarten and primary education", international STEAM summer schools, in-service teacher professional development programs about STEAM, student STEAM projects, but also for introducing STEAM innovations to international delegations and conducting STEAM lessons for regular teachers of schools and kindergartens. In addition, the laboratory has been used for conducting studies about Technology-Enhanced Learning and STEAM learning, for instance a collaboration project "Bee-Bot educational robot as a means of developing social skills among children with autism-spectrum disorders" with the University of King Juan Carlos (Spain) in 2021. EDUSPACE laboratory has been used also for conducting several international ERASMUS+ collaboration projects (including FreeEd, Digiloping Teachers, Enliven, etc.), all about developing teachers' digital competence. Together with the business sector, the laboratory is used for collaboration and knowledge transfer projects, helping EdTech enterprises prototype innovative solutions for education, for example, an educative augmented reality game for kindergartens by Mobi Lab (Figure 4).

Figure 4. An augmented reality game for kindergartens.

University of Stavanger

At the University of Stavanger the Didactic Digital Workshop (DDV) is a STEAM-laboratory mostly for use in teacher training. It is a different learning arena with zones for exploration and experimentation and for sharing in plenary. The workshop contains all possible equipment from gaming machines, drones and coding equipment, to VR glasses, drawing boards and iPads with a number of useful apps. We also have our own creative room with, among other things, 3D printers, vinyl cutters and laser cutters. The idea is to give teacher training courses as a taste of the classroom of the future.

DDV has been created specifically with teacher training in mind, and all the digital tools that are available must be relevant for teaching contexts. The aim is to make it possible for the students to be able to reflect on processes, learning, competences, didactics and pedagogy, and in that way make it possible to develop their own professional didactic competence.

The DDV is divided into three different zones, which are suitable for different activities:

- Wild Child (exploration, sharing and critical thinking)
- Make it (makerspace, coding, 3D printing)
- Game on (computer games, VR, Adobe)

Figure 5: The DDV in use during an international teacher training event (Photo: F. Skarstein, UiS)

University of Jyväskylä

University of Jyväskylä's Faculty of Education and Psychology has three dedicated Learning Labs, which consists of two laboratory facilities and a testing room (Figure 6). One of the lab spaces capacity is ca. 30 people. It is a flexible space that supports e.g. interaction research, VR research, technology education and new experiments. This lab space is equipped with

- System of four Marshall CV503 ceiling cameras and four Revolabs HD Dual microphones
- Insta360 Pro camera (other one can be added if needed)
- Zoom Livetrak L-12 mixer ja 10 pcs AKG C 111 LP headset microphones (installed in a mixer case)
- Two movable 65" touchscreens, linked with powerful computers, Minnray video conference cameras and Jabra speakerphones
- Two movable VR-cabinets: customized charging cabinets including Valve Index VR-headsets and controllers, powerful computers, 22" monitors, keyboards and mouses
- Four wall mounted VR base stations
- Foldable green screen (4 m x 2,9 m) and green screen vinyl (2,75 m x 6,09 m) for flooring
- Modifiable furniture of the space contains one movable battery-driven electric table, six group desks and 20 chairs. Additional group desks and chairs are available if needed.

The other lab space is a modifiable and spacious room that supports e.g. XR-development and analysis. It is also a space for storing, loading and testing mobile infra equipment.

The equipment includes

- Two powerful computers with monitors
- 65" wall screen and soundbar
- Two Varjo VR-2 Pro headsets and controllers
- Two Varjo XR-1 Developer Edition headsets and controllers
- Four wall mounted VR base stations
- Modifiable furniture of Kaarle contains four movable battery-driven electric tables and four chairs.

Figure 6: University of Jyväskylä's Learning Labs.

University of Jyväskylä's Library Building is intended for children and youth. It has a learning space for this purpose, and an exhibition (Figure 7) and event facility. The learning space accommodates STEAM activities provided for children and young people. Science education, science events, and civic science activities are supported by means of a specific concept (Tietoniekka) to provide science for all. Multi-disciplinary and -artistic events and exhibitions serve the third mission of the University, i.e. societal interaction. By means of the Tietoniekka concept JYU's rich event activities are even more accessible to all citizens. The events and exhibitions in the Library Building challenge the citizens to consider topical issues (Figure 8).

Figure 7: Art Gallery and Event Space in University of Jyväskylä's Library and Open Science Center.

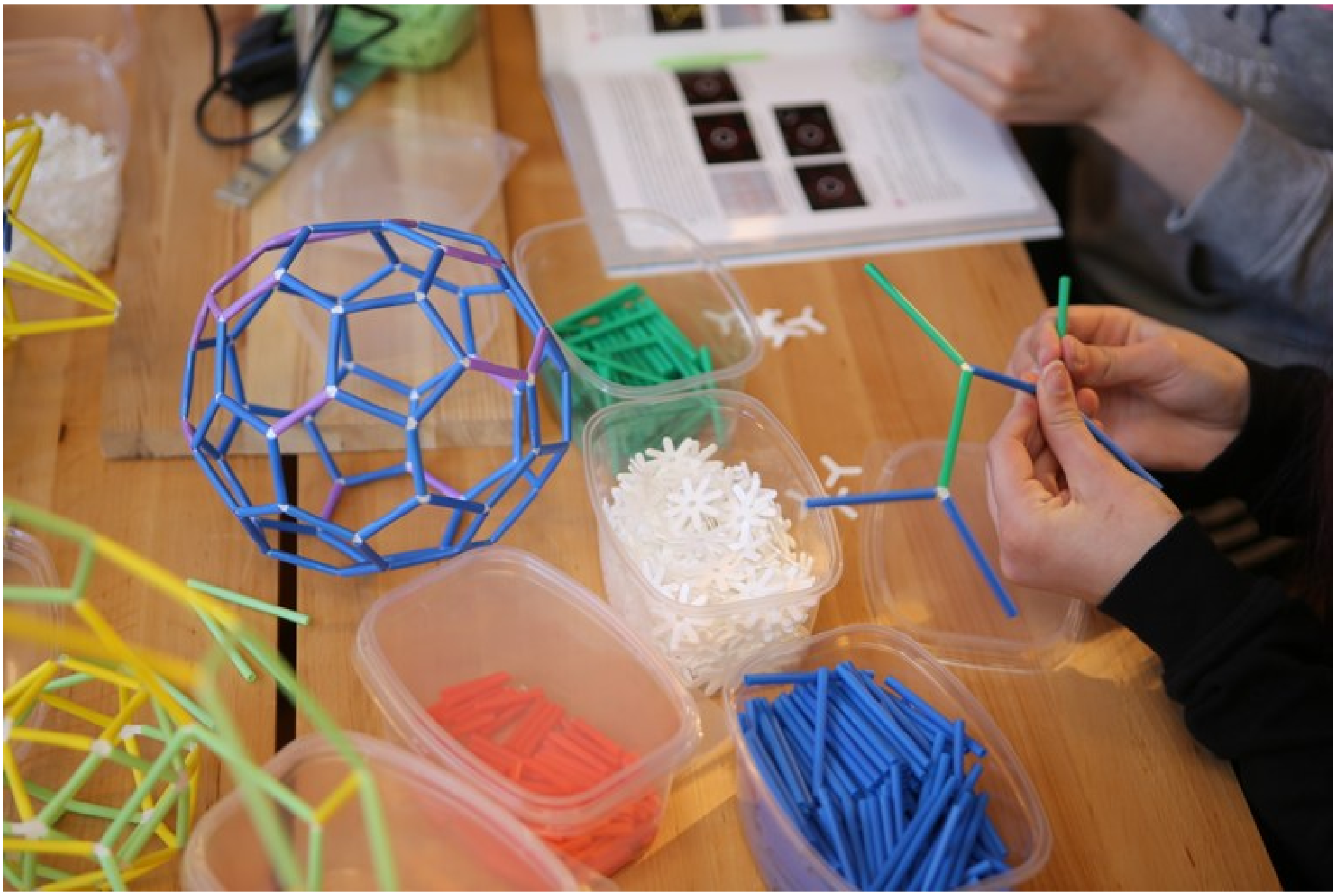


Figure 8: Hands-on STEAM Lab activities for schools in University of Jyväskylä's Library and Open Science Center.

University of Jyväskylä's Science Museum and Natural History Museum has collections and special spaces that are a valuable research infrastructure that is used for teaching and exhibitions, including STEAM activities.

Finnish Institute for Educational Research's unit for Innovative Learning Environments utilize a variety of educational toolkits that are designed to teach science, technology, engineering, art, and mathematics. These toolkits include hands-on materials and activities, as well as technology-based resources such as software and hardware kits. Examples of toolkits used in STEAM education include 4Dframe, LUX, Polyuniverse, Logifaces, ItsPhun, MicroBits, 4Dframe Mechatronics, Arduino and Raspberry Pi. The specific toolkits used depend on the goals and objectives of the particular STEAM program and the age group of the students being taught (Figure 9).

Figure 9: 4Dframe Hands-on Mechatronics STEAM toolkit by University of Jyväskylä's Innovative Learning Environments.

University of Jyväskylä uses LEGO robots as a teaching tool in their STEM education programs. In these programs, students can learn about robotics, engineering, and computer science by building and programming robots using LEGO components. The LEGO robots are used to teach a wide range of concepts, including mechanics, electronics, and algorithms, and they provide hands-on, interactive experiences that help students to develop their problem-solving skills, creativity, and critical thinking. Additionally, LEGO robots can be used to teach programming languages, such as Scratch, which is designed for kids and beginners.

Figure 10: Lego Robot challenge in University of Jyväskylä's Faculty of Information Technology.

Johannes Kepler University

Circus of knowledge

The circus smokes, hisses, whistles, and smells. They play, dance, and make music. The world presents itself analogously and digitally at the same time. Actors, musicians, scientists, artists, acrobats, and sometimes robots and clowns transform science into art and create sensual, pleasurable, and inspiring experiences. The circus of knowledge, figure 1 is an institution of the Johannes Kepler University Linz, which is intended to bring society, especially young audiences in contact with science in a playful way. The circus of knowledge stands for open dialogue and knowledge transfer between science and society and their developments. With the means of art, the circus addresses people of different age groups in order to deal with the topics of science and also to participate in joint artistic projects.

Figure 11: Summer stage of the circus of knowledge.

The magic of knowledge and the magic of knowledge can be experienced here. When you enter the circus, it will amaze you and ignite your enthusiasm. You are invited to discover our world with all your senses. See, understand, and learn, driven only by curiosity and enthusiasm. JKU also cooperates with theaters, circus operators and other showmen and strives to work with the Education Directorate of Upper Austria. The aim is to reach people from all over Upper Austria. The "circus of knowledge" is the commitment of the Johannes Kepler University Linz to meet the goal of sustainably interlinking art, science and education.

The performances performed in the circus of knowledge are based on scientific facts that are presented to the circus visitors in an interesting way. An example of a scene from one of the performances from the circus of knowledge is shown in figure 12.

Figure 12: An example of a scene from Circus of Knowledge.

Entrance to the circus of knowledge is free, and visitors can donate money if they want to support certain performances or the circus of knowledge as an organization. Announcements of events in the circus can be followed on the website:
https://www.jku.at/campus/freizeit/zirkus-des-wissens/eventarchiv/

Rey Juan Carlos University

The STEAM laboratory of the Rey Juan Carlos University is divided into several units. On the one hand, it has a laboratory located on the Vicálvaro campus (Figure 13 a-b) equipped with educational mobile robots, and with the capacity to carry out small workshops and courses aimed at teachers and teachers in training (In this campus they teach, among others, the degrees of Early Childhood Education and Primary Education).

Figure 13 a-b. Different views of the STEAM-Lab campus of Madrid-Vicalvaro. URJC

The second STEAM unit is a larger capacity laboratory located on the Móstoles campus. In this laboratory there is a team dedicated to the design and construction of robots (Fig. 14 a,b), apart from containing a large number of educational robots (Fig. 14 c). Its greater equipment allows the different workshops that have been held in recent years to be carried out on this campus.

Figure 14 a-ASD.robot; b-3D printer for CAD designing; c-3D printer filament and various educational robots

Finally, there is the possibility of deploying a mobile STEAM laboratory (Fig. 15 a-b) based on a set of equipment in the form of educational robots, games for robots, etc. that are usually moved to take the activities to the different schools and educational centers.

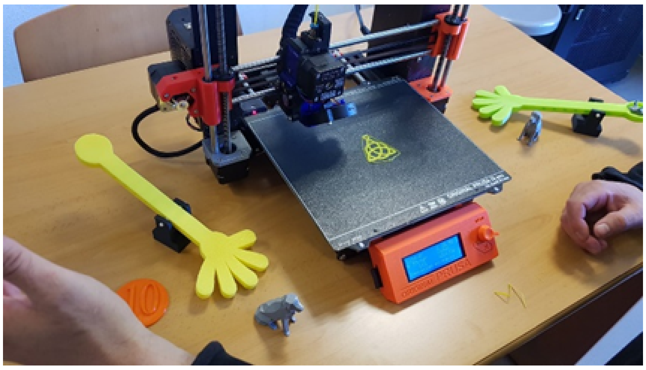




Figure 15. Mobile laboratory at Science Week 2019 (a) and 2021(b-c).

MaxWhere

The importance of the 3D printing simulation space in education

The space serves both public education and science communication purposes. The operation, maintenance and eventual repair of a "real" 3D printer can be expensive, time-consuming, and require knowledge that a teacher with general training does not necessarily have. The price of an entry-level 3D printer and the cost of the materials needed to operate it would be too high for most schools. Furthermore, not all institutions have trained staff to handle an actual 3D printer.

Anyone can open the MaxWhere 3D Printing Workshop space, then bring it into their class and introduce students to the process of 3D printing. Thanks to the virtually printed objects, learning becomes experiential and fun. The space can be made public once the development is complete so anyone can use it.

Learning does not end when the object is printed: students can even create the geometry to be printed, so the whole process unfolds under their hands. An easy and short task can be transforming a hand-drawn 2D contour into a 3D figure with interesting and free software like Tinkercad and Kiri:Moto, then start slicing and printing.

How does the 3D Printing Workshop work?

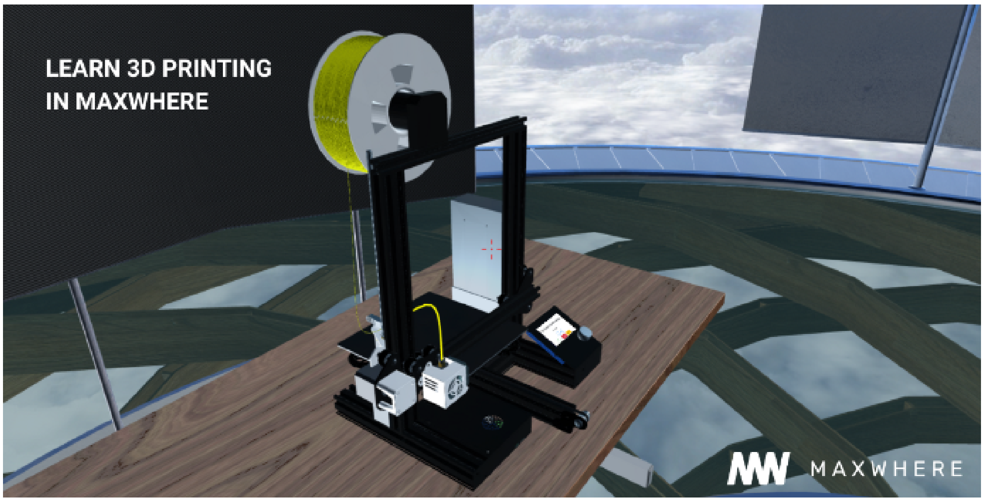
This MaxWhere space is available from the browser, so it is not necessary to install the MaxWhere client. A user account is not required either. After loading MaxWhere, we find ourselves in space immediately. Anyone can open this space without special training. A basic user level of MaxWhere (navigation, use of smartboards) is required.

Entering the space, we see smartboards. On these, we can learn the basics of 3D printing: from the history of 3D printing to the operating principles of today's printers. In the center of the space is a virtual twin of a Craftbot and a Creality Ender 3 printer with a simple control panel. We chose this model because it is common, popular and accessible, so anyone working with an actual 3D printer will already be familiar with the device.

After successfully loading the space, you can start printing by following these simple steps:

- approach the printer display and select the Browse button
- in the file browser window, you can select the gcode file you want to print
- at the bottom of this article, we also recommend two gcode files with which anyone can try the printer simulator
- click the start button
- the printer starts the job

The space is fully customisable. On the one hand, users with an Editor role can modify the content of the smartboards. On the other hand, the operation of the 3D printer can be illustrated by importing any gcode file that was created for the Craftbot and the Ender 3 printer.



3D printing simulation in MaxWhere

Tutorial: https://docs.maxwhere.com/usersguide/index.html

Gcode files:
https://mw-public-downloads.s3.eu-west-1.amazonaws.com/3D-printing-resources/mw-logo.gcode

https://mw-public-downloads.s3.eu-west-1.amazonaws.com/3D-printing-resources/steamupgrade-logo.gcode

Craftbot in the education

Craftbot (formerly CraftUnique) is a developer, innovator and manufacturer of 3D printers with a strong focus on the educational, industrial and medical market. The Hungarian company is based in Budapest and was founded in 2014. The company's first 3D printer to utilize FFF technology, entered the market in August 2014 backed by a successful launch.

Being an innovator with our own in-house capabilities, hardware development is not the only part of what we provide. Craftbot also creates the firmware and a slicing software, in order to provide a complete 3D printing solution to all of our users. Many Craftbot printer models have won "Best Plug 'n' Play" titles which is a very good reassurance for us. When designing our printers, we always keep those in mind who are not necessarily from an engineering background but would like to enter the captivating world of 3D printing: teachers and students for example.

Since our strong start in 2014, we have made education and development for education one of our main goals. A Hungarian educational project which we have been developing and producing for over 2 years will soon put 600 of our printers in Hungarian schools. We are also the 3D printer provider of a Romanian SmartLab project which will result in thousands of Craftbot 3D printers in Romanian schools.

We are also partnered with PrintLab where schools can purchase a 3D printer and 3D curricula which they can use in their classrooms. See further details here.

3D printer in the school – a new chapter in education

As the synergy of knowledge is getting more and more invaluable in today's world, learning, being creative and mastering the usage of the new digital technologies are becoming basic skills. Due to this, the education of the newest generations needs to start as soon as possible, so they can adapt to the technologies by instinct.

Our overall goal is to help teachers and children to discover the world using the tools of modern technology. They accomplish this through experience, efficiency training, and by improving skills in both programming and STEAM fields.

There are several skills 3D printing can develop:

- Development of capabilities: attention, memory, perceptions and thinking processes
- Further development of the connection between reality and mathematics
- Development of accuracy in perception
- Social competence: acceptance of the hierarchical relationship in pair/group work
- Improvement of design capability
- Analyzing: comparison, identification, differentiation, sorting into classes
- Prioritization according to various properties
- Development of flexible thinking by searching for more solutions
- Cooperation, paying attention to others
- Improvement of constructive thinking and capability of context recognition
- Development of logical and critical thinking
- Internet based communication and participation in the networks
- Development of depth perception
- Open-mindedness for innovations.

Figure 16: Photo by Craftbot

Embedding on-line training modules into teacher-students' courses

There are several aspects to consider when integrating STEAM Upgrade on-line training modules to universities' teacher-students' courses. For instance, using learning theories (constructionism and constructivism), teaching methods (project based learning, problem based learning, discovery based learning, collaborative learning, game based learning, etc.), didactics (how to integrate STEAM approach in different subjects' teaching), digital competences (using the modules for enhancing digital competences), STEAM in education (using the modules for showing how STEAM is used at different school levels).

Depending on the availability of the course time, it is possible to choose one activity of freely chosen modules and, based on that activity, to conduct a workshop with a duration of 2-4 academic hours. As an independent work, students can also conduct this workshop to other students or use the activity as an inspiration for developing their own activities, together with conducting guidelines and an open digital resource. Next, they would conduct their newly developed activity in their educational organization with their peers or teachers who are interested in STEAM teaching and learning.

Next, we describe a workshop that can be conducted, based on the "self-driving bus" activity from the secondary education module.

Conducting a Workshop

This STEAM learning activity workshop aims at familiarizing pre- and in-service secondary school teachers with Educational Robots (ER) as didactic tools. In particular, this activity introduces hardware and software ER related concepts to teachers without any previous robotics experience, providing them with some examples and discussions about actual classroom activities.

The participants will construct and program a LEGO Mindstorms EV3 robot based prototype of a self-driving bus in this workshop. Consequently, the task for the participants is to make their robot travel from one destination to another while detecting pedestrians on its path.

As commented above, we do not expect participants to have any previous knowledge about programming or working with robots. However, within the workshop, participants will become familiarized with the concepts of robots and robot programming, applying simple math measurements and calculations in order to create code for the different robots. Collaborative teamwork, problem solving skills, digital skills, self-paced learning and peer tutoring are employed.

The robot to be used in this workshop is the LEGO Mindstorms EV3 robot.

At the beginning of the workshop, we supply participants with the vocabulary, terms and concepts needed for using ERs. We explain afterwards the role of ERs as engaging learning tools and how they could be integrated to different subjects. Then we cover the topic of age-appropriateness of robots. We also describe the principles of block-based programming by drawing analogies with language learning and forming sentences. We discuss afterwards for some minutes the concepts of inputs and outputs of the robots used in the workshop and describe in detail how to put all these robots to move and what the loop (repetition) block stands for. Finally, yet importantly, for the theoretical part we share our research-based understanding of why robots and other STEAM sets are still not widely used by teachers. Next, we form three robot-centered teams (one team per type of robot) and we continue with solving the challenge.

The teams have to negotiate about the path their robot should move on and sensors their robot is going to use for detecting its surrounding environment. Next, they have to familiarize themselves with the robot their team selected, and program the robot so that it acts as a self-driving bus. When doing so, math calculations, together with logic and research mindset will help participants to achieve the best possible solution. The teams will present their solutions to other teams. Finally, a group discussion will take place, where team members first will discuss among each other and then share to everybody their thoughts about the workshop activity and its pedagogical benefits on interdisciplinary teaching, emphasis on math, arts, robotics and coding.

The learning outcomes for the participants are listed below. Each participant is able to:

- see the possibilities of using ERs as motivating tools in math and art classes;
- program simple movements of the LEGO Mindstorms EV3 robot with the help of step-by-step instructions;
- use digital interactive learning resources created in GeoGebra;
- critically evaluate the quality and applicability of the digital learning resource.

The 90 minutes workshop will give teachers hands-on experience and emotion about how they could benefit from robots as learning tools during their regular math lessons. We hope to have a fruitful discussion with the workshop participants about the effectiveness of such short workshops. The focus of the discussion is to find out whether these workshops can be used for creating awareness about the benefits of STEAM kits, especially robots, and reducing the anxiety towards using STEAM in teaching practices.

Robot-integrated learning in kindergarten and primary syllabi

STEAM Upgrade modules can be used for conducting a STEAM course at the bachelor's or master's level. Tallinn University syllabus "Robot-integrated learning in kindergarten and primary" can be helpful for this purpose. The mentioned syllabus is worth 6 EAPs and available for all Tallinn University students, including those outside the educational field. The course is conducted in English in order to include international students. The students have various motives for participation. While the students of the educational field highlight the need to use the acquired knowledge in their future work, or the desire to develop their STEAM competence, the students of other fields wish to understand the directions of the future education and the prospects of STEAM education in improving competitiveness of future workers. The international students are mainly interested in understanding the differences and similarities of technology use in classrooms and the expectations of teachers in their home countries and in Estonia.

We have a few recommendations for conducting training courses that are based on STEAM Upgrade modules:

1. Conducting the course at a leisurely pace – once per week (or a couple of times per month) is enough, as the homework (collaborative activities with peers) would take additional time.

2. Active learning methods should be used during more than half of the course volume and carrying out learning activities or creating new ones should be done in a collaborative manner.
3. Plan spare hours for conducting a workshop or a seminar, as prototyping, building and constructing always takes more time than initially planned. Four academic hours should be enough for acquiring new knowledge, having hands-on exercises, collaborating, presenting and reflecting.
4. Although lessons should be conducted in a STEAM lab, there can be occasions when either the teacher or students are not able to participate in-person. Learning and teaching should be conducted in a hybrid way, as it is easy to bring learners synchronously together this way. However, hybrid lessons in a STEAM lab require good quality document cameras and skills of demonstrating details with the camera of a mobile phone. In addition, the audio capacity of the room needs to be good enough for transmitting voice without distortions in both directions. This is even more important with bigger rooms. As more than 50% of the time is filled with active learning methods, including teamwork, then it is necessary to consider forming separate teams of online learners and to use separate break-out rooms for them. Online team members tend to be ignored by in-person learners, especially with hands-on activities, and the normal discussion that accompanies such activities can be transmitted as an unintelligible noise to online learners.
5. If distance participation is allowed, ask your students to plan it and lend them necessary STEAM tools that allow them to take part in hands-on activities during hybrid lessons.
6. If students are required to conduct sample lessons then take into account the possibility that some of them are not working in their profession (yet). In this case, try to find interested teachers who allow these students to conduct the sample lessons in their facilities.
7. Let your students present both group assessments and individual assessments. In order to ensure learning goals, it is necessary for the students to experiment with STEAM approaches in real world teaching, to create (collaboratively) lesson plans, and to be able to reflect their conducted lessons – to describe what worked, what did not and what could be done differently.
8. Students should be provided with a reasonable amount of newest papers about STEAM teaching and learning. These papers should be discussed during the lessons and one of the assessed results of the course could be an essay about the potential of teaching STEAM. The essay should be formatted as an academic paper, with references to academic literature.

Syllabus overview

Course title: Robot-Supported Learning in the Kindergarten and Primary School

Course volume (ECTS credits): 6

Contact lessons (hours): 42

Independent work (hours): 114

Prerequisites: -

Aims of the course: Support the development of practical skills and educational technological competences for the safe use of simpler robotics tools in the context of primary and primary education, for the integration and diversification of educational and educational activities.

Brief description of the course: The contact day includes learning of a robotics platform (BeeBot, BlueBot, Ozobot, Dash, Edison, Sphero, Lego WeDo), co-creating a learning resource (a structured document about how to conduct a daily activity or lesson using a robot as a learning tool), conducting a demo lesson to other participants, and reflection.

Learning outcomes of the course: The student...

- has an overview about basic educational robotics tools that are suitable for preschool and primary school;
- is able to collaboratively create and adapt robot supported integrative learning materials;
- is able to evaluate security risks related to the use of robotics tools and make proposals for their management;
- is able to reflect one's own teaching and to design changes in teaching and educating processes.

Schedule and activities: eight meetings as follows:

1. The course kick-off
   Robotic digital storytelling
   Being acquainted with Ozobot robots
2. Storytelling and pre-programmed robots will be continued
   Remote controlled robots
   Introduction to the STEAM K12 project related homework
   First look into H5P
3. Storytelling and spatial concepts
   Button programmed robots
   Creating open educational resources with H5P
   Computational thinking and graphical programming
   Programmable and constructor robots
   First STEAM K12 project workshop
   Swimming figures workshop
4. Learning H5P
5. STEAM K12 workshops
6. STEAM K12 workshops
7. Presenting H5P learning designs
8. Exam

Teacher-student experiences

Next, we present the feedback from teacher-students who experimented with STEAM Upgrade pre-school modules in Estonia during the spring, 2021.

STEAM Upgrade I project: an astronomy game

Our group took part in the STEAM Upgrade project. Our focus was on testing and developing materials for “Astronomy in Early Childhood Education: Solar System and outer space” by E. Peribanez and C. Garre from GHAME-Rey Juan Carlos University, Spain.

First, we translated the English materials to Estonian, therefore we understood them better and we could later share the materials with other kindergarten teachers. We decided to create a board game “Solar system and outer space” for preschool children between ages of 3-7 (Figure 17). We created digital assets and physical materials for the game. We introduced the topic of the Solar System to children and tested the game with them in kindergartens, where our group members work.

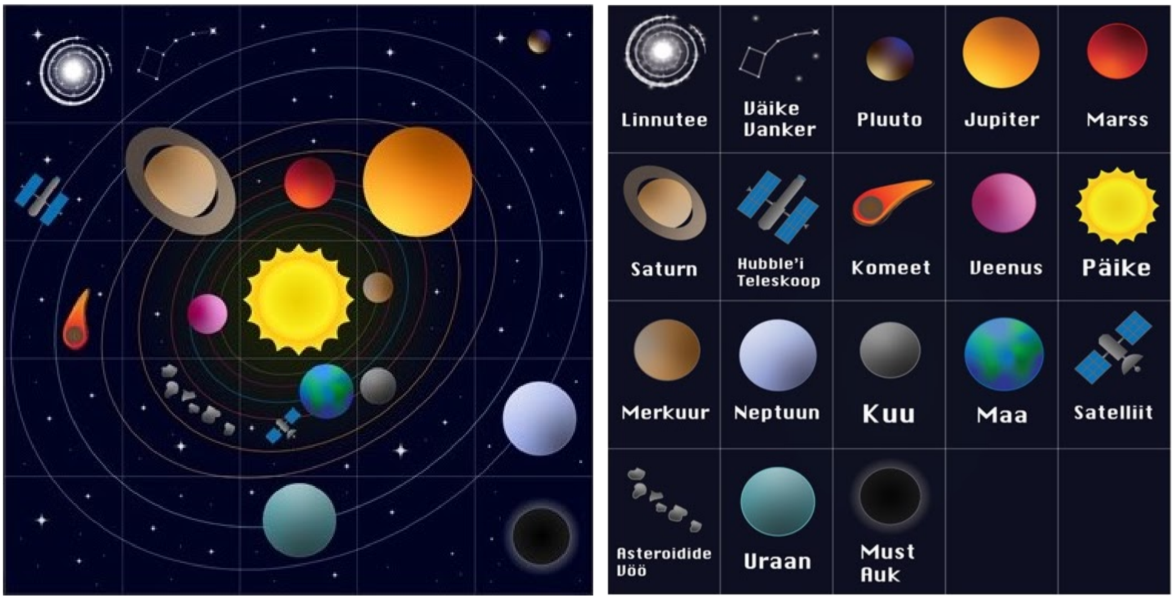


Figure 17. Board game “Solar system and outer space”

After the testing process we added some suggestions on how to play our game in different ways according to children's age and knowledge. Also we shared our game with our colleagues to get their feedback on this game.

Nowadays, the transition to digital culture in our society is inevitable and will continue to influence education in the future. Using digital technologies in the learning process supports children's non-linear thinking, provides new experiences, teaches new ways of thinking and is related to student-centered learning. There is no doubt that digital technologies are important tools for teachers and their integration into teaching is considered important in all levels of education (Swan, Lin & Van’t Hooft, 2008).

According to this, we agreed that dealing with the implementation of digital assets in Estonian kindergartens is definitely a necessary process.

So, we decided to test and improve the educational game “Solar system and outer space” which involves using digital technologies such as augmented reality cards and educational robots.

As the result of the project we created digital and physical game materials and descriptions of the game. We tested the game in 3 kindergartens with kids in different age groups and improved our game. Then we created a poster and shared it on social media with other early childhood teachers in Estonia.

Sustainability

The primary goal of the project is to be incorporated into the SteamUpgrade project, our materials will be added to their repository for classroom materials that aim to improve the digital competencies of pre-school teachers. We created a set of instructions in addition to the digital files of the game so it can be tried and tested by other people. Additionally we shared the materials with other pre-school teachers on social media to increase accessibility even more.

STEM Upgrade II project: enhancing ICT skills in kindergartens

Could you anticipate such changes a decade ago that physics would be taught as early as in kindergartens and teachers would utilize 3D printers in their ICT practice?

No matter how fantastic it sounded, progress is stepping straight into the early stages of education, pre-school, and other spheres of life. Educators should deal with it and catch up with new tools and practices. The issue is how to facilitate the process for teachers and their young chargers. Gamification solutions have become an indispensable part of it.

STEAM upgrade II project is part of one of the major ICT projects conducted with the partnership of Universidad Rey Juan Carlos, University of Jyvaskyla, Johannes Kepler University Linz, University of Stavanger and Craftbot - developer and manufacturer of 3D printers. Our team of Tallinn University students has further developed it within its LIFE interdisciplinary project.

Members from various TLU Schools including Social Pedagogy and Child Protection, Early Childhood Education and Digital Learning Games, had to integrate their viewpoints and skills to introduce a new object, Archimedes' lever, as an engaging part of a preschool curriculum with the focus on its physics component. It aimed to develop teachers' digital competence since only 30% of teachers, as reported in the 2018 OECD TALIS survey, feel sufficiently prepared to use ICT in teaching (Taimalu et al., 2018).

Multiple questions accompanied the process of defining the problem – how to incorporate a lever model into a regular curriculum? What if a teacher possesses vague ideas about physics and 3D printing or is reluctant to apply new technology in class? How do you engage younger students with a subject that is conventionally delivered from the 8th grade? According to Souza's (2016) claim, we have to bear in mind that scientific concepts are substantive, although "they should be part of the child's everyday physical world so that the scientific exposure does not devalue childhood."

In our next steps, we printed the model (Figure 18) and tested it on three different groups of children. Tests were conducted by members of our team. Observations of children's reactions, creative ability and critical thinking resulted in the lesson plan. Experimenting is an essential part of any physics lesson, and not a single child will refuse to experiment outside on a seesaw. Exercising by putting weight on different lever points helped the children discover the core concept of Archimedes' lever.

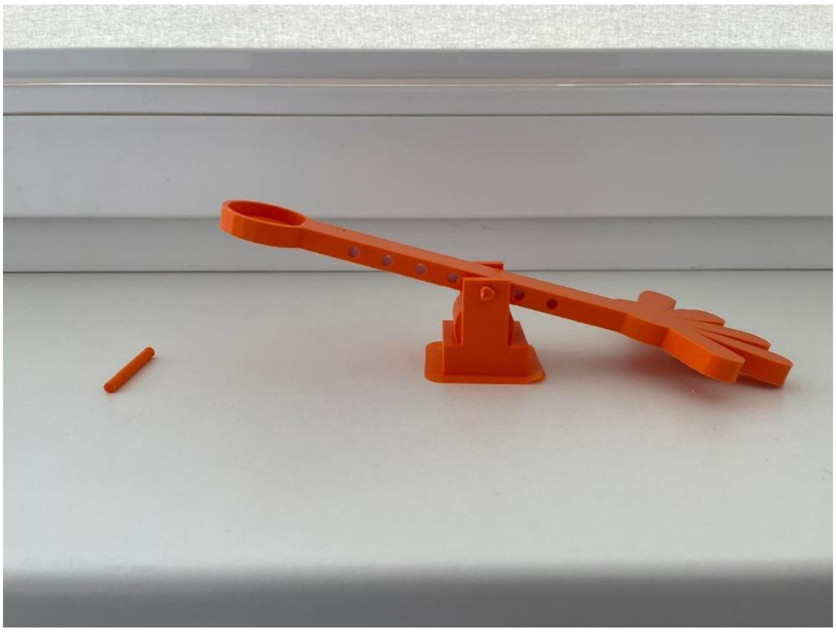


Figure 18. Archimedes lever printed in TLU Eduspace

However, testing revealed some limitations of the model used. Firstly, only a few kindergartens obtain a 3D printer, and therefore the issue of the access to digital study materials and instruction manuals occurs. Finally, enhancing new ICT skills along with compulsory tasks raises concerns about being time-consuming for a teacher, taking into account that not each of them is technically perceptive enough.

Further modifications are well welcomed, although, for now, it has become obvious that physical concepts and new ICT skills are possible to include in the curriculum if teachers have a lesson plan, necessary instructions and opportunities to equip the learning environment in the framework of a training strategy.

References

Leif Marklund (2019) Swedish preschool teachers' perceptions about digital play in a workplace-learning context, Early Years, DOI: 10.1080/09575146.2019.1658065

Luik, P., Taimalu, M., & Suviste, R. (2018). Perceptions of technological, pedagogical and content knowledge (TPACK) among pre-service teachers in Estonia. Education and Information Technologies, 23(2), 741-755.

Martins, Marlucio De Souza & Posada-Bernal, Sandra. (2016). Games as a pedagogical tool of physical education in the development of psychosocial skills within early childhood education. 961-968. 10.21125/iceri.2016.1216.

https://op.europa.eu/webpub/eac/education-and-training-monitor-2020/countries/estonia.html#five

Santos, Rosana & Mackedanz, Luiz Fernando. (2019). Physics Teaching for Children: A Bibliographic Review. Acta Scientiae. 21. 213-230. 10.17648/acta.scientiae.v21iss3id4628.

4. Applying digital competences framework into teacher-students' courses

As the demands on teaching professions are changing rapidly, teachers need more digital competence related knowledge and skills that allow them to meaningfully manage 21st century educational technologies – both in the interest of using modern digital devices, and helping students become digitally competent. In order to help teachers map their digital competence, understand their needs of self-development, and to choose proper training courses, various relevant frameworks, self-assessment tools and training programs have been developed at the national and international levels. In the EU, a common European framework for the digital competences of educators (DigCompEdu) was developed, based on analysis and grouping of these tools, frameworks and programs. DigCompEdu, being a research-based background framework, has several purposes. It can be used as a tool for guiding policy, but it can also be adapted in order to implement regional and national training programs and tools. In addition, it provides stakeholders with a common language and approach that makes it easier to exchange ideas and best practices of various parties from different regions. The DigCompEdu framework (Figure 1) can be used by educators of all educational levels, from early childhood to adult education, including general and vocational education, special pedagogy and non-formal learning contexts. Based on these characteristics, the framework can be used by relevant stakeholders (relevant national and regional authorities, educational organizations, professional training providers, and others) as a common reference framework for developing digital competence models.

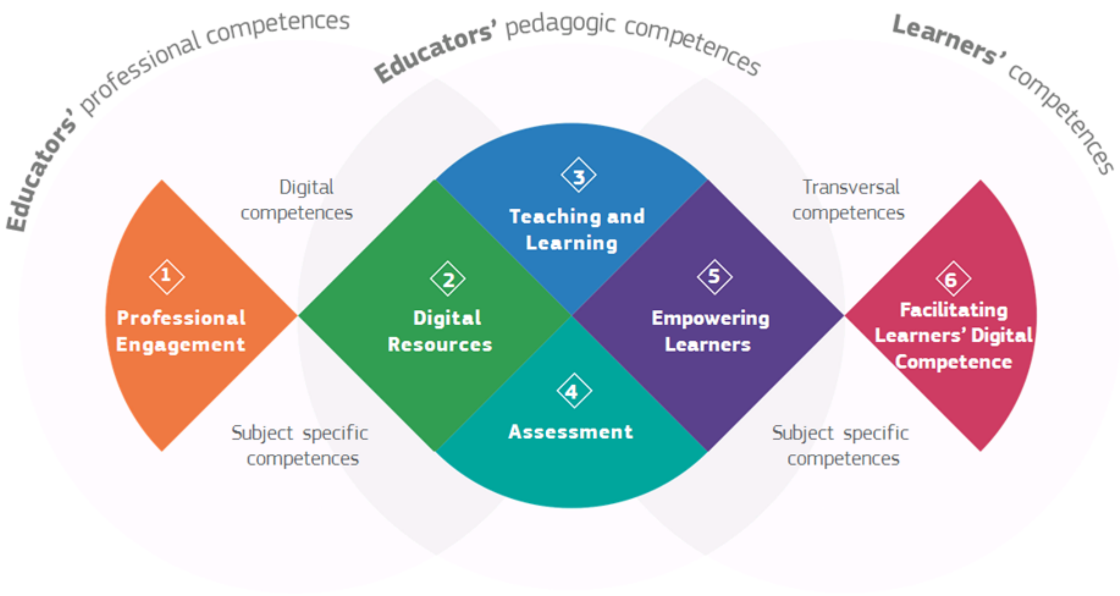


Figure 19. The DigCompEdu framework.

DigCompEdu has six areas (Figure 19): professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. The guide for using DigCompEdu can be found at the following link: publications.jrc.ec.europa.eu/repository/handle/JRC107466.

Progressing from the beginner's level to the advanced level is not a question of a couple of days or weeks or even months. When using self-assessment questionnaires, such as SELFIE, teachers need to remain self-critical and understand if they have only superficial knowledge about a certain competence area (through reading papers or watching videos), or if they have been engaged in this competence area through hands-on learning activities – or if they have already used their competence in their classes (this can be difficult for teacher-students). In addition, teachers need to understand if they have been engaged in relevant activities only once or twice – or has it been a part of a longer process of professional development, with the target of (for example) reaching the advanced level in two years, while routinely conducting relevant activities.

Digital Learning Resources

When working with teacher-students, using the STEAM Upgrade online training modules, the most influenced area is Area 2 – Digital Resources. Teacher-students learn at first by using the digital resources of STEAM Upgrade, next they learn to look for necessary resources from the internet, and then they learn to adapt existing resources, create new ones, manage them, protect them with copyright and share them.

Next we will present a summary with key concepts, activities and resources that can be used in addition to using the STEAM Upgrade modules in order to develop one's digital competence in the area of Digital Resources.

In principle, every digital resource that is used for teaching and learning, is a digital learning resource. However, some of the key concepts are the following:

- *Digital learning resource* (DLR) – a digital resource, such as application (app), software, program, or website that engages students in learning activities and supports students' learning goals. There are three categories of DLRs: a digital academic content tool, a digital productivity tool, and digital communication tool. DLRs as defined here do not include the hardware or infrastructure needed to use the digital resources[11].
- *Open educational resource* (OER) – a learning, teaching and research material in any format and medium that resides in the public domain or, while under copyright, is released under an open license that permits no-cost access, re-use, re-purpose, adaptation and redistribution by others[12].
- *Educational platform* – an integrated set of interactive online services that provides the teachers, learners, parents information, tools, and resources to support and enhance educational delivery and management[13].
- *Interactive learning resource* – as opposed to traditional teaching materials like PowerPoint presentations or PDFs, where all information is flat and presented on the same canvas or

[11] U.S. Department of Education, Office of Planning, Evaluation and Policy Development, Policy and Program Studies Service. (2018). National Study of English Learners and Digital Learning Resources. Washington, DC. https://tech.ed.gov/files/2018/10/matrix-digital-learning-resources-supports.pdf
[12] UNESCO (n. d.). Open Educational Resources. https://www.unesco.org/en/communication-information/open-solutions/open-educational-resources
[13] IGI Global (n. d.). What is Educational Platform? https://www.igi-global.com/dictionary/emerging-platform-education/42260

page, interactivity allows us to share information in a short and concise way, using layers to add details, and distribute content in a friendly way[14].

Creating, modifying and adapting educational resources

Modern digital educational resources are mostly interactive, making it possible for the resource to "react" to students' actions by either choosing the correct teaching path, providing students with feedback, or carrying out actions that are usually done by a human teacher. Besides being interactive, educational resources quite often include various types of elements with the purpose of providing students with optimal learning experience. It is possible to include videos (for example, do demonstrate how do wolverines live in their natural habitat), audio (for example, to demonstrate a correct pronunciation of French words), quizzes (allowing students to enter they responses) – but an educational resource can also include many different types of elements at once. Read more about properly designing interactive educational resources here: ctl.wiley.com/creating-interactive-content/.

To create a professional educational resource you would need to use a specialized platform that would provide you with all the necessary tools for creating, managing and sharing your resources. For example, H5P (h5p.org) is a free and open-source content collaboration framework that aims to make it easy for everyone to create, share and reuse interactive content. Another platform, GeoGebra (geogebra.org) is an interactive geometry, algebra, statistics and calculus application, intended for learning and teaching mathematics and science from primary school to university level. Depending on the rules of your school, you could be required to use some other, albeit similar, platform for creating and managing your educational resources. Next, read how to easily and quickly create an interactive educational resource by using H5P: h5p.org/documentation/for-authors/the-basics or by using GeoGebra: wiki.geogebra.org/uploads/1/1d/GeoGebraQuickstart-en-40.pdf.

Understanding license conditions

In many collaboration platforms it is possible to re-use the works of other authors. You can take an existing educational resource and adapt it to your classroom needs. When doing so, you need to be sure that you are following the copyright license conditions. For this you need to find and read the copyright information of the work you are using. Most often, educational resources use Creative Commons licenses. These are standard license agreements that make it possible for the copyright owner to allow anyone in the world to use their copyright work in any manner consistent with that license. There are six types of Creative Common licenses with different limitations. For example, with some licenses modification of the original work is not allowed. Or with other licenses it is forbidden to use the original work for commercial purposes. Read more about Creative Commons licenses here: copyrightalliance.org/faqs/what-is-creative-commons-license.

Finding and managing digital learning resources

Using search engines is a good way to start finding digital resources on the Internet. However, this search will yield numerous matches that need to be evaluated on an individual basis. It is

[14] GeniallyBlog (n. d.). How to create interactive educational materials with Explain Everything and Genially. https://blog.genial.ly/en/interactive-educational-materials-explain-everything/

somewhat easier to locate some open repositories or collaborative platforms (or in some cases, the repositories of your own organization) that provide good quality content and limit yourself with their content.

When you have found useful repositories, you need to see how to integrate resources to your teaching. Take note if the resources are free to use or you (your school) should pay for using them. Check if it is allowed to adapt the resources to your purposes. Make sure that the resources can be used by your students. In addition, verify that the resources provide accurate information that comes from trustworthy sources and are otherwise high-quality. If you notice any repository-related biases (e.g., concerning the authors or financers) then it is possible that you need to discuss the bias with your students.

Before sharing the resources with your students, learn if the resource data is up-to-date, with all links working, and if students are required to create an account or install an app, and what kind of data is collected from the users. If necessary, the resources need to be adapted in order they would be appropriate for your students, meeting the curriculum requirements. In some cases it is better to team-up with your colleagues and to develop and maintain the resources jointly. In addition, educational resources should be properly annotated, allowing richer and more interactive experiences for students. Annotation can also allow students to support other students when working in teams, or allow them to provide feedback about the usefulness of the educational resource and suggest improvements. Read more about annotating educational resources: web.hypothes.is/blog/annotating-educational-resources/.

In time you and your colleagues will have gathered a number of useful digital resources that could be helpful for other teachers. For this, it is a good idea to organize the resources based on subject, grade level, lessons, etc., and to share them publicly. This can be done either through existing repositories or, in some cases, through a shared online document (for example, a Google Drive document).

Read about efficiently managing digital educational resources:
hapara.com/blog/how-to-use-digital-education-resources-effectively/.

Co-creating digital resources

The difficulty of creating digital resources depends on the complexity of your resources. Worksheets and simple quizzes are easy to develop, even without proper planning. However, things get more difficult when you are aiming at providing your students (or other teachers) with more thorough resources. For example, you might want to develop a course of lessons that make use of the ideas of gamification. Or maybe you would like to create a series of video-lessons that include animated content? In these cases you should consider involving your colleagues or experts of other areas through co-creation. In educational co-creation, all participants are equally represented in shaping the end product, while in the process their best skills are employed as needed. For example, if you are going for an educational app, then you should have both strong didactics and good software developers in your team.

Next, when you have assembled your team, you would need to start properly planning the co-creation process to ensure quality, relevance and sustainability of your educational resources. For example, you could make use the following process planning model: (a) plan; (b) choosing a tool; (c) addressing accessibility; (d) if necessary, using other resources; (e) sharing; and (f) at a later time, updating and evaluating your resource[15]. Read more about creating a digital educational resource: libguides.wpi.edu/oer/create.

Besides including advanced elements to your educational resources, you should consider also including advanced approaches, such as gamification that could make learning more fun and engaging for your students. According to Buljan (2021): "*Gamification is using gaming strategies to improve learning and make it more engaging for individuals. Gamification for learning can be beneficial because games instill lifelong skills such as problem-solving, critical thinking, social awareness, cooperation, and collaboration. Games also motivate individuals, increase interest in certain subjects, reduce the rate of attrition among learners, improve grades, and enhance their cognitive abilities.*" Read more about using gamification in development of digital educational resources: elearningindustry.com/gamification-for-learning-strategies-and-examples. And also, if you should find that your ideas can be best delivered to your students via an app, then please read this: shakuro.com/blog/how-to-create-an-educational-app-and-how-much-it-costs.

Sharing Digital Resources

Before starting to share your resources, make sure that they are adequately annotated. More complex educational resources may become difficult to follow and understand for students. In a classroom, the student is able to ask for an explanation when needed. With digital educational resources the teacher support needs to be provided in a different way, for example, through annotations. Tseng (2021)[16] suggests that 58% of student engagement is associated with teacher annotation scaffold. When you annotate your resource you should consider the following: the purpose of annotating is increasing student engagement with the resource; increased engagement expands student learning by guiding their thinking about the subject learned – helping achieve mastery in a subject; when annotating your resources, ask how you would explain the topic to a friend; use simple words and help students draw connections between what they already know and what they are learning.

Over time when you have built up a reasonable number of resources, you would perhaps like to share your works through a dedicated repository, instead of emailing the resources one-by-one to your students or colleagues. Repositories can improve access to your digital learning resources and allow you to disseminate your work beyond the direct boundaries of your classes or schools. Setting up a repository allows students to more easily access learning materials but also enables your colleagues to both learn from and contribute to your resources. Starting a simple repository is quite easy. First of all, in many educational platforms you can use your own account as a repository of your resources. But creating a separate repository on your webpage is also easy. For example, to create a H5P repository[17] you would only need to (1) use H5P authoring tool h5p.org/testdrive-h5p; (2) add a plugin h5p.org/getting-started to your existing publishing system – WordPress, Moodle or Drupal; and (3) add materials.

Take note that when publishing your resources, they should contain information about the copyright conditions you have chosen. Read about it in 2.3.3 – Protecting and Sharing Resources.

---

[15] Worcester Polytechnic Institute (2022). Open Educational Resources: Create. http://libguides.wpi.edu/oer/create

[16] Tseng, S. S. (2021). The influence of teacher annotations on student learning engagement and video watching behaviors. Int J Educ Technol High Educ, 18(7). https://rdcu.be/cPIG4

[17] See also: www.youtube.com/watch?v=STK7QXsfesI

Assessment

Another important DigCompEdu area is "Assessment" that describes the possibilities and strategies for digital assessment, giving feedback, analyzing proof, and planning. Similarly to the Digital Resources area, teachers need to become aware of different approaches and evaluate the usefulness of these in their own teaching practices. In the STEAM Upgrade modules assessment and feedback are realized through interactive tasks that are created in GeoGebra and H5P environments.

Next we will present a summary with key concepts, activities and resources that can be used in addition to using the STEAM Upgrade modules in order to develop one's digital competence in the area of Assessment.

In order to support students' learning, it is very important to get an overview of their level of development, abilities, interests, progress and learning difficulties. Getting such information is important not only for the teacher but also for the students. From the point of view of learning, the speed and frequency of receiving such feedback is also important - the more often we receive feedback about our learning, the better we can plan our learning activities, and the feedback we receive directly during the activity helps us to correct our activities immediately. Based on these notions, assessment can be categorized as follows:

- Formative assessment[18] – a wide variety of methods that teachers use to conduct in-process evaluations of student comprehension, learning needs, and academic progress during a lesson, unit, or course. Formative assessments help teachers identify concepts that students are struggling to understand, skills they are having difficulty acquiring, or learning standards they have not yet achieved so that adjustments can be made to lessons, instructional techniques, and academic support.
- Summative assessment[19] – is used to evaluate student learning, skill acquisition, and academic achievement at the conclusion of a defined instructional period – typically at the end of a project, unit, course, semester, program, or school year. Generally speaking, summative assessments are defined by three major criteria:
  - The tests, assignments, or projects are used to determine whether students have learned what they were expected to learn. In other words, what makes an assessment "summative" is not the design of the test, assignment, or self-evaluation, per se, but the way it is used—i.e., to determine whether and to what degree students have learned the material they have been taught.
  - Summative assessments are given at the conclusion of a specific instructional period, and therefore they are generally evaluative, rather than diagnostic—i.e., they are more appropriately used to determine learning progress and achievement, evaluate the effectiveness of educational programs, measure progress toward improvement goals, or make course-placement decisions, among other possible applications.
  - Summative-assessment results are often recorded as scores or grades that are then factored into a student's permanent academic record, whether they end up as letter

[18] www.edglossary.org/formative-assessment/
[19] www.edglossary.org/summative-assessment/

grades on a report card or test scores used in the college-admissions process. While summative assessments are typically a major component of the grading process in most districts, schools, and courses, not all assessments considered to be summative are graded.

- Summative assessments are commonly contrasted with formative assessments, which collect detailed information that educators can use to improve instruction and student learning while it's happening. In other words, formative assessments are often said to be for learning, while summative assessments are of learning. It should be noted, however, that the distinction between formative and summative is often fuzzy in practice, and educators may have divergent interpretations and opinions on the subject.

Focusing on assessment is important for the development of teaching and learning processes. Assessment enables teachers and students to draw inferences from the information obtained and act accordingly. Such actions may aid in making the necessary improvements to teaching and learning, or simply provide a picture in time of students' competence or achievement. (Monteiro et al., 2021)[20]

Effective assessment should be based on evidence and should lead to evaluation that is meaningful, relevant, and fair to students. Assessment process should consider the following in order to minimize possible biases (Suskie, 2019)[21]: (1) take your time; (2) plan assessments carefully; (3) provide students with tasks with crystal clear meaning; (4) remove unintended bias; (5) let your colleagues with different perspectives to review your assessment tools; and (6) before using large-scale assessment tools, test them with a small group of students. The assessment methods you are using, should[22]: (a) be reliable; (b) allow standardization; (c) give valid results; and (d) be practical.

Formative assessment can make a good use of digital educational tools. These tools can capture and store student progress with digital educational resources. The data, gathered through these means, allows easier analysis for recognizing learning behavior patterns and requirements. In addition, this data provides teachers with real-time feedback about their students' learning progress. Using advanced digital educational tools could lead to remarkable saving of teacher time by providing automated grade assignments or quizzes. In theory, with the help of big data and artificial intelligence technologies, students can be provided with individualized learning goals and content adjustments in real-time, based on student activity and progress.

Creating digital educational quizzes and polls

Quizzes and polls are two common methods for testing student knowledge. One of the easiest ways of creating digital quizzes and polls is using Google Forms. Read the beginner's guide about using Google Forms: www.howtogeek.com/434570/the-beginners-guide-to-google-forms/. More complex educational resources, however, use specialized tools. One of them is H5P. The H5P

[20] Monteiro, V., Mata, L., & Nobrega Santos, N. (2021). Assessment Conceptions and Practices: Perspectives of Primary School Teachers and Students. Front. Educ. doi.org/10.3389/feduc.2021.631185

[21] Suskie, L. (2019). 6 Ways to Ensure Your Assessment Practices are Fair and Unbiased. The Wiley Network. www.wiley.com/network/featured-content/6-ways-to-ensure-your-assessment-practices-are-fair-and-unbiased

[22] www.algonquincollege.com/profres/assessing-students/qualities-of-good-assessment-practices/

interactive content tool includes several content types for making quizzes. The simple Quiz content type allows for a single question. For a series of questions, use Question Set. You can also embed questions into Course Presentation and Interactive Video. If used within Moodle, students' results from the activity are recorded in the module grade book. H5P activities may easily be exported, and recreated in other Moodle Module Spaces. You might also want to consider Moodle Quiz as an alternative, as this provides more sophisticated features such as question banks, randomized selection of questions, and certainty-based scoring. Read about using H5P quizzes: vucollaboratehelp.vu.edu.au/help-guides/interactive-tools/h5p-interactives/176-using-the-h5p-question-set-tool and h5p.org/tutorial-question-set.

Using polls is a simple method to engage students, allow them to express their opinions and to get an overview of their peers' opinions while staying anonymous in order to avoid peer pressure. One of the popular polling tools is Kahoot, a website that is based on the principles of gamification. The aim of Kahoot is to make learning more fun and engaging, while being accessible to learners of different backgrounds and age groups. Read a step-by-step guide about creating a Kahoot poll: streamyard.com/blog/live-streaming-tutorials/how-to-run-polls-trivia-on-live-streams-using-kahoot/

Benefits and Risks of Digital Surveys and Quizzes

Traditional quizzes and surveys are done using paper. Usage of digital evaluation approaches, due to their novel nature, involves both various risks and benefits. For example, digital evaluation can have dissonance between respondents' measured knowledge and their actual knowledge. However, using digital evaluation can be a lot cheaper to conduct and manage and the results can be easier to analyze, compared to the traditional approach. Studies (Ugboaja et al., 2021)[23] point out that digital quizzes and surveys can help save time for both students and teachers, are more natural for contemporary students, have reduced cost and can provide detailed results. In addition, it is easy to include helpful features with digital resources and in general, they are easier to use. However, the limiting factors include scoring discrepancy, reliability of digital environment and demand for fast internet (with enough data in case of students' private mobile devices).

Depending on the course's structure (i.e., do the quizzes replace traditional methods – or are they used as an additional tool for measuring student progress?), quizzes and surveys can be perceived as an additional workload by students. However, digital methods may have an engaging influence on students, resulting in higher learning outcomes. (Salas-Morera et al., 2012)[24]

As the exact benefits and risks of using digital surveys and quizzes depend heavily on the quality of integrating these tools to curriculum, their implementation should be preceded by a thorough planning process. Read more about advantages and disadvantages of using online surveys: www.cvent.com/en/blog/events/advantages-disadvantages-online-surveys. Read more about the problems of planning an educational innovation: www.mifav.uniroma2.it/inevent/events/idea2010/doc/47_7.pdf.

---

[23]Ugboaja, U. C. A, Adene, G., Iweama, W. C., Adannaya, S. I., Agu, J. A., Inya, O. U. (2021). Administering continuous assessment using google forms: advantages & disadvantages. 2nd ASUP Unwana International Conference. Akanu Ibiam Federal Polytechnic, Unwana. https://www.researchgate.net/publication/355927551

[24]Salas-Morera, L., Arauzo-Azofra, A., & Arauzo-Azofra, L. (2012). Analysis of online quizzes as a teaching and assessment tool. Journal of Technology and Science Education. www.redalyc.org/pdf/3311/331127613005.pdf

Summative assessment with digital technologies

Summative assessment is generally done via standardized tests, aiming at identifying, demonstrating and analyzing the knowledge and skills that learners have acquired after their studies. These tests are highly controlled and regulated, having a huge impact on a student's educational attainment. One bad test score can greatly influence a learner's educational opportunities. Compared to formative assessment, there are significantly fewer summative evaluation solutions. Standardized multiple-choice question formats retain dominance, resulting in over-reliance on simple, highly structured problems with finding facts and using algorithmic solutions. However, by using digital technologies, it is possible to use complex data sets, moving closer to supporting more effective ongoing learning. (Oldfield et al., 2012)[25]

A more thorough overview about the problems of ensuring high-quality summative assessment can be found here: ctl.utexas.edu/sites/default/files/digiassass_eada.pdf and here: http://www.jisc.ac.uk/whatwedo/projects/reaq.aspx.

Crosswords and tests are types of summative assessment that are relatively easy by teachers to integrate to their daily classroom practices. Crosswords can increase student self-confidence and their self-motivation to learn and study more. In addition, compared to other assessment forms, crosswords have the potential of easing student anxiety. (Seikaly, 2017)[26]

When using crosswords as summative assessment tools for students, the teacher should decide whether to provide students with a word list. The crosswords should be designed so that an average student would be able to solve them without teacher help. Teachers can involve more active students in the process of designing relevant crosswords. (Spencer-Waterman, 2009)[27]

There are several educational platforms that enable creating and using crosswords. For example, in H5P "the crossword is highly customizable allowing you to configure all colors, upload a background image, decide how scoring should work and even randomize the words in it so that your audience gets a new crossword each time if you want" (h5p.org/content-types/crossword). In Moodle crosswords are included in the Game module (docs.moodle.org/400/en/Game_module), although its use can require help from educational technologists. In addition, there are plenty of separate crossword engines – you can find them with Google Search (search for "educational crossword").

Summative assessment may require more complex testing that is also possible to achieve via, for example, H5P. It is possible to combine multiple types of tasks (quizzes, crosswords, question-sets) in a linear way, but it is also possible to use tests that take into consideration the level of skills and knowledge of students, allowing automatically personalized tests by following the branching scenario. Learn more about the branching scenario: h5p.org/branching-scenario.

[25] Oldfield, A., Broadfoot, P., Sutherland, R., & Timmis, S. (2012). Assessment in a Digital Age: A research review. University of Bristol. www.bristol.ac.uk/media-library/sites/education/documents/researchreview.pdf

[26] Seikaly, K. (2017). Teaching With Educational Crossword Puzzles Based on Research. blog.mycrosswordmaker.com/teaching-with-educational-crossword-puzzles-based-on-research/

[27] Spencer-Waterman, S. (2009). Differentiating Assessment in Middle and High School English and Social Studies. Routledge.

Benefits and challenges of digital assessment

Digital technologies offer a number of benefits to assessment. However, it is equally important to understand the accompanying challenges and threats, due to its significant influence on determining students' future. Of the beneficial side, assessments with the use of digital technologies have been demonstrated to (Oldfield et al., 2012)[28]:

- Provide rapid feedback; real-time feedback can quickly offer diagnoses and reduce misconceptions, providing opportunities to novel useful forms of teacher-student dialogue, assessment experience improvements, and increased student engagement.
- Increase student autonomy, agency and self-regulation; personalized responses to student work and progress can facilitate self-evaluative and self-regulated feedback.
- Support collaborative learning via peer assessment, collaborative knowledge building, co-evaluation and social interaction.
- Widen measurement range via novel ways of presenting and visualizing complex data and models. For example, by using simulations, it is possible to measure simultaneously computer skills, decision making and strategy processes.
- Provide flexible and appropriate responses via enabling students to choose the time and place for accessing assessments.
- Increase efficiency and reduce teachers' workload via improved data management and environmentally friendly administration.
- Improve student performance via quick feedback.
- Integrate formative and summative assessments via integrating assessment with instruction.
- Improve assessment validity and reliability.

There is also, however, plenty of evidence about challenges in assessment, introduced by digital methods. In its nature, assessment is a delicate area, due to its consequences to students' future. The challenges can be directly technology-related (e.g., the usability of technology) but can also be related to working out reliable methods of using technology for assessing students. These challenges include (Oldfield et al., 2012)[29]:

- Practitioner concerns about plagiarism detection and invigilation issues.
- Scalability and transferability problems.
- Reliability and validity concerns (e.g., how to ensure equality with random questions).
- User identity verification and security issues.
- Lack of tested assessment strategies.
- Investment costs.

Lack of suitable physical space for digital assessment.

Research on developing teachers' digital competence

Universities have studied the influence of STEAM training, conducted as either in-person or online courses, on the development of teachers' digital competence. Next we present short overviews of

[28] Oldfield, A., Broadfoot, P., Sutherland, R., & Timmis, S. (2012). Assessment in a Digital Age: A research review. University of Bristol. www.bristol.ac.uk/media-library/sites/education/documents/researchreview.pdf

[29] *ibid.*

two academic articles. The first paper studies the influence of using STEAM Upgrade online modules on teacher-students' digital competence, and the second one examines how creating digital resources and using them in classrooms would impact teachers' digital competence.

Growth of student digital competence as a result of the STEAM Upgrade course

In order to understand if students' digital competence grew because of the course, it is necessary that (a) the course has a long-enough duration for students to apply their new knowledge, and (b) students would assess their digital competence before and after the course, using the SELFIE or some other DigCompEdu-based questionnaire. Due to using self-assessment, it can happen with some students that their initial assessments are overestimated in some areas and they would become more realistic in their self-assessments during the course.

A paper by Heinmäe et al. (2021)[30] suggests that the average teacher's digital competence still falls short of the level needed to teach in technology-rich classrooms. Teacher-students need the skills and knowledge to enhance their lesson plans and activities with technology. Educational robots can be used to improve the digital literacy of teacher-students to support their problem-solving, communication, creativity, collaboration and critical thinking skills. Together with STEAM kits, learning robots offer good opportunities to teach subjects such as mathematics, chemistry, biology and physics. The purpose of the case study was to find out whether robot-enhanced training could promote the development of teacher-students' digital competence and which learning robots or STEAM kits teachers-students prefer to use in learning activities. In the study, digital competence of the participants of three different (albeit similar) teacher training courses was measured before and after the courses, using a self-assessment tool. The overall durations of the courses were 78, 156, and 156 academic hours. As the courses took place during the COVID-19 era, they were first conducted in the in-person, then in the hybrid, and last in the distance learning form. The authors used the European Digital Competence Framework for Educators to assess the competence of teacher-students in four domains (digital resources, teaching and learning, empowering learners, facilitating learners' digital competence) before and after a robot-enhanced training course. The results demonstrated that activities with learning robots (practical experiments and creating innovative lesson plans) supported and developed the digital competence of teacher-students. Their digital competence grew in all four observed DigCompEdu areas. However, some of the study participants rated their digital competence in the context of teaching and learning much lower after the course, most probably because they acquired a more realistic understanding of their capabilities during the course. In conclusion, the authors recommended that using learning robots or other STEAM kits could help develop teachers' digital competence.

Influence of the training course duration on participants' digital competence development

The study by Heinmäe et al. (2021) did not find remarkable differences in participants' digital competence development when comparing training courses of different duration. This notion is important because shorter training courses would allow training more teachers and

[30] Heinmäe, E., Leoste, J., Kori, K., Mettis, K. (2022). Enhancing Teacher-Students' Digital Competence with Educational Robots. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R., Obdržálek, D. (eds) Robotics in Education. RiE 2021. Advances in Intelligent Systems and Computing, vol 1359. Springer, Cham. https://doi.org/10.1007/978-3-030-82544-7_15

teacher-students with less resources. In order to confirm the observations of Heinmäe et al., a study was conducted by Leoste et. al (2022)[31]. The study examined two teacher professional development (TPD) programs that were based on Tallinn University's curriculum of in-person training courses. The volume of these original courses was 40 contact hours each, and the aim of the courses was conducting co-design courses for early childhood teachers on STEAM integrated learning activities. The TPD programs were designed as online courses, but in two different duration: 11 months (similarly to that of the courses before the COVID-19 era) and 4 months (adapted to the participants' COVID-19 era needs). The long-format course had 31 participants and the short-format course had 50 participants. The participants' digital competences were measured before and after the both courses, using a self-assessment survey that was based on the DigCompEdu framework. In addition, structured live video presentations were used to allow participants retrospectively reflect on their learning experiences. According to the results, the participants of both courses had improved their digital competences and achieved the learning outcomes set by course content. There was no significant difference in increase of digital competences or the way the course was perceived between participants of both courses. However, with the short-term training course the share of beginners among the participants decreased more vigorously. In addition, the increase of experts was greater than with the longer training course. The participants' feedback suggested that the long-term courses could yield better results in increasing participant motivation, developing their self-analysis skills and changing their teaching practices. However, it is also possible that some of these developments (or maturation of knowledge) can be achieved outside the training format naturally, when teachers apply their new knowledge in their classrooms. If so, this would allow saving resources when shorter-term training courses were conducted instead of long-term ones, provided that a reasonable follow-up training is offered in order to prevent competence decay. These results lead the authors to suggest that achieving desired outcomes with STEAM courses is also possible with shorter duration online courses, in turn making it possible to save both financial resources and teachers' time, while allowing more teachers in a shorter time to become digitally competent.

The Digital Competence Framework for Educators (DigCompEdu) offers a comprehensive methodology for assessing digital competencies related to STEAM teaching and learning. One crucial area of the framework is "Assessment," which addresses digital assessment, feedback, analysis of proof, and planning. In the STEAM Upgrade modules, assessment and feedback are achieved through interactive tasks in GeoGebra and H5P environments. To determine students' progress in STEAM competencies, teachers need to understand their level of development, abilities, interests, progress, and learning difficulties, and the frequency of receiving feedback is critical.

Assessing the components of a STEAM-Eco requires a holistic approach that considers multiple factors, including collaboration opportunities, problem-solving approaches, learner ethos, expert connections, and access to resources. The assessment should also be ongoing and iterative to ensure that the STEAM-Eco is continually evolving and meeting the needs of learners and stakeholders.

---

[31]Leoste, J., Lavicza, Z., Fenyvesi, K., Tuul, M., & Õun, T. (2022). Enhancing Digital Skills of Early Childhood Teachers Through Online Science, Technology, Engineering, Art, Math Training Programs in Estonia. Frontiers in Education, 7:894142. doi: 10.3389/feduc.2022.894142

Assessing the components in STEAMupgrade project's STEAM Ecosystem (STEAM-Eco) requires a multi-faceted approach that examines the following:

- Opportunities for collaboration: To assess opportunities for collaboration, it is important to evaluate the frequency and nature of collaborations among teachers, students, and external partners. This assessment should also examine the infrastructure in place to support these collaborations, including digital platforms, physical spaces, and communication channels.
- Multi-faceted problem-solving: To assess multi-faceted problem-solving, it is important to examine the nature and complexity of problems, ideas, and projects that are being tackled within the STEAM-Ecosystem. This assessment should also examine the extent to which multiple perspectives and approaches are being considered and the degree of collaboration that is required to address these challenges.
- Ethos of exploration: To assess the ethos of exploration within the STEAM-Eco, it is important to evaluate the degree to which learner curiosity, inquiry, innovation, and creativity are driving the learning process. This assessment should also examine the extent to which learners are encouraged to take risks, experiment, and engage in self-directed learning.
- Connections with experts: To assess connections with experts and creative actors in the fields of potential inquiry, it is important to evaluate the extent to which learners are engaging with external partners and experts to deepen their learning. This assessment should also examine the nature and quality of these connections, including the degree of collaboration and mentorship involved.
- Access to tools and materials: To assess access to a wide variety of tools, materials, and technologies, it is important to evaluate the availability and quality of these resources within the STEAM-Ecosystem. This assessment should also examine the extent to which learners are encouraged to invent, redesign, think-with, and make-with these tools, materials, and technologies.

5. Using a virtual STEAM laboratory and online repository

STEAM learning, as mentioned above, is based on the constructivist learning theories. Contrasting the behaviorist theories that saw students to memorize the instructions and information given by the teacher, the constructivist methods encourage students to construct their own understanding by merging knowledge with skills when individually experimenting with learning content. This process of active knowledge construction is supported by the "constructivist practices" that are applied in the learning environment (usually in the classroom), helping students to understand abstract topics of science lessons. Utilizing the "learning by doing" concept, physical laboratories are important educational tools that allow students to combine their first-hand practical experience with theoretical knowledge. However, physical laboratories involve several problems:

- laboratories are costly to construct, maintain and equip, making learning in laboratories relatively expensive;

- conducting activities in laboratories is time consuming – this includes time spent on planning and using the laboratory, but also guiding students and evaluating their progress.

As a result, teachers tend to use laboratories for demonstration purposes, with little opportunity for students to conduct individual experiments – deviating from the constructivist approach.

One of the alternatives for physical laboratories are virtual laboratories, realized via digital technologies. In virtual laboratories, simulations are created via combining various digital technologies, such as virtual reality, augmented reality, artificial intelligence, and machine learning, allowing students to perceive a virtual laboratory similarly to a real-world laboratory[32]. These simulations of real-world events can be used to allow students cost efficiently to visualize and experiment with difficult concepts. In general, virtual laboratories can save teacher and student time, financial resources of schools and stakeholders, but also provide a safe environment for experiments that would be dangerous in the real world. With the advancement of digital technologies, virtual laboratories proved to be a viable alternative to physical laboratories during the COVID-19 era when distance learning was preferred to in-person learning.

STEAM Upgrade Virtual STEAM laboratory

The virtual STEAM laboratory of the STEAM Upgrade project is a virtual room in the MaxWhere environment[33], that has all the STEAM Upgrade learning materials and guides. MaxWhere is a universally available and easy to use 3D virtual platform with a captivating visual world, proven to support the reception and comprehension of virtually shared information, and to improve collaboration. It is not necessary to have virtual reality tools to visit this lab, only a PC with NVIDIA 1050 GPU (or better) is needed[34].

Guide For Using Steam Upgrade Workspace by Maxwhere

As a virtual laboratory, a space called “3D printing workshop" has been created in MaxWhere. The user manual is available here: https://www.maxwhere.com/blog/3d-printing-simulation

MaxWhere general user guide: https://docs.maxwhere.com/usersguide/index.html

The experience of a finnish teacher who made a virtual exhibition in the Maxwhere environment

The teachers who worked closely on the preparations of a virtual exhibition in the MaxWhere environment by uploading kindergarten projects and activating several presentation methods had an engaging and immersive experience. MaxWhere's 3D virtual platform allowed them to create a visually appealing and interactive environment for showcasing their STEAM in early childhood education projects. The platform's user-friendly interface made it easy for teachers to organize the

[32] Tüysüz, C. (2010). The Effect of the Virtual Laboratory on Students’ Achievement and Attitude in Chemistry. International Online Journal of Educational Sciences, 2010,2 (1), 37-53.
[33] https://www.maxwhere.com/
[34] https://www.maxwhere.com/get-maxwhere

projects, as well as to activate different presentation methods such as virtual consoles, various presentation methods, animations, and videos.

Moreover, since MaxWhere has been proven to support the reception and comprehension of virtually shared information, the virtual exhibition in the MaxWhere environment made it easier for viewers to understand and appreciate the projects. The immersive nature of the platform allowed viewers to explore the projects in a more engaging and interactive way, potentially enhancing their learning experience.

The use of MaxWhere to create a virtual exhibition of kindergarten projects was a rewarding experience for the teachers involved, as well as for the viewers who interacted with the projects. The platform's capabilities for creating immersive and engaging virtual environments would make it an ideal tool for showcasing and sharing STEAM learning experiences.

Online repository

A repository – a central location in which data is stored and managed. Educational repositories of digital educational material and learning objects allow teachers and students to store and retrieve educational resources to be used in virtual teaching and learning environments as well as in face-to-face educational spaces. They are also an important means of disseminating and evaluating the quality of educational resources produced by teachers. In its essence, a digital repository can be a simple Google Docs document that contains links to various learning materials. However, there are also dedicated platforms that contain works of thousands of teachers (and students). Some of these platforms are national or regional, for example, in Estonia, there is e-koolikott (https://e-koolikott.ee/), in Norway Nushub https://nushub.org/en , in Finland Peda.net https://peda.net/, in Austria Linz School of Education https://www.jku.at/en/linz-school-of-education/research/stem-education/steam-upgrade/, and in Spain, INTEF https://intef.es/ or Educalab http://educalab.es/RECURSOS and, at regional level, many others such as EducaMadrid https://www.educa2.madrid.org/ or Medusa https://www3.gobiernodecanarias.org/medusa/ecoescuela/recursosdigitales/

In addition, there are global online repositories, available to teachers and students all over the world. These repositories can be used both for using already existing materials, adapting them, but also for adding your own materials. Two large online repositories are GeoGebra (https://www.geogebra.org/) and H5P (https://h5p.org/). GeoGebra "*(a portmanteau of geometry and algebra) an interactive geometry, algebra, statistics and calculus application, intended for learning and teaching mathematics and science from primary school to university level. GeoGebra is available on multiple platforms, with apps for desktops (Windows, macOS and Linux), tablets (Android, iPad and Windows) and web*"[35]. The STEAM Upgrade online repository is organized as a GeoGebra book (Figure 20). In this book the chapters consist of online modules for different educational age levels, and of guiding materials for using the learning materials. The main book is in English and available at the following link: https://www.geogebra.org/m/mpznnga7.
In addition, the book is translated into following languages:

[35] https://en.wikipedia.org/wiki/GeoGebra

Estonian (https://www.geogebra.org/m/bdamvpxt),
Finnish (https://www.geogebra.org/m/eygxvzqj),
Norwegian (https://www.geogebra.org/m/ka6cxbhb),
German (https://www.geogebra.org/m/axux2rh4)
Spanish (https://www.geogebra.org/m/ctscyjjj) languages.

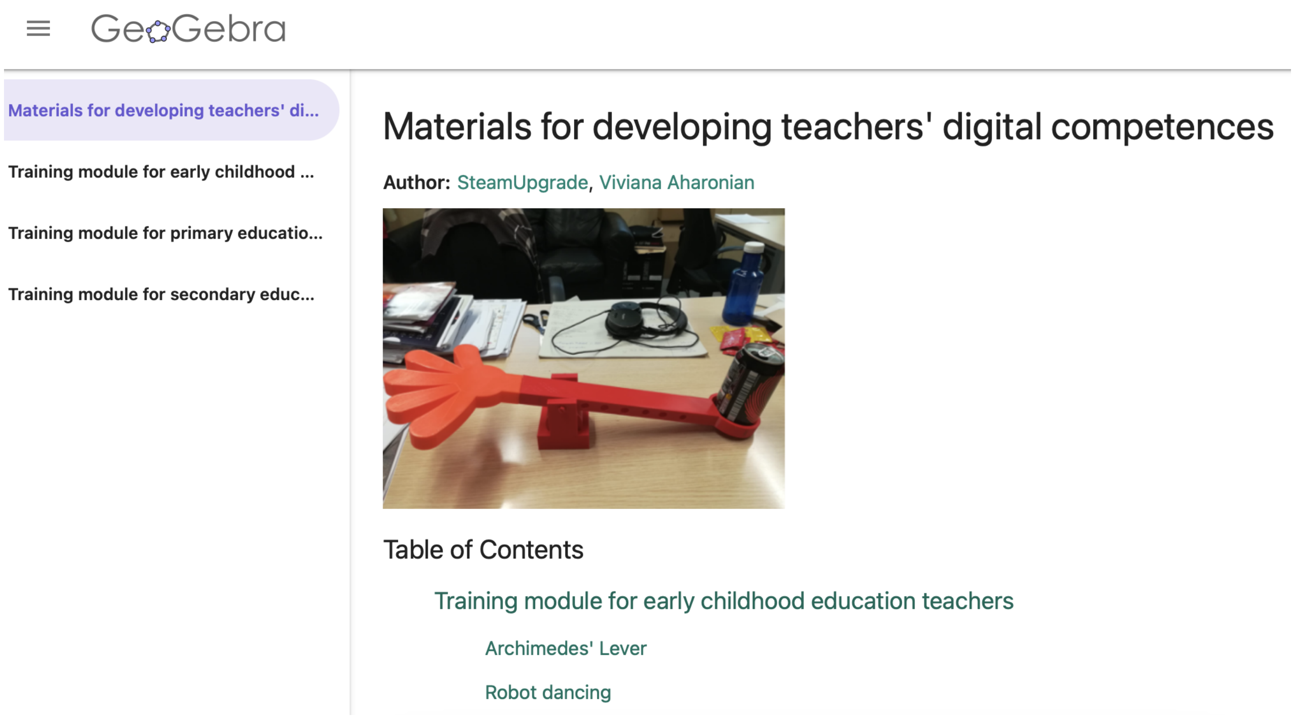


Figure 20. The STEAM Upgrade online repository in GeoGebra.

6. Teacher experience from teacher-training events related to piloting the STEAM Upgrade modules

Testing the pre-school modules in Madrid, November 2021

Figure 21. Photo by: Maire Tuul

One of the main problems encountered during the STEAM-Upgrade project was the incidence of the COVID-19 pandemics on the project development process. In particular, the face-to-face activities planned in the proposal could not be carried out during the first months of the project. For the Teaching Training event to be held in Madrid in November, there was a lot of uncertainty, because traveling restrictions were set and removed at a fast pace, depending on the medical conditions and the regulations established by the different countries. Nevertheless, the evolution of the pandemic seemed favorable, and it was decided to try to organize the Teacher Training event in a hybrid format. That way, if the sanitary conditions worsened, the event could take place completely on-line, if needed. Just a few days before the event, only one partner (TLU) had confirmed their attendance. In the following days, the rest of the partners jumped in, having an exponential increase in foreign attendants. Additionally, registration from local teachers evolved in a similar way, going from very few to a fair number, something that placed quite a bit of stress on the event logistics.

The second problem to be solved during the November meeting in Madrid involved *language*, since an appreciable percentage of the Spanish First Child Education teachers who signed up for the activity were not comfortable performing the activities in English. Therefore, two groups were established, for English and Spanish speaking teachers, again at the cost of complicating logistics and multiplying the needs for additional instructors for each of the planned activities.

Regarding this last issue, IO2 planned four activities, devoted to 3D printing, using robot-based choreographies & dance in First Child Education, designing robot-based gamified activities embedded into narratives and creating projection-based environments for creating (semi-immersive) activities, again based on a storytelling approach. In order to support the activities, a number of workshops about using tools were also planned, including issues such as modeling for 3D printing, educational robot programming both for line-following and push-button programmable robots, and creating and editing images and videos, including post-processing stages based on Adobe Creative Cloud.

Even though the last-minute changes affected the event preparation task, in general,the first child education teachers who attended the seminars learned the basic techniques practiced in the activity seminars, even designing their own activities. In that sense, the Teaching Training event results were satisfactory.

Testing the primary school modules in Stavanger, April 2022

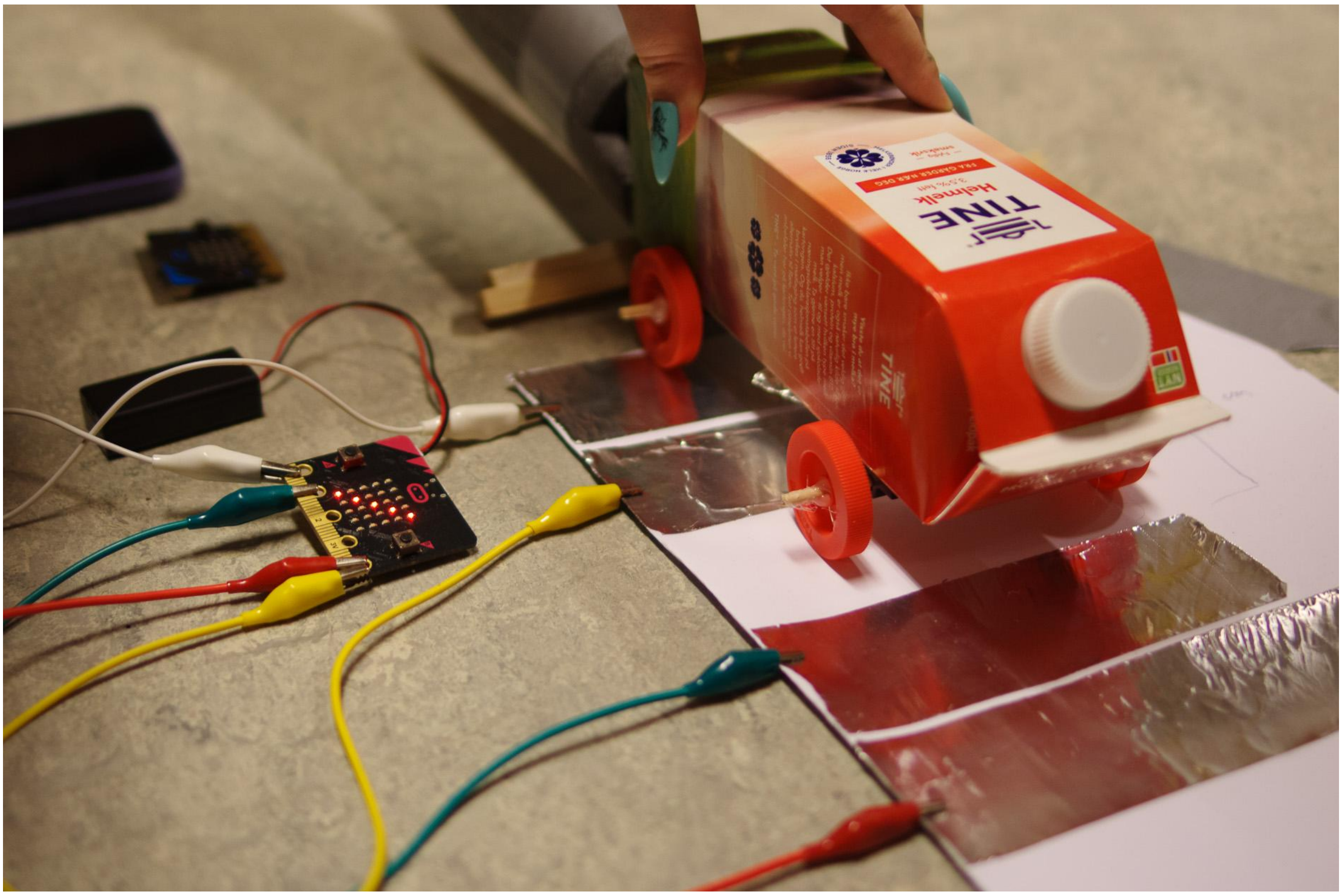


Figure 22: Developing a timing gate with the micro:bit microcontroller during the teacher training event in Stavanger, April 2022. Photo: F. Skarstein

Planning for the teacher training event in Stavanger in April 2022 started early, and an invitation with a preliminary agenda and a form for signing up was shared amongst the STEAM-upgrade members and relevant teachers early in the spring of 2022. Even though the COVID-situation had abated, Norway was still experiencing lock-down episodes in January, but in February/March the situation was fairly predictable and it was possible to let the event go ahead as initially planned.

The goal of the event was the piloting of four different STEAM-upgrade-developed modules for primary school, and was conducted in the well-suited premises of the UiS-run DDV (Digital Didactic Lab). The participants consisted of a mixed group of teachers and pre-service teachers from all the STEAM-upgrade member countries. The modules all involved practical hands-on activities, and were conducted in parallel, in order to be able to break the full number of participants down into groups of a more manageable size. Several assistants were involved in the execution of each module, in close interaction with the participants.

The run-through of each module during the workshop provided valuable feedback from the participants. This included feedback on the practical aspect of conducting the module, but also on the pedagogical content value of the exercise. Several adjustments, revisions and redesigns of the modules were done after the teacher training event, and the event therefore provided IO3 with useful feedback for its progression and final output. Also, the feedback from the participants during and after the event gave us the clear impression that this was a useful set of modules that they might want to use in their own practice in the future, and that the event in itself was very useful and inspiring in itself.

Figure 23: Participants of the April 2022 teacher training event in Stavanger, Norway. Photo: F Skarstein

Testing the secondary school modules in Linz, October 2022

This event, figure 24, served as a platform to test and present secondary education modules, inviting educators, students, and experts from various fields to come together and explore innovative educational topics. Aimed at creating a positive learning environment and promoting organizational development, these workshops for secondary school teachers covered a wide range of topics and addressed the areas of STEAM, sustainability, augmented reality, robotics, digital teaching materials, synchronous hybrid learning, and GeoGebra book development. The workshops were designed to spark curiosity and enthusiasm among participants and to emphasize the importance of creative integration and critical thinking in education. The first workshop, aptly titled "aMAZE me with STEAM and Level Up! Sustainability and Augmented Reality Mazes," was an engaging experience that seamlessly combined science, technology, engineering, art, and math (STEAM) with sustainability principles and augmented reality. Participants were fully immersed in an interactive learning environment where they were presented with innovative mazes that challenged them to solve complex problems while gaining a deeper understanding of sustainability practices. The workshop not only demonstrated the power of creative integration, but also encouraged learners to think critically and fostered strong environmental awareness. In the second workshop, "Robotics as a Promoter of Sustainable Development Principles in Education," participants delved into the world of robotics and explored its potential for promoting sustainable development principles within the curriculum. Cutting-edge robotics technologies were presented and their applications to solving real-world challenges were explored. The workshop emphasized the importance of incorporating sustainable practices into education and inspired educators and students alike to advocate for positive change. Through hands-on activities and collaborative problem solving, participants learned firsthand how robotics can shape the next generation and foster their ability to drive sustainable development. Given the rapid pace of technological advancement, sharing digital educational materials has become increasingly important in modern classrooms. This need was addressed in the third workshop, "Sharing Digital Educational Materials" The workshop provided a valuable platform for educators to share ideas, strategies, and resources to enhance digital learning experiences. Through collaborative discussions and hands-on demonstrations, participants discovered new and effective ways to use digital tools in their classroom practice. The workshop fostered a sense of community and collaboration among educators and illustrated the power of shared growth in the digital age. The fourth workshop, "Challenges in Synchronous Hybrid Learning," addressed the unique obstacles associated with this educational model that combines face-to-face and online instruction and took into account the emergence of synchronous hybrid learning. Participants engaged in thoughtful conversations, shared their experiences, and exchanged best practices. The workshop provided a supportive environment in which educators learned from each other and gained valuable insights for optimizing synchronous hybrid learning environments. By sharing solutions, the workshop paved the way for improved student engagement and personalized learning experiences in this evolving educational landscape. The event concluded with the fifth workshop, which focused on the development of GeoGebra books. These innovative resources combine mathematics with dynamic visualization, encourage student engagement, and deepen their understanding of mathematical concepts. The workshop highlighted the importance of creating interactive and accessible materials that cater to different learning styles. Equipped with new skills and ideas, educators left the workshop with the tools necessary to develop engaging GeoGebra books that will ultimately enrich math instruction in their respective classrooms. Overall, the October 2022 testing of modules for secondary schools in Linz proved to be an exceptional event that left a resoundingly positive impression on all participants. The workshops, which covered a wide range of topics including STEAM, sustainability, augmented reality, robotics, digital teaching materials, synchronous hybrid learning, and GeoGebra book development, illustrated commitment to innovation in education. Attendees left the event inspired.

Figure 24: Participants at the October 2022 teacher training event in Linz, Austria. Photo: B. Andjic

Mathematics teacher Kelly Paabut from Pirita Gymnasium of Economics:
"From October 26 to 30, 2022, I participated in the international training of the Erasmus+ project SteamUpgrade in Linz, Austria. The training was conducted at the Johannes Kepler University of Linz.

The practical training was aimed at middle level teachers. All the training days were very concise and experts in their field shared their knowledge and thoughts. They talked about different ways of enriching teaching with digital tools, using both well-known platforms and robots. All the participants were able to get hands on, test different educational materials, create them and share their experiences. In addition, hybrid learning and its various challenges were discussed at the training.

One part of the training was also a visit to the Ars Electronica center, where it was possible to see various exhibitions. The main topics were life science, environmental problems and preparation for upcoming technological developments that are likely to have an impact on society."

Participants of the October 2022 teacher training event in Linz, Austria. Photo: Sirly Väät

7. Summary

The document covers a wide range of topics related to the STEAM UPGRADE project and its online training modules.

Section 1 introduces the structure of the digital resources used in the training modules, providing an overview of how the content is organized and accessed.

Section 2 focuses on setting up the infrastructure for STEAM labs in universities. It includes information about shared STEAM laboratories, the process of establishing individual labs, and tips for efficient utilization of the laboratory space. The section also mentions specific STEAM laboratories at partner universities, such as Tallinn University EDUSPACE, University of Stavanger, University of Jyväskylä, Johannes Kepler University, Circus of Knowledge, Rey Juan Carlos University, MaxWhere, and Craftbot in education.

Section 3 delves into conducting workshops and implementing robot-integrated learning in kindergarten and primary school syllabi. It provides an overview of syllabi, shares teacher-student experiences, and highlights specific projects like the STEAM Upgrade I project focused on an astronomy game and the STEM Upgrade II project aimed at enhancing ICT skills in kindergartens.

Section 4 discusses the application of a digital competences framework in teacher-students' courses. It covers various aspects such as digital learning resources, creating and modifying educational resources, understanding license conditions, finding and managing digital resources, co-creating digital content, sharing resources, and different types of assessment, including digital quizzes, polls, and summative assessments. It also explores the benefits and challenges of digital assessment and presents research on developing teachers' digital competence and the growth of students' digital competence as a result of the STEAM Upgrade course. Additionally, the section examines the influence of the training course duration on participants' digital competence development.

Section 5 explores the utilization of a virtual STEAM laboratory and an online repository, highlighting their benefits and functionality within the STEAM Upgrade program.

Section 6 presents the experiences of teachers who participated in teacher-training events related to piloting the STEAM Upgrade modules. It mentions testing the modules in different educational settings, including pre-school modules in Madrid (November 2021), primary school modules in Stavanger (April 2022), and secondary school modules in Linz (October 2022).

Overall, the document provides comprehensive information about the structure, implementation, and outcomes of the STEAM UPGRADE project, focusing on digital resources, infrastructure setup, teacher training, and the integration of STEAM education in various educational levels.