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EDUSIMSTEAM | Erasmus+ KA3 Forward Looking Cooperation Project

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PREFACE

'Fostering STEAM Education in Schools' (EDUSIMSTEAM) is one of 27 innovative projects selected by the European Commission as part of the Erasmus+ Support for Policy Reform programme[1]. The main objectives of this project are to support new learning approaches using information and communication technologies and to develop high-level skills such as scientific, creative and critical thinking by integrating innovative practices in education with STEAM Education that supports the development of 21st century skills and multidisciplinary learning spaces. The EDUSIMSTEAM Project is a three-year pan-European project led by the Turkish Ministry of Education in collaboration with ten partner organisations from Ireland, Lithuania, the Netherlands, Portugal, Spain and Türkiye.

In this project the acronym STEAM stands for the combination of Science, Technology, Engineering, Arts and Mathematics disciplines in School Education. The project has been inspired by the reality that we are living in an every-changing world where:

> *"Education systems operate in a world that is constantly evolving towards new equilibria, yet short-term crises may disrupt, accelerate, or divert longer-term evolutions. Balancing the important and the urgent thus emerges as the key everyday task of today's education systems. To do so, successful education systems must harness the kinetic energy of the ever-changing world they inhabit, becoming more dynamic and agile to meet the needs of an increasingly diverse set of students.[2]"*

Therefore, there is an onus on education systems to constantly evolve and innovate to meet the needs of all in our society, but especially those in our school systems. EDUSIMSTEAM is operating at multiple levels by addressing the needs of students, teachers, curriculum developers, school leaders and policy makers in implementing integrated STEAM in their schools. The project is underpinned by the following principles to:

- Make education more challenging, and relevant, by providing opportunities for active learning and by increasing students' potential, across a range of phases of education and training, in primary and secondary schools, higher and further education and their professional careers and life-long learning.
- Inspire students, in primary and secondary education, to question the interdependency of topics/curriculum areas in order to develop an integrated understanding of how the world works.

[1] https://erasmus-plus.ec.europa.eu/programme-guide/part-b/key-action-3

[2] Education Policy Outlook 2021: Shaping Responsive and Resilient Education in a Changing World | Education Policy Outlook | OECD iLibrary (oecd-ilibrary.org)

- Provide opportunities for students' problem solving and creative design capacities to flourish by engaging with real-world problems in a holistic way, where they apply and re-apply prior knowledge in ever more realistic contexts. (For example, EDUSIMSTEAM provides opportunities for school students to contribute to solving real world-wide problems, such as urban planning in a simulated online environment).

A key project output is the development of a **STEAM Implementation Guide for Policymakers and Practitioners** that captures the key learnings from this project in relation to implementing integrated STEAM approaches in schools, so as to better support the development of key 21st century skills. In compiling this Guide, project partners engaged in a series of **consultations** with key stakeholders, in their countries, in relation to how STEAM approaches are being implemented in their schools. This consultation process has informed the project, and some of the high-level observations from these events are captured in this document. We have included a high-level analysis of the consultations throughout the document and we have included the key reflection questions at appropriate locations in the guide.

This Implementation Guide has been informed by the project activities and provides guidelines for ministries, schools, universities, and other stakeholders on how to implement an integrated STEAM approach in schools or in out of school settings **using EDUSIMSTEAM materials and approaches. The Implementation Guide concludes with several** observations and suggestions around implementing STEAM education in schools and these are designed to assist ministries, regional authorities and schools take a holistic implementation approach.

Driving Factors behind the EDUSIMSTEAM Project

From the inception of this project, it has been clear that the educational sector has received many stimuli to innovate itself over the last four decades. The main agenda for the EDUSIMSTEAM project has been to target an optimal balance between theoretical and ideological desires and pragmatic factors so that teachers could implement change in real-life school settings. In this regard the project considered three key issues in the early design phases:

- How to update the pedagogical soundness of schooling by making a better fit between the social-/cognitive developmental stages of learners of the 21st century.
- How teachers and school leaders could update their own competences, so they could address challenges in the future and realise their own life-long learning ambitions.

- To recognise that education needed to open its eyes to address the newly emerging societal trends and needs.

Within this context it should be noted that engagement with new technologies for their own sake was last factor in the minds involved in the EDUSIMSTEAM Project. Thus, the project was designed to apply emerging research and technologies, where they fit, to create educational experiences that reflected the challenges and complexity of the real world young people today live in. It therefore strove to be relevant to the needs of education and of society at large.

1. THE IMPORTANCE OF STEAM IN EDUCATION

STEAM education[3] is a contested acronym or term, despite having been devised by the National Science Foundation (NSF) in the United States in 1990. While the acronym might be new the foundations of STEAM education can be traced back to educators, such as Vygotsky (1920), Piaget (1940), Ausubel (1960), Bruner (1970) and Papert (1980) who increasingly diverted the attention from 'learning by heart' to a more meaningful learning that placed an emphasis on active learning in the real world. Jerome Bruner pioneered such approaches when he proposed a 'Spiral Curriculum' that offers a recurring conceptual scaffold from the preliminary (more concrete) to the later more abstract concepts approaches in education. From here the overall attention in education shifted towards 'thematic education' and finally the notion of 'constructivism'. It is interesting to ask why it has taken us almost 30 years to create the acronym STEAM but we can surmise that this has been influenced by the aggregation of the a number of factors, such as:

- The shift towards labour force that can act more autonomously and more creatively in an ever-increasing complex world
- New fields of expertise (i.e. ICT, Eco, new shapes of citizenship etc) needed to become accommodated in existing curricula and thematic education promised a way of dealing with this complex issue.

Thus, STEAM is the result of a long evolution that progressively sees the learner's mind as a wholistic constellation, where finally knowledge rests upon wide strands of associations, that are not necessarily hierarchic as we believed from the old Greek metaphysics as before. This idea of interdisciplinary education is increasingly seen as a key element of future school scenarios[4].

In this project we have developed a very clear definition of STEAM education[5], which states that:

> *STEAM is an interdisciplinary educational approach that engages students around the subjects of Science, Technology, Engineering, the Arts, and Math. It aims to promote students' higher order thinking skills, productive skills, and their innovative capacity (MoNE, 2016). Project-based learning through collaborative exploration, problem-based learning which focuses on solving real-world problems and place-based learning where students learn by doing are innovative*

[3] http://www.scientix.eu/documents/10137/782005/Scientix_Texas-Instruments_STEM-policies-October-2018.pdf/d56db8e4-cef1-4480-a420-1107bae513d5
[4] https://www.oecd.org/education/ceri/Brochure-Four-OECD-Scenarios-for-the-Future-of-Schooling.pdf
[5] https://edusimsteam.eba.gov.tr/?p=413&lang=en

> *approaches that support STEAM education. STEAM education covers the whole educational process including pre-school education and higher education.*

The OECD has stated that the *main purpose of STEAM education is to raise students who can solve real life problems with their interdisciplinary STEAM knowledge and 21st century skills*. This view aligns closely with the EDUSIMSTEAM Project where we see STEAM as an integrated approach, where students engage in project-based learning activities, that are cross-curricular, and enable them to engage with and solve real-world problems. The project believes that students and teachers, of all ages, should have opportunities to engage with STEAM education from early years right through to higher and further education and throughout their lives.

Consultation Findings

The project consultations unearthed a range of definitions and expectations when contributors were asked to define STEAM education. For some, they noted that they needed to create a new acronym in their language that aligned with what is meant by STEAM, so that teachers and others better understand what it means. There was widespread agreement among participants that STEAM education typically had the following features:

- It involves the integration of all 5 disciplines (Science, Technology, Engineering, Arts and Mathematics).
- It focuses on developing skills, such as problem solving, critical thinking, creativity, curiosity and much more (i.e., Key Competences or 21st Century Skills).
- It involves students and teachers collaborating and working together. This should see teachers co-designing and co-teaching STEAM activities also.
- It enables students to use technology, old and new technologies, to solve problems.
- It is a mindset, or a philosophy, that is designed to prepare young people for today's complex world.
- It is designed to motivate, particularly hard to reach students, to engage in meaningful real-world problems.
- It involves students actively taking responsibility for their own learning, where they make decisions, mistakes, and artefacts.

Multiple contributors stressed how important it is to provide students with opportunities to engage with STEAM education so they can experience the benefits of such approaches in school. Within schools it was noted that thematic integrated approaches (i.e., STEAM) are regularly found in the early years of primary school where teachers operationalise the thinking of educators, such as Johann Pestalozzi

and Maria Montessori. However, such approaches come under pressure as children mature and transition to secondary schools where they primarily experience the curriculum as subjects, for example in Math and Physics. It is at this juncture that real challenges emerge for schools in terms of how they organise their school timetables so that teachers, from different subject areas, can collaborate and coteach using STEAM approaches. While such approaches are undoubtedly challenging to organise and operationalise some schools are engaging in such practices and enabling their students to ask critical questions and to apply their knowledge to solve real-world problems.

Furthermore, some respondents noted that often STEAM education is offered outside of the formal school timetable and this can preclude some young people from experiencing STEAM and there is need to provide all students with such opportunities, not just those that are more advantaged.

Implementing STEAM in Schools

STEM/STEAM are often used interchangeably and there is no universal agreement in relation to a definition. It is a suitcase term that needs to be unpacked and defined, so that others know what we mean when we use the term. Furthermore, STEAM is often used as a synecdoche[6] for one or more of its constituent disciplines (referred to as STEAM domains in the EDUSIMSTEAM Project), particularly science (Bybee, 2013). This dilutes STEM to a generic label that can be applied to almost any subject outside of arts and humanities[7]. The EDUSIMSTEAM Needs Analysis Report found that not all teachers have the same understanding of STEAM education, something that is also reflected in the wider literature. There are additional challenges around the use of the term STEAM in schools, "*where the historical structure of schools, curriculum, instruction, and assessment in an educational system in which subject segregation has long been established*" (p.5)[8]. School systems are designed to teach subjects in silos and therefore the idea of taking an integrated approach can be challenging for teachers and for the structures in schools. The literature on STEAM proposes taking **an integrated approach** where teachers design learning activities that include one or more of the 5 disciplines. This idea of integrated STEAM, while desirable, is often challenging for teachers who lack the knowledge and confidence in all 5 disciplines to design and activate such learning activities.

While there are 5 disciplines included in the STEAM acronym (Science, Technology, Engineering, Art and Mathematics), teachers typically struggle with **Engineering** and **Technology** as these are not routinely treated as discrete subjects in the

[6] "a figure of speech by which a part is put for the whole" (https://www.merriam-webster.com/dictionary/synecdoche)

[7] https://www.atsstem.eu/resources/report-2-summary/

[8] https://www.frontiersin.org/articles/10.3389/feduc.2021.666608/full

school curriculum[9]. Teachers often don't possess the necessary knowledge (Pedagogical Content Knowledge) to teach integrated STEAM, as it requires a high level of knowledge and as a result, they often request clarity on what an integrated STEAM curriculum or learning activity might look like, so they have resources and an approach to implement[10]. Furthermore, there is a need to develop a STEAM mindset among all teachers, and they should engage critically with STEAM education at the earliest opportunity in their formation. Teachers, at all levels, need to critically consider what STEAM is[11] and why they should 'transform' their mindset and approaches. Such approaches need to ensure that teachers and parents don't just see STEAM as a fad or recent trend, and that it is essential in our complex digital world.

EDUSIMSTEAM provides such learning activities and a platform where teachers and their students can engage in a range of cross-curricular learning activities. In this project we believe that all teachers should be a STEAM teacher and therefore we need to provide supports to all teachers to engage in integrated STEAM activities. The project has developed a set or materials and approaches that schools can activate to make this happen.

Challenges Faced by Schools when implementing STEAM Education

We have found that teachers want explicit guidance on what to do when implementing STEAM with their students[12]. This can be a very common mindset at primary level where teachers tend to be generalists and teach Maths, Science and Art, in the wider curriculum fit to the age-level of the students. An added complication is that primary school teachers are often not qualified or equipped to teach Engineering or Technology. While at secondary school level teachers also face challenges to implement integrated STEAM approaches (ibid), as they are subject specialists, and they are required to teach a predefined curriculum. This is a major challenge, as often STEAM is not on the prescribed school curriculum at primary and second level and this raises questions around when and where teachers can engage in such learning activities.

If STEAM is not included in the curriculum and on the school timetable teachers may encounter challenges to teach in this way and/or to find time to plan with their fellow teachers to implement an integrated STEAM approach. The reality is that teachers merely teach STEAM subjects or topics in isolation, and they don't integrate the 5 disciplines to solve real-world problems. There can also be a

[9] https://doi.org/10.1186/s40594-018-0127-2
[10] https://www.frontiersin.org/articles/10.3389/feduc.2021.666608/full
[11] https://blog.acceleratelearning.com/the-pros-and-cons-of-stem-education
[12] This recently emerged during Focus Group conversations with teachers in Ireland also.

hierarchy in terms of the STEAM disciplines with Science and Mathematics taking precedence over Technology, Engineering and the Arts, as captured in Figure 1 below.

Figure 1, Weighted STEAM diagram

There is also some confusion around what is meant by **Technology** in the STEAM acronym. In many instances it refers to the use of digital tools (often referred to as ICT in the past and more recently as Digital tools/technologies) but there are also technology subjects, such as metalwork, graphical design etc. In some countries the **T** can include dedicated spaces, such as Maker Spaces, and related learning activities[13], that tend to take place outside of school. Similarly, challenges exist around Engineering, the **E**, and teachers often seek advice and guidance on how to use new technologies, along with integrated approaches to develop student 21st century skills. This is where EDUSIMSTEAM can help.

Consultation Findings

The consultations confirmed that integrated STEAM education is not very prevalent in schools in the partner countries and there are good reasons for this. Contributors listed a range of challenges, and these typically included:

- Lack of clarity in relation to what STEAM looks like in practice.
- Main focus in schools is often on teaching STEAM subjects separately and on performance in associated terminal examinations.
- Lack of facilities (i.e. suitable spaces) or underutilisation of same where they exist.
- Lack of equipment and resources (i.e. hardware – not just computers and learning activities).
- Lack of Time on the curriculum and lack of time to plan and to implement such practices in schools.
- Lack of qualified people (i.e. lack content knowledge) in schools
- Lack of opportunities for teachers, and others, to co-teach.
- Need to ensure teachers believe in STEAM, that they see the value in such approaches.

[13] https://www.frontiersin.org/articles/10.3389/fpsyg.2021.725525/full

- Student disengagement from school learning.
- Need to update the curriculum to reflect reality of today's world.
- Ensure it aligns for schools and VET.

The majority of contributors place a very high value on STEAM education and are keen to ensure that these challenges are addressed, so that young people are better prepared for today's world, and many identified the resources and approaches in EDUSIMSTEAM as having the potential to solve a number of these challenges.

Contributors to the consultation process considered the following questions and these should also be considered by organisations planning to implement an integrated STEAM approach, similar to that in EDUSIMSTEAM.

In planning for integrated STEAM, we would invite you to consider the following questions:

- What does STEM or STEAM mean to you and your colleagues?
- Do you have existing policies or guidelines on implementing STEAM in your school?
- Is STEM or STEAM referenced in other curricula (e.g. Digital, Maths, Science etc.)?
- Do you provide dedicated curriculum time to STEAM?
- Do teachers teach STEAM subjects in an integrated way?
- Do you provide time and resources to support teachers implement STEAM?

When our stakeholders considered these questions, they reported that a range of viewpoints. For those in the schools it meant the following:

- *STEAM refers to a set of interconnected fundamental subjects that are essential for developing skills to help students understand the world around us.*

While those in universities and the policy level described it as:

- *STEAM is a term created by combining Science, Technology, Engineering, Art and Mathematics sciences. The term is often used to describe an educational curriculum or approach that includes these topics and emphasizes the integration of science and technology with the arts and humanities. The aim of STEAM education is to provide a versatile education that prepares students for the challenges of the 21st century by developing their critical thinking, problem solving and creativity skills.*

STEAM education looks differently in schools from:

- *STEAM has potential for building 'civic' education (learning about society, law, polity, democracy, human rights, etc.)* ***So far STEAM does not yet penetrate to all other curricular domains****.* ***Each curriculum domain has its own relationship with STEAM****. For instance, recently we (I and my colleagues) built a 'canon' for the human body so that kids can draw better its proportions. Also****, teachers mention the value of STEAM for subjects in language teaching****.*

To

- *At a curricular level we have programming lessons. As a Complement to the curricula (optional subjects with no additional charges for parents) we have a subject related to mathematics, a subject related to science, and a subject related to arts. And extracurricular (with additional charges) we have Robotics and programming*.

The above are just examples of responses that we recorded, and it should be noted that there is no right or wrong answer. STEAM is viewed differently by many in education and hence there is a need to discuss what it means to you and your ministry, your school, or your university. Such discussions should ultimately focus on how learners are experiencing STEAM and how schools are equipped to implement STEAM. Such discussions should result in a shared understanding and a vision for what kind of educational experiences schools want to offer their students and this is a first step.

2. EDUSIMSTEAM – PRACTICAL SOLUTIONS IN ORDER TO MITIGATE THE BIG CHALLENGES

In Chapter 1 we shared some of the big challenges in implementing STEAM education in our schools. It should be noted that many of these challenges are embedded in the way we have designed curricula and our school routines (i.e. separate subjects, specialist teachers etc.). While many in education are acutely aware of these challenges, they are bigger than the EDUSIMSTEAM project and they will take time to resolve and in the process our education systems will evolve and change. However, this will take time, and, in the meantime, we need to offer schools practical solutions to address these challenges.

EDUSIMSTEAM is centred around an inquiry-based learning approach that showcases how a range of new technologies, such as Arduino, Raspberry Pi, and the BBC Micro:bit can support STEAM learning, as often these tools are *"not a self-evident tool for STEAM projects"*[14]. The project has stated that this *"is the reason that EDUSIMSTEAM needs to invest in didactic templates in order to work as a demonstrator for teachers who have the interest but might hesitate to start"* (ibid). In addition, the project has developed an online platform: SimuLearn, where teachers and students can solve a range of real-world problems even if they don't have access to the new technologies listed above. Schools want a range of supports including teacher training and access to practical examples of such real-world problems and spaces where they and their students can work collaboratively to solve these problems.

Aligning STEAM with the Digital Education Action Plan (DEAP)

STEAM education in Europe is closely aligned with The Digital Education Action Plan (DEAP) [15]. While the DEAP does not specifically refer to STEAM, many elements of the EDUSIMSTEAM Project align with elements of DEAP, specifically Action 10, the creation of a Council recommendation on improving the provision of digital skills in education and training and Action 13, Women's Participation in STEM Studies and Careers. Action 10 deals with issues such as Computational Thinking[16], which is specifically referenced in the EDUSIMSTEAM project. It also covers areas such as Informatics and the teaching of digital skills, which are also addressed in EDUSIMSTEAM materials. EDUSIMSTEAM anchors integrated STEAM education in the

[14] EduSimSteam Needs Analysis Report, p. 10
[15] https://education.ec.europa.eu/focus-topics/digital-education/digital-education-action-plan
[16] https://publications.jrc.ec.europa.eu/repository/handle/JRC128347

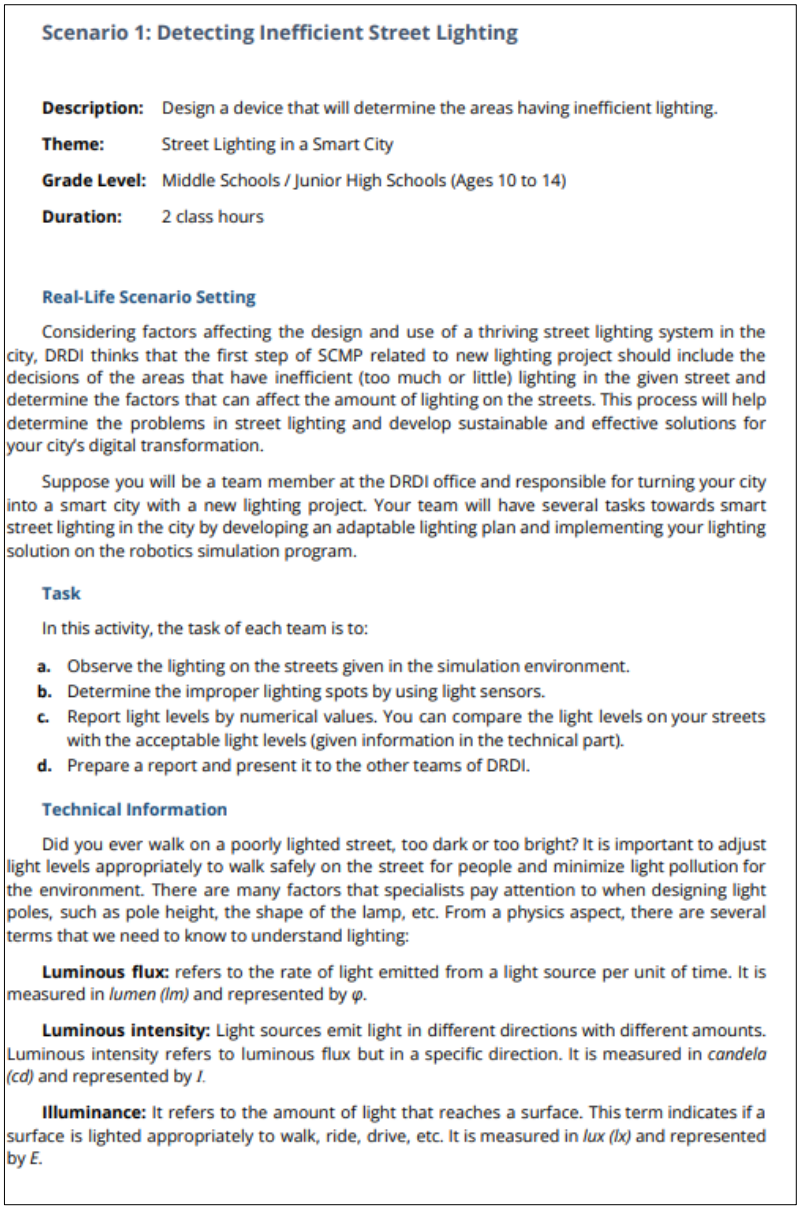
context of robotics education and computational thinking, where students can then use this knowledge to solve real-world problems in an online platform.

Providing Didactic STEAM Templates

The project carried out an extensive Needs Analysis to capture teachers' STEAM practices at the outset of the project and found that school leaders and teachers want clarity on how STEAM Education can be activated in schools. These STEAM templates are designed to help teachers taste and test the value of STEAM education by observing how their students react to these activities. To address this challenge the project developed a range of didactic templates[17] or learning scenarios to assist teachers get started. These scenarios are grouped thematically, and teachers have access to a set of activities where they are provided with all the information, they will require to activate the integrated STEAM activity with their students. Each scenario (see Figure 2 below) suggests the appropriately grade level, the amount of time required, the STEAM learning outcomes across all 5 disciplines and guidance on how to implement the activity in terms of teaching, learning and assessment activities. The document with a complete collection of 22 learning scenarios for simulating STEAM practices in SimuLearn can be accessed here and on the project website.

The example below, detecting inefficient street lighting, showcases that STEAM learning activities should be embedded in wider societal issues and in this case, it goes well beyond a mere Physics activity. A multitude of factors and disciplines including Physics, economic conditions, human perception, ensuring citizens are safe on the roads need to be considered. This is in reality an urban planning activity that has been designed to be accessible to teachers and students, depending on their levels of prior knowledge and comfort with the learning scenario. The learning scenario is a good example that any aspect of optimal human environment can be a good trigger for STEAM learning activities.

[17] https://stemeducationjournal.springeropen.com/articles/10.1186/s40594-018-0127-2



Scenario 1: Detecting Inefficient Street Lighting

Description: Design a device that will determine the areas having inefficient lighting.

Theme: Street Lighting in a Smart City

Grade Level: Middle Schools / Junior High Schools (Ages 10 to 14)

Duration: 2 class hours

Real-Life Scenario Setting

Considering factors affecting the design and use of a thriving street lighting system in the city, DRDI thinks that the first step of SCMP related to new lighting project should include the decisions of the areas that have inefficient (too much or little) lighting in the given street and determine the factors that can affect the amount of lighting on the streets. This process will help determine the problems in street lighting and develop sustainable and effective solutions for your city's digital transformation.

Suppose you will be a team member at the DRDI office and responsible for turning your city into a smart city with a new lighting project. Your team will have several tasks towards smart street lighting in the city by developing an adaptable lighting plan and implementing your lighting solution on the robotics simulation program.

Task

In this activity, the task of each team is to:

a. Observe the lighting on the streets given in the simulation environment.
b. Determine the improper lighting spots by using light sensors.
c. Report light levels by numerical values. You can compare the light levels on your streets with the acceptable light levels (given information in the technical part).
d. Prepare a report and present it to the other teams of DRDI.

Technical Information

Did you ever walk on a poorly lighted street, too dark or too bright? It is important to adjust light levels appropriately to walk safely on the street for people and minimize light pollution for the environment. There are many factors that specialists pay attention to when designing light poles, such as pole height, the shape of the lamp, etc. From a physics aspect, there are several terms that we need to know to understand lighting:

Luminous flux: refers to the rate of light emitted from a light source per unit of time. It is measured in *lumen (lm)* and represented by *φ*.

Luminous intensity: Light sources emit light in different directions with different amounts. Luminous intensity refers to luminous flux but in a specific direction. It is measured in *candela (cd)* and represented by *I*.

Illuminance: It refers to the amount of light that reaches a surface. This term indicates if a surface is lighted appropriately to walk, ride, drive, etc. It is measured in *lux (lx)* and represented by *E*.

Figure 2, Screen grab from the Deliverable 3.1 EDUSIMSTEAM Learning Scenarios for Schools

This structure should help teachers when planning their STEAM activities and it enables them to take a cross-curricular approach to solving real-world problems in a controlled environment. Moreover, for teachers and all interested in trying out the learning scenarios a document called '*EDUSIMSTEAM Guidance for STEAM Scenarios*' was developed as a roadmap to help with all the concerns they have when working in the STEAM education context.

Furthermore, the project developed an online platform[18] where teachers and students can work collaboratively to solve these scenarios. This resource is particularly valuable as it provides a self-contained environment where teachers and students, irrespective of the digital technologies available to them in their school, can engage in solving these problems. Teachers in such scenarios can act

[18] https://riders.ai/

of facilitators of learning and use the tools and the platform to support their students learning.

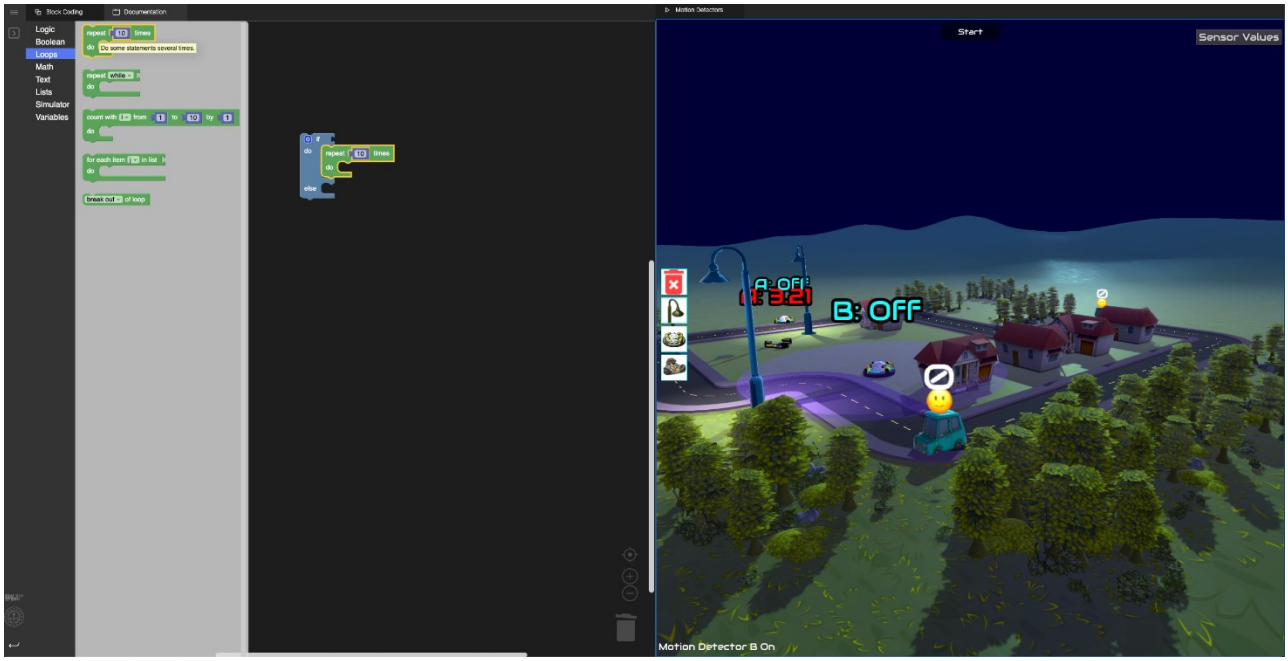


Figure 3, Image of online platform

Consultation Findings

The consultations identified a wide range of practices and challenges in relation to STEAM education across the partner countries and numerous contributors noted that schools often lack appropriate settings, resources, and teaching materials to engage in integrated STEAM activities. EDUSIMSTEAM has addressed these challenges by developing a series of differentiated learning scenarios and an online platform, where teachers and learners can interact with the environment and experience STEAM education in a very motivating way. These resources provide a sandbox for teachers and students to collaborate and develop their key STEAM competences and you can find more on this approach if you listen to the following podcast with Professor Erdinc Cakiroglu[19]. They are designed to be user-friendly and will enable teachers and students to explore and play while negotiating the process rather than focusing on the end product.

Providing STEAM Teacher CPD Materials and Activities

The Needs Analysis also identified the areas in which the participating teachers required additional Continuous Professional Development (CPD) so that they could better support students engage with the STEAM learning scenarios. The project created an online Moodle course, consisting of 30 hours training, to help teachers embed STEAM into their classroom practices and present the main principles for

[19] TeachNet Podcast Episode 7: https://cpd.h2.ie/teachnet-podcast07

STEAM Education. The online course consists of a number of self-contained modules, and it progresses from generic ideas in STEAM education in Unit 1 to helping teachers create their own robots using Arduino chip sets in Unit 4. The course materials can also be used to support in-person teacher training; however, this was not possible during Covid-19 and the participating teachers, in Türkiye and Spain, engaged online. However, the training materials are available online for others to use in their contexts.

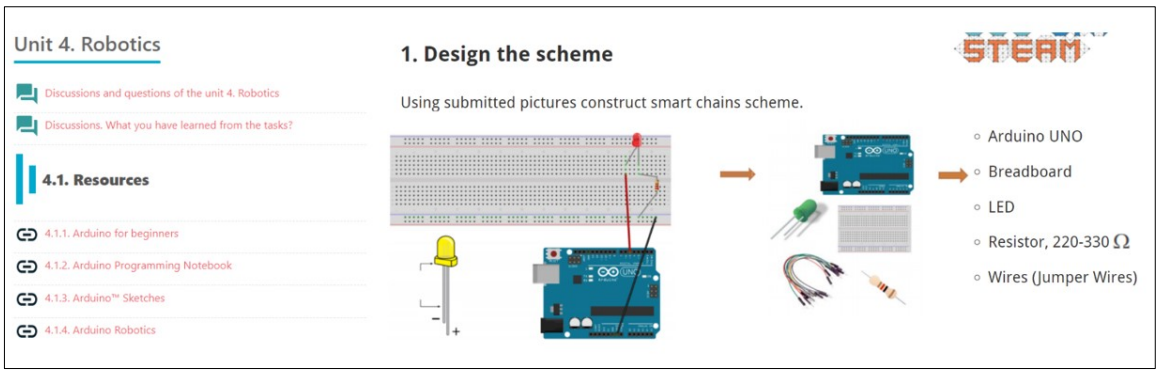


Figure 4, Screengrab from the EDUSIMSTEAM online Training Materials

There was tremendous interest in pilot trainings and 466 teachers (trainees) from Türkiye and Spain registered on the platform and 129 trainees successfully received their certificates of completion. Ultimately interested teachers need time and support to embed STEAM activities into their classroom and the project has evaluated the trainings and is about to embark on further teacher CPD activities in the coming months.

Consultation Findings

The consultations confirmed that many schools are already engaged in STEAM activities, such as robotic education, computational thinking, and computer programming/informatics. Computational thinking has been embedded in our project, but it is not the central focus. Furthermore, it should be a natural ingredient for learners if they are engaging with algorithms, simulations, and computation as part of a problem-solving approach. However, these activities are often engaged in as stand-alone activities are not always utilised to solve real-world problems, as in EDUSIMSTEAM. Multiple contributors noted that there is a need for enhanced teacher training supports and these materials can contribute to such actions. They can be used in multiple ways to develop specific skills in areas such as the creation and programming of robots or they can be adapted and localised for local contexts. Furthermore, the consultations confirmed that schools often struggle to find integrated learning scenarios that combine the various STEAM disciplines, and the project now has developed a set of differentiated real-world problems. In addition, many contributors observed that schools often lack the technological

resources, both in terms of technology, materials, and spaces, to solve these problems. EDUSIMSTEAM now provides a space where schools have all the necessary resources available on a secure digital platform designed specifically for exploring the learning scenarios.

In planning for integrated STEAM, we would invite you to consider the following questions:

- Are teachers and students engaged in STEAM activities, such as robotics education and computational thinking, in schools?
- Do teachers and students have opportunities to engage in such STEAM activities during school time?
- Do teachers receive STEAM education CPD in areas such as robotics education and computational thinking?
- Do teachers and students have access to didactic templates (i.e. learning scenarios) that support integrated STEAM education?
- Do teachers have access to online platforms where teachers and students can solve simulated real-world problems using integrated STEAM approaches?
- What kinds of supports do teachers require to embed STEAM approaches into their classrooms?

3. IMPLEMENTING INTEGRATED STEAM APPROACHES

There is a growing recognition of the key role digital technologies are playing in our lives today and of the need for governments and other stakeholders to **increase their support for STEAM education** if we want to ensure that future citizens have the necessary skills to live and work in a growing digital world. The development of integrated STEAM competences will be key in this regard and now is the time for member states to act. While some member states are engaged in STEAM education, it is not universally available in all European schools and in some cases, it is only available privately after school. As in other areas of education there are challenges around how we label or describe such integrated learning activities. Many teachers are actually engaged in such activities unknown to themselves. They are engaged in thematic learning units where they are exploring themes, such as climate, poverty or energy using a range of digital and non-digital technologies. These teachers are also engaged in STEAM education, but maybe they are unaware of this fact. Ultimately EDUSIMSTEAM is trying to support teachers to create thematic units that can allow students to collaborate and develop a range of key skills which are essential in today's world. Unfortunately, such approaches run the risk of creating a two-tier system, where some in society are offered the opportunity to develop integrated STEAM competences, while others are excluded. The consultations highlighted the need to ensure that all teachers and students are afforded the opportunity to engage meaningful with STEAM education.

The EDUSIMSTEAM Project has developed a comprehensive set of resources that member states, regions, schools, and STEAM education organisations can use to promote integrated STEAM approach. The project has also identified a range of key ingredients and supports that need to be in place if we want all students in Europe to have opportunities to engage with STEAM and to develop those key 21st century skills of critical thinking/reasoning, creativity/creative thinking, problem solving, metacognition, collaboration, communication, and global citizenship[20]. The project has demonstrated that when teachers and students are empowered to create curricular and instructional STEAM scenarios, it can have a very powerful impact on teachers, their students and their communities.

Member states, regions and or schools embarking on STEAM education should consider the following key supports which the project identified as being key to enabling all schools to implement an integrated STEAM based approach.

[20] https://www.brookings.edu/blog/education-plus-development/2019/02/14/integrating-21st-century-skills-into-education-systems-from-rhetoric-to-reality/

Consultation Findings

The contributors to the consultation process represented the voices of schools, universities, the wider community, and ministries of education. We have grouped these under a number of headings below and we will subsequently create a set of recommendations based on these observations.

Promoting a STEAM Philosophy or Mindset

STEAM education is much more than a curriculum, it is a philosophy or a mindset that is required to live, learn, and work in today's world.

- The majority of contributors stated that integrated STEAM education should be visible in all schools, not just those with the resources and competences to implement it. STEAM education needs to be valued by all in education and there is a need to promote this approach so that politicians, ministry officials, teacher unions, education leaders, parents, wider society and teachers are clear of its importance and how it can be activated in schools. Thus, there is a need for a wide-ranging awareness campaign on multiple levels, so that real change takes place in schools.
- STEAM education should place a premium on active student participation. Students should be afforded opportunities to actively design and engage meaningfully in STEAM education activities. They should have opportunities to satisfy their curiosity and co-construct knowledge and understanding with others, such as their fellow students, their teachers, outside experts etc.
- There is a recognition that schools are busy places and thus there is a need to provide school leaders and teachers with the resources and supports to implement integrated STEAM education. There is a need to provide all teachers, not just those who teach STEAM subjects, with an understanding of STEAM education and how they can activate it with colleagues in their schools. EDUSIMSTEAM can help in this regard by showcasing integrated STEAM in action through SimuLearn(i.e. the learning scenarios) and by providing access to relevant teacher training materials.
- Multiple contributors stressed the importance of disseminating the EDUSIMSTEAM project approach and materials widely across Europe to increase awareness of STEAM education and to further develop a common understanding and approach to STEAM.

The above comments from those involved in the stakeholder consultations needs to be further supported by the following observations in relation to the evolving

world of work and the findings from recent studies, such as a recent report from McKinsey[21] on the future of work.

1. Workers will encounter more complex and autonomous tasks for which there are no ready-made solutions on the shelves.
2. Knowledge was a prerequisite resource that needed to be in each person's mind all the time. Now knowledge has become a distributed and collaborative process, in which search skills (even with ChatGPT) are key.
3. Human expertise is always in semi-optimal stages; it is important to develop the right intuition, and to develop a life-long learning attitude.
4. One of the most important findings emerging from research on work is that learning and task performance are mainly based on teamwork; Soloplay is still needed in certain professions, however one's willingness to embed colleagues from other disciplines in your own approach 'makes the difference'. Thus, we need to develop the skills to collaborate effectively while in school and STEAM can help in this regard.
5. Curiosity and the willingness to change yourself is the deeper attitude that prevents workers from burn-out. This leads on to ensuring we develop learner curiosity and the ability to regulate their own learning from the earliest years.

Thus, education should anticipate these new dimensions of personal development; and should invest in our teachers so they are working in schools that recognise and activate these dimensions in their own organisations. Teaching should no longer be a solo activity and, where possible, it should enable staff to collaborate and design and teach with colleagues. Such approaches would go a long way to ensuring all students will have opportunities to engage in STEAM education.

Invest in STEAM Education

Many member states acknowledge the importance of STEAM education but there is now a need to invest holistically in transforming our education systems to truly embrace this philosophy and mindset.

STEAM education requires ongoing investment, so that all young people in Europe have similar opportunities to develop key STEAM competences. The investments need to include the following:

- Investment in appropriate space and resources for STEAM education. This includes both in-person and online spaces (such as SimuLearn) and learning scenarios, similar to those created by EDUSIMSTEAM.

[21] https://www.mckinsey.com/industries/public-sector/our-insights/defining-the-skills-citizens-will-need-in-the-future-world-of-work

- Investment in a range of teacher professional learning supports that includes initial teacher education and ongoing career development. There is a need to create new models of teacher professional learning that engage teachers and affords them opportunities to reflect, document and share their practices with likeminded teachers in communities of practice and elsewhere.
- Investment in new models of schooling where teachers have opportunities to co-design and co-teach STEAM. STEAM education is interdisciplinary and therefore there is a need for teachers to collaborate and, where necessary, co-teach with colleagues.
- Invest in approaches that support all teachers to engage in STEAM education, not just those who have an interest in science, technology, mathematics, and engineering. There is a need to invest in all teachers.
- Invest in rewarding teachers for engaging in STEAM education by recognising their efforts and highlighting good practices.

STEAM Policies

Multiple contributors noted that much good work is taking place in schools and in after-school facilities, such as STEM Centres, in the member states. However, they also noted that schools and other learning organisations can only do so much on their own and there is a need for policy changes at the national, regional and school level to ensure all student experience STEAM education.

- There is a need to create national STEAM education policies to provide clarity in relation to what is STEAM and how it should be activated in schools and other learning spaces.
- There is a need to link such policies with other relevant policies, in areas such as digital education, literacy, numeracy etc. STEAM education should take an integrated approach and it should be cross-referenced in relevant policies and strategies.
- Schools should also reflect on STEAM education and develop appropriate policies and plans for their context. Schools should codesign such policies with their key stakeholders and they should constantly refine these policies, to reflect their local context. Appendix 1 provides a potential template for such policies.
- There is also a need to embed STEAM education in the curriculum. Schools are expected to 'implement' the curriculum and therefore STEAM needs to appear in the curriculum documentation, so that teachers are clear on what is expected of them.

The EDUSIMSTEAM Project has provided an impetus for the partner organisations to engage in focused conversations around STEAM education. The project has developed key outputs that can help other member states, regions, and educational organisations to implement integrated STEAM. In addition, the project has outlined a number of key actions that are needed to further develop STEAM education across Europe, and we share a number of high-level recommendations below.

4. Creating a holistic STEAM Policy for All

It is vitally important that ministries of education take the lead in developing a **holistic vision** for STEAM education and outline an integrated vision for STEAM education. The creation of such a policy should involve all relevant stakeholders and should outline what an integrated STEAM education approach will look like in schools. It is important that such a policy endorses:

A strong rationale for STEAM

- Present a strong case for why we need to ensure all students have access to quality integrated STEAM education.
- Identify the key skills that such learning activities should develop.
- Identify why STEAM competences are so important in the world of today and in the future.
- Commit to supporting STEAM education across all levels of education.

An integrated curricular approach to STEAM

- While all member states teach STEAM subjects there is a need to promote and support an integrated approach involving content from different disciplines in a natural way.
- There is a need to build this into curriculum development and into curriculum planning activities.
- Teachers need time on the curriculum to engage in such activities.
- Commit to investing in integrated STEAM education.

Innovative teaching, learning and assessment approaches

- We now have access to a wide range of powerful digital technologies in education and these provide opportunities to teach, learn and assess in new ways.
- These technologies will allow us to design innovative teaching, learning and assessment strategies and we need to share these with all teachers.
- Teachers will need access to integrated STEAM learning activities that will allow students to collaborate and engage in active learning approaches using a wide of tools.

Inclusive quality teacher professional learning supports

- Teachers will need a range of professional learning supports to ensure they have the confidence and competence to engage in integrated STEAM.
- Teachers will need ongoing CPD to develop:
    - Their digital competences (for example see DigCompEdu[22])

[22] https://joint-research-centre.ec.europa.eu/digcompedu_en

  - Their STEAM competences (their content knowledge in relation to STEAM)
  - Their pedagogical knowledge to teach using an integrated approach (PCK[23]).
- Teachers will need time to collaborate with their peers and to design and activate integrated STEAM in their schools.

Reliable and user-friendly digital infrastructure

- Schools will need access to digital devices (i.e. computers, laptops and tablets) and to STEAM friendly technologies (i.e. Arduino, Raspberry Pi, and the BBC Micro:bit etc.) in their classrooms.
- Schools will need access to reliable digital infrastructure, such as high-speed broadband and reliable WIFI within their schools.
- Schools will need access to digital learning resources (i.e. digital learning scenarios) to assist them in activating STEAM in their classrooms.

The creation of a vibrant STEAM and evolving ecosystem

- There is a need to create a multi-stakeholder approach to STEAM education.
- STEAM education should be available to learners in all aspects of their lives from early years, through their formal schooling and on into vocational and higher education.
- STEAM education should involve families, the education community, businesses, NGOs and other interested organisations and sectors of society.
- All stakeholders should work together to develop a connected STEAM Education ecosystem.

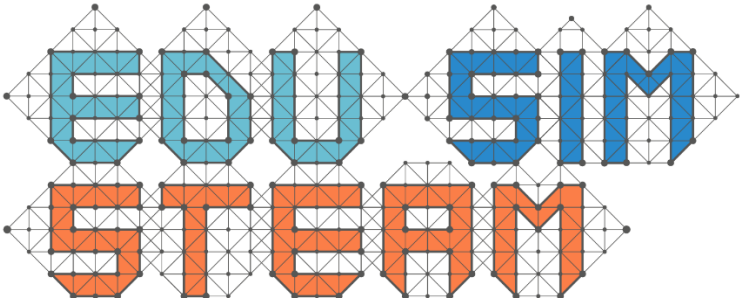
Ultimately STEAM education needs to find a place in the over-crowded timetables in our schools[24] and it needs to be valued by key stakeholders in our education systems. We need STEAM champions at all levels within our school systems – at the ministry, the regional, the school and the classroom level. We need to find ways to link STEAM education to other parts of our existing school curricula so teachers and students can see that this not extra work, but a more engaging way to develop key 21st century skills and to do this in an integrated, not a siloed way. We need to believe in STEAM and support our schools and especially our teachers to implement it creatively in their classrooms and now is the time to take action.

[23] https://www.researchgate.net/publication/332998944_STEM_Pedagogical_Content_Knowledge_Scale_STEMPCK_A_Validity_and_Reliability_Study

[24] https://stip.oecd.org/stip/interactive-dashboards/policy-initiatives/2021%2Fdata%2FpolicyInitiatives%2F25943

In planning for integrated STEAM, we would invite you to consider the following questions:

- Having reviewed this document, what is your vision for STEAM education?
- What supports are needed to help teachers implement integrated STEAM in your schools?
- What might integrated STEAM look like in your schools?
    - At primary and at second level?
- What curriculum/assessment changes will be needed in order to embed STEAM in your schools?
- What additional supports will be needed to ensure teachers are confident and competent to activate integrated STEAM in their classrooms?
- What will success look like for STEAM education in your schools in 5 years' time?



Erasmus+ KA3 Forward Looking Cooperation project

https://edusimsteam.eba.gov.tr/en