Implementing STEAM Education

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Author Note

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Abstract

Research shows that teaching integrated STEAM-related content areas using different subjects as tools or applications helps develop students' 21st Century skills. These skills also heighten the ability to solve real-world problems, guide students towards Sustainable Development Goals and prepare them for future jobs that don't yet exist. Teaching and implementing STEAM needs teachers' co-operational planning. Recommendation proposed includes a workshop implementing STEAM to the city of Vantaa, Finland.

Keywords: STEAM education, 21st Century skills, integrated content areas, implementing

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Implementing STEAM education

In Finland STEAM education is a fairly new type of approach in education. Many teachers teach it in separate content silos. The idea of STEAM is to teach integrated content areas using different subjects as tools or applications to solve real-world problems to gain 21st Century skills (Singh 2021). The purpose of this inquiry is to provide more experience in STEAM education to assist with the implementation by organizing a workshop for the teachers in the city of Vantaa, Finland.

Literature review

Sustainable Development Goals and 21st Century skills

The modern world is changing, and people need to keep up with it. The 21st Century students will require different kinds of skills and knowledge than the previous generations. (Singh, 2021) It is essential that elementary and high school students are ready to embrace the skills and competencies to solve complicated problems and to work in professions that do not yet exist.

In Sustainable Development Goals (SDGs) for 2030, United Nations Educational, Scientific and Cultural Organization (UNESCO) has defined SDG 4, education, to be the key enabler for the other SDGs. United Nations (2020) also shared the concern for interconnected global challenges we are facing:

> "Acknowledging also the importance of adopting science, technology and innovation strategies as integral elements of national sustainable development strategies to help to strengthen knowledge-sharing and collaboration and the importance of scaling up investments in science, technology, engineering and mathematics and digital literacy education…" (United Nations, 2020).

UNESCO recognized the importance of including these skills into the curriculum so that students learn 21st Century skills to provide for future generations.

In literature, there appeared many different definitions and models for 21st Century skills also known as transferable skills. Viinikka et al., (2019) defined 21st Century skills: 1. Learning and Innovation Skills, 2. Information, Media and Technology Skills, 3. Life and Career Skills and 4. Dialogue Skills. See the definitions of these groups in appendix A. Hadinugrahaningsiha et al. (2017) defined 21st Century skills to be a skill set of learning, literacy, and life skills. Many definitions are aligned with each other regarding the actual skills, skill sets might have different definitions.

In socially responsible science education, students will also review citizenship education and global issues (Taylor, 2016). When STEAM (Science, Technology, Engineering, Arts and Mathematics) is used students will learn about the very significant Sustainable Development Goals and skills related to them as well as the 21st Century goals. This will provide students with a more comprehensive understanding of the topics and how they are related to the real world.

There has been discussion on whether 21st Century skills are only Information Communication Technology (ICT) skills (Van Laar et al., 2017):

> "The results show that 21st Century skills are broader than digital skills – the list of mentioned skills is far more extensive. In addition, in contrast to digital skills, 21st Century skills are not necessarily underpinned by ICT. Furthermore, we identified seven core skills: technical, information management, communication, collaboration, creativity, critical thinking and problem solving. Five contextual skills were also identified: ethical awareness, cultural awareness, flexibility, self-direction and lifelong learning."

The 21st Century skills are not only the skills related to ICT but also skills that are usually

combined with social skills.

When STEM becomes STEAM

STEM (science, technology, engineering, and math) was established to respond to demands made by the 21st Century needs of professionals in the workforce. Students need to have knowledge in the individual areas and know how to apply their knowledge in situations to be successful. (Widya et al., 2019) The goal of STEM education is to prepare the students to be competitive and ready to work in their favored fields.

The honour of promoting STEM to STEAM by adding the Arts goes to Georgette Yakman, who is an engineer and technology teacher from the U.S. (Singh 2021). STEAM (Science, Technology, Engineering, Arts, and Mathematics) was considered as a new pedagogy in the Arts - National Policy Roundtable discussion in 2007. It arises from the need to strengthen students' skills and motivation towards Science, Technology, Engineering, and Mathematics (STEM) fields. Each of STEAM's five subjects shares a common approach and target. STEAM education combines the arts with STEM subjects with the aim to improve student innovation, engagement, creativity, problem-solving skills, and other cognitive benefits. It also aims to improve teamwork, communication, adaptability, all of which is needed for career and economic advancement. (Perignat & Katz-Buonincontro, 2019) STEAM education means teaching different integrated contents using for example mathematics or technology as a tool or application to solve real-world problems. It develops skills how to think outside the box,

The skills achieved through STEAM grant opportunities for students to succeed in and out of school, using 21st Century skills. Merging A (arts) to STEM (Science, Technology, Engineering and Mathematics) students can operate both their analytical and creative minds to deal with complex problems. “Its goal is to foster true innovations that result from combining the

minds of scientists and artists." "STEAM education incorporates 4 C's of 21st Century skills: Creativity, Critical thinking, Collaboration, and Communication" (Singh 2021). It is both a learning and teaching method. STEAM integrates different subjects together with real-world learning applications and tools (Singh 2021). STEAM gives students possibilities to be critical thinkers, problem solvers and next-generation innovators.

How will STEAM education improve students' 21st Century skills?

Elaine Perignat and Jen Katz-Buonincontro (2019) made an integrative literature review (44 articles) on STEAM in practice and research and found out that 31 articles mention creative thinking, creative skills, creative process, innovation, or imagination as connected with STEAM or the Arts. Sixteen articles reported that making processes increases skills in exploration, creative thinking, designing, technique, creative expression, critique, evaluation, and redesign. Maker-centered learning environments are those in which students imagine, design and create projects that align the content of learning with hands-on application. According to Perignat and Katz-Buonincontro (2019) educators around the world widely agree that STEAM increases creativity and thinking skills.

In their research Liao, Motter and Patton (2016) found out that highlighting the course content and activities engages students in 21st Century learning. They stated: "A STEAM curriculum provides the opportunity to show connections between STEM and art can be thought about, used, and explored in relevant and personal ways for 21st-century learners" (Liao, Motter & Patton, 2016). Creating digital media enabled students to learn essential skills for the 21st Century and see the creative possibilities in pursuing STEM related careers.

Hadinugrahaningsiha *et al.* (2017) presented that the STEAM approach can be combined with chemistry learning through projects that are related to chemistry concepts. Their study,

which focused on developing 21st Century skills of chemistry students in secondary schools, discovered that STEM integration can be implemented to promote these 21st Century skills: critical thinking, communication, motivation, creativity, respect, disciplined, collaborative, responsible, adaptation, leadership, flexibility, adaptability, initiative, self-direction, social and cross-cultural skills, productivity information and media literacy.

> "Based on the result and discussion, STEAM approach has several advantages of students' 21st-century skills without ignoring knowledge development, such as: engaging students as partners in their own learning, harnessing the capacity of technology to engage learners, and to optimize and amplify student learning and achievement, creating more teacher-student learning partnerships through real world, authentic learning tasks enabled by technology, emphasizing and teaching important higher-order skills such as critical thinking, communication, collaboration, creativity and entrepreneurship, supporting educators in preparing our students for a rapidly changing, technology driven, globalized world " (Hadinugrahaningsiha *et al.*, 2017).

Charlie Harper (2017) wrote about the advantages of using PBL (problem-based learning) and STEAM together. Students are challenged by everyday problems. These kinds of challenges provide students with inquiry and analysis which offers multiple learning possibilities. Usually, students are challenged by collective group activities that have no apparent right/wrong answers. Students are interacting and collaborating with each other and learning from the experience itself. The challenge teaches and requires students to use critical thinking, problem-solving skills and analysis. It offers several potential academic gains, collaborative and social-skills improvement, strengthened communication and increased family engagement. (Harper, 2017) STEAM and problem-based learning together speak for a realistic approach to

school development.

Implementation needs teachers

Implementing a new educational initiative needs teachers' input. It is important to ensure that teachers are involved in the designing and the development of the change being initiated. “Teachers’ commitment was necessary to ensure initial engagement, while curricular and organizational resources were needed to maintain implementation in the long term” (Martinez 2016). After involving teachers in the change, the teachers will need to embrace and implement the new initiative.

In their study White and Delaney (2021) spoke about the importance of collaboration. “...This preliminary research points towards a strong reliance on project or problem-based learning pedagogy with the use of community and collaboration both between students and the greater community”. Teachers will need to work as a team, not forgetting also the arts teachers. It is easier done in lower grades when students usually have only one teacher. “This suggests that more research is required prior to wide-scale implementation within high school education systems.” Evidence is harder to document in high school because the teachers at this level have a harder time thinking in an integrated way according to White and Delayne (2021).

White and Delayne (2021) also conclude that “the implementation of STEM/STEAM as a platform for interdisciplinary learning does result in higher results in assessed learning outcomes (RQ1) such as greater results in comparable testing, awards and participation in relevant academic pursuits." STEM being transformed into STEAM is still in the early stages of implementation but it already shows the importance of teacher cooperation when teaching STEAM.

Discussion

Students and teachers in Finland learn and teach STEAM-related subjects (Science, Technology, Engineering, Arts and Mathematics) separately in content silos. Many teachers are not well educated or well versed in STEAM teaching so do not see the reasoning for integrating the content areas of S, T, E, A, M as they are in the real world. Teachers planning together the integrated content areas plays an important role in teaching STEAM.

Teaching STEAM means teaching different integrated content areas together, using different subjects (Science, Technology, Engineering, Arts and Mathematics) as tools or applications to solve real-world problems. STEAM education combines the arts with STEM subjects to improve student innovation, engagement, creativity, problem-solving skills, and other cognitive benefits along with the other 21st Century skills.

The students of the 21st Century will require different kinds of skills and knowledge than the previous generations. STEAM gives students possibilities to be critical thinkers, problem solvers and next-generation innovators. STEAM education merges Creativity, Critical thinking, Collaboration, and Communication, the four C's of the 21st Century, together (Singh 2021).

Studying and applying integrated STEAM-related content areas prepares students for future jobs that do not exist yet. It gives students a bigger picture of real-world issues. In our world everything is interconnected, everything has an impact on everything. This also applies to education, it is better to study the subjects together to change the world towards achieving Unesco´s 2030 Sustainable Development Goals.

Implementing a new educational initiative needs teachers' input. Research (White and Delaney 2021; Martinez 2016) show that teachers need to plan together and collaborate on content to get the benefits from teaching STEAM-related subjects. This can easily be done in

primary grades but can be a bit more challenging in secondary grades. Implementing STEAM foundation into education allows for more insight, innovation and education in the classroom.

Conclusion

Research shows that teaching integrated STEAM-related content areas using different subjects as tools or applications helps develop the 21st Century skills and ability to solve real-world problems. Adding A (arts) to STEM gives students an opportunity to operate both their analytical and creative minds to deal with complex problems. STEAM improves for example student innovation, engagement, creativity, problem-solving skills, and other cognitive benefits. Teaching and implementing STEAM needs teachers' input and cooperation in planning.

The author of this project proposes to develop and organize a STEAM workshop called "Full Steam Ahead Vantaa" for teachers of the city of Vantaa to help them develop a better understanding of STEAM education (See appendix D). The goals of the workshop will include: 1. Understanding the importance of an integrated STEAM curriculum, 2. How STEAM education develops 21st Century skills, 3. The advantages and requirements for developing a STEAM education, and 4. How teachers can organize STEAM education by planning together the integrated STEAM projects.

Based upon the information presented in this paper, teachers will be given a set of eSTEAM projects cards that help them to plan and teach integrated STEAM areas together (See appendix E). Teachers are also given a list of used materials and information where they can either borrow or get them, or their school can buy the materials (See appendix F). Recycling and materials you can loan are favored. In Finland, teachers don't spend their own money on the materials. The author is providing the cards to support teachers to quickly implement them into the classrooms and start teaching STEAM lessons. eSTEAM project cards will include

background knowledge, targeted competencies and skills, step-by-step instruction and other useful information to make the projects successful. The length of the projects varies and can be used in different grade levels.

It is important that teachers feel competent when they go back to their classrooms. In the workshop, teachers will experiment with the project cards themselves. They will be able to master the required projects themselves so that they will be able to experience the essence of STEAM better.

Plan of Action Worksheet

Full STEAM Ahead Vantaa Workshop(s)

What steps or actions need to be done?	**Who will do this step or action?**	**Timeline When will you do this step? How long will it take to complete this step?**	**What do I need to do this step or action? Other teachers, Staff, supplies and materials, Time, PLC time**	**Date completed** ✓ and write date when completed
Share inquiry project with xx	Myself	First month	Arrange a Google Meet, share project (same meet for everybody) and workshop to come	☐
Share inquiry project	Myself	First month	Arrange a Meet, share project and idea of workshop to come. Make an arrangement about who teaches in which rotation point.	☐
Share inquiry project with x x	Myself	First month	Arrange a Meet, share project and workshop to come.	☐
Make practical arrangements for the "Full STEAM ahead Vantaa" workshops,	Myself,	Spring 2022	Fix schedule, place (robotics center), needed equipment, coffee and buns (always needed)	☐
Ask XX if they can be part of workshops	Myself	Spring 2022	Project idea	☐
Ask Aalto University if they can also give one of the workshop rotation points,	Myself	Spring 2022	Project Idea	☐
Meeting with tutor teachers: go throw all the projects taught in this workshop.	Myself, tutor teachers	Spring 2022	Decide who teaches what	☐
Advertise the "Full STEAM ahead, Vantaa" workshop for teachers	Myself, L.K.	Spring 2022	Add workshop to Eduvantaa, TVT Vantaa facebook, Wilma and	☐

			koulutusportaali	
Organize and buy the equipment needed	Myself, XX tutor teachers	Spring 2022	Recycling center for free materials, buy if needed	☐
Conduct the workshop /mini workshop for the teachers.	Myself, XX, tutor teachers, XX. and XX	Spring 2022		☐
Conduct assessment to gather data from the teachers about the workshops: Google forms used in tutor teacher meeting	Myself, XX	Spring 2022	Google forms, see appendix B	☐
Ask for if there is a need for extra workshops	Same as above	Spring 2022/ Fall 2022		☐
Conduct them if needed	Same as above	Spring 2022 / Fall 2022		☐
Send an inquiry form to teachers that were in the workshop. Ask about student performance.	Myself, XX	Spring 2022	Google form, see appendix C	☐
Share assessment results with boss of education department in Vantaa and in STEAM Finland, perhaps Call of papers (ICT days) and Vantaa STEAM days	Myself, XX,XX, XX	Spring 2022/ Fall 2022	Slides	☐
Erasmus STEAM courses in Europe for tutor teachers	Myself, XX (tutor teachers)	Spring 2022	Money ok, course arraignments	☐
Erasmus Assessment	XX and myself	Fall 2023 or at the end of Erasmus season (depends of Eramus)	Write assessment for Erasmus, specific form.	☐

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Appendix A

List of 21st Century Skills

1. Learning and Innovation skills
    - Critical thinking
    - Creativity
    - Collaboration
    - Communication
    - Learning to learn

2. Information, Media and Technology Skills
    - Information literacy
    - Media literacy
    - Technology literacy
    - Religious literacy

3. Life and Career Skills
    - Flexibility
    - Leadership
    - Initiative
    - Productivity
    - Social skills
    - Accountability
    - Citizenship

- Combining life and career
- Global responsibility and sustainable development

4. Dialogue Skills

- Generic dialogue skills
- Dialogue education
- Dialogue self-skills

Appendix B

Survey questions used immediately after the workshop (with Google Forms)

Workshop content	Strongly disagree	Disagree	Agree	Strongly agree
The content presented was aligned with the workshop summary description.				
I found the content to be valuable and relevant to my teaching.				
The content of the workshop supports curriculum goals for student achievement.				
The instructors were knowledgeable about the content.				
The needs of the learners were met.				
Time was appropriated for participants to apply/discuss new knowledge and skills.				
I feel confident about applying what I have learned to my own classroom instruction.				

What additional support would you like to have to assist you in applying what you have learned?	
Free feedback.	

Appendix C

Survey questions used about two months after the workshop (Google Forms)

Question	**Free feedback**
How have you used STEAM in your teaching after the workshop?	
Which ideas/project cards you found to be most useful?	
Were there any that didn't work? Why?	
How was the students' motivation/ how they were engaged?	
How did you evaluate the student learning outcome?	
What were the student learning outcomes? What did they learn?	
What benefits did you find teaching integrated STEAM with different subjects as tools or applications?	
Suggestions for future workshops.	
Free feedback.	

Appendix D

FULL STEAM AHEAD VANTAA - Workshop

a) Goals

1. Understanding the importance of an integrated STEAM curriculum,
2. How STEAM education develops 21st Century skills,
3. The advantages and requirements for developing a STEAM education
4. How teachers can organize STEAM education by planning together the integrated STEAM projects.

b) Agenda

1. Information about STEAM education in general with SLIDES together with a little snack Link to the general SLIDES of the workshop, also in appendix G.
2. Presentation of the eSTEAM project cards (see examples in appendix E)
3. Rotation /stations: Author and other tutor teachers give mini workshops where teachers can experience the projects themselves.
4. Final discussion, questions and answers.
5. Feedback survey for the teachers (see appendix B)
6. Tutor teachers offer additional help in classrooms implementing STEAM if needed
7. After a two months survey for teachers. See (appendix C)

c) Time and place

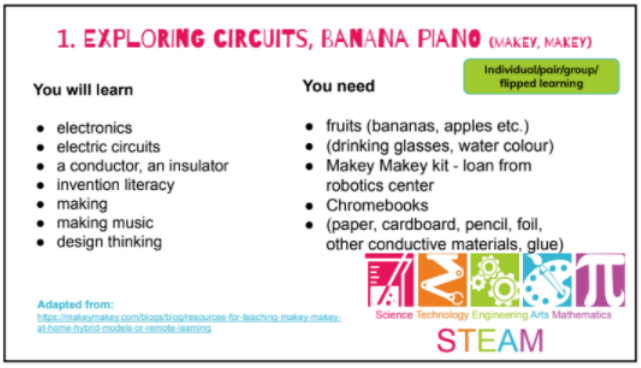
1. Time is set together with robotics center that offer the place
2. Usually these kind of workshops are after the school from 13.30 - 17.00

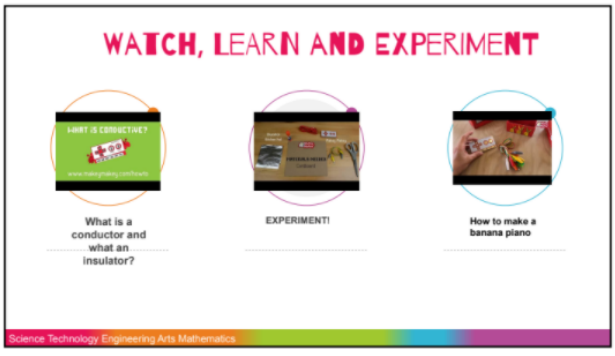
Appendix E

eSTEAM Project Cards

1. These eSTEAM project cards are designed into Finnish school system. They can be compared to lesson plans in the U.S.
2. Teachers can decide themselves the way they use the eSTEAM cards: Pair/team work, everybody at the same time, part of the individual learning path etc.
3. Some of the eSteam project -cards can also be used for flipped learning pedagogical approach
4. Part of the cards can be used in remote learning
5. Cards are shared to teachers via Full STEAM Ahead - Google Classroom
6. See Appendix F for the places you can get the materials.

Examples of eSTEAM project cards





Background info for the teacher

- **Conductivity** is the measure of the ease at which an electric charge or heat can pass through a material.
- **A conductor** is a material which gives very little resistance to the flow of an electric current or thermal energy. Materials are classified as metals/conductors, semiconductors, and insulators.
- **Electric circuit**, path for transmitting electric current. An electric circuit includes a device that gives energy to the charged particles constituting the current, such as a battery or a generator; devices that use current, such as lamps, electric motors, or computers; and the connecting wires or transmission lines.

2. DIGITAL NATURE REPRESENTATIONS (MICRO:BIT)

Teacher teaches / pairwork

You will learn

- That LEDs can be used to create image representations.
- To plan LED image representations.
- Block coding with micro:bit

You need

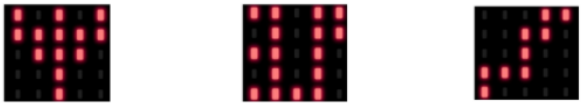
- printouts of items to represent with LEDs and LED Planner handouts
- laptops/chromebooks, access to the MakeCode editor,
- micro:bits (you can loan these from Robotics Center).

Adapted from: https://microbit.org/lessons/nature-art-digital-representations/

Science Technology Engineering Arts Mathematics
STEAM

Teachers instructions for representations of nature made using micro:bit

1. Show students the images and ask what animals they can see in the pictures and why. What makes them identify that particular animal? What similar features they have?



2. How micro:bit works? Watch videos

a) b) c) d)

3. Make representations of the nature with MakeCode and Micro:bits using knowledge gained from videos

https://makecode.microbit.org/

3. 3D MODELLING

Teacher teaches

You will learn

- 3d modelling
- designing
- spacial thinking and designing

You need

- chromebooks
- go to Robotics center to print or school might have own Minifactory 3d printers

Science Technology Engineering Arts Mathematics
STEAM

LINK to instructions

4. A PROSTHETIC PROTOTYPING

Teacher teaches / groupwork/teamwork

You will learn

- empathy and social skills
- biomedicine
- engineering
- physical prototyping
- creative problem solving.

You need

- popsicle sticks
- stuffed animals to as models
- cotton balls and swabs
- paper and cardboard
- rubber bands
- aluminum foil and paper clips
- pipe cleaners

Adapted from: Boone, A. et al. (2020)

Science Technology Engineering Arts Mathematics
STEAM

1. Make a conversation in what kind of situations teddy bears (other stuffed animals) might loose a leg etc.

2. Let students design prosthetics using given materials.

Appendix F

List of places where you can either loan, use or get the materials for free. School secretaries have an online list where schools can buy equipment themselves. School´s craft classrooms also have many materials and equipment to use.

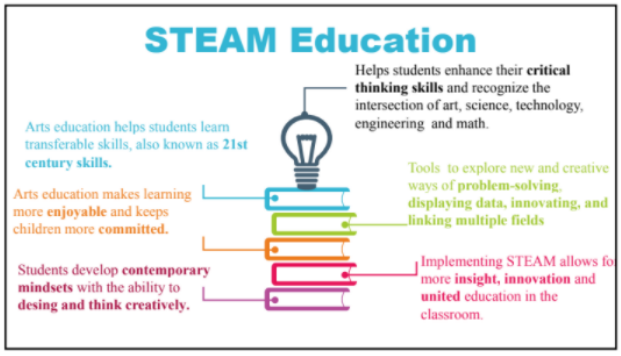
- Robotics Center of Vantaa
    - Digital fabrication: Roland vinyl cutter, Edulaser laser cutter,
    - Collum drilling machine, jigsaw, sewing machine
    - Ultimaker 3 3D-printer, Prusa imk3 3D printer
    - Soldering slots
    - 3D cave (for large 3D projections)
    - Educational microcontrollers/robots from Lilypads, Arduinos, Makey Makeys, Micro:bits and Raspberry pi's to early learning KUBOs, Bluebots, Photons and Dash robots.
    - Various LEGO ROBOTS: EV3s, Spikes, WeDos and science kits
    - Google Redbox class VR set
    - Provides guiding how to use equipment

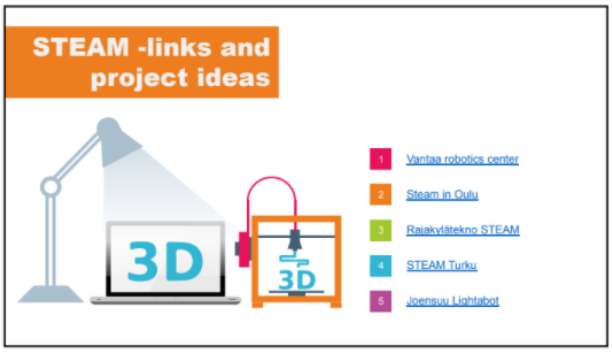
- University of Helsinki
    - Loan a research package (3 different themes: “tidy research”, “untidy research” and “outside research”
    - Easy to use equipment to use in different kind of inquiry

- Free recycling material
    - Schools can order or pick up materials for free from the recycling center
    - Recycled cloth patches
    - Paper and board products
    - Various plastic, wooden and metal nipples and buttons
    - Other materials

Appendix G

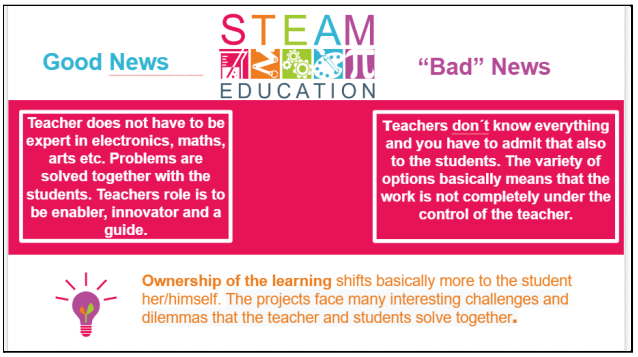
Workshop general slides




STEAM -links and project ideas
3D
3D
1 Vantaa robotics center
2 Steam in Oulu
3 Rajakylätekno STEAM
4 STEAM Turku
5 Joensuu Lightabot


Things to visit in Vantaa and near by area
Robotics center in Vantaa
Helsinki University
Chemistry class Gadolin
Aalto University jr.
Science for teachers and students
Aalto junior lab

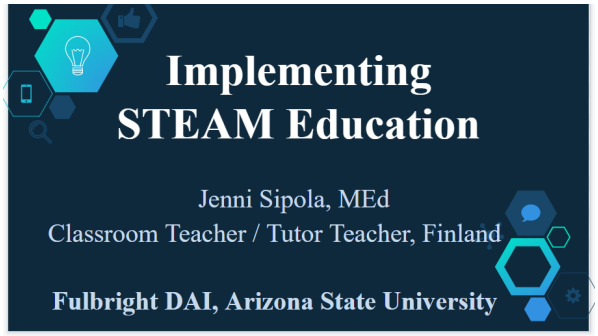

Materials to loan or get for free
Helsinki University
Materials to loan for free
Free recycling materials

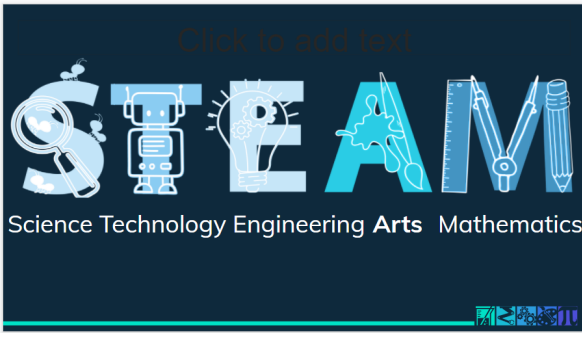

Good News
STEAM EDUCATION
"Bad" News
Teacher does not have to be expert in electronics, maths, arts etc. Problems are solved together with the students. Teachers role is to be enabler, innovator and a guide.
Teachers don´t know everything and you have to admit that also to the students. The variety of options basically means that the work is not completely under the control of the teacher.
Ownership of the learning shifts basically more to the student her/himself. The projects face many interesting challenges and dilemmas that the teacher and students solve together.

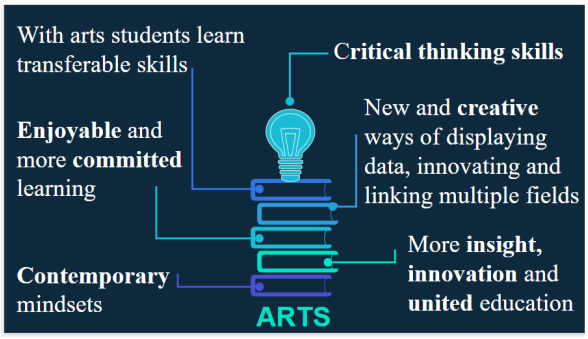
https://steamvantaa.blogspot.com/

Appendix H

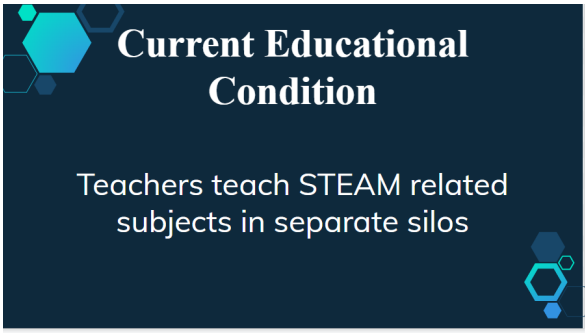
Panel Presentation

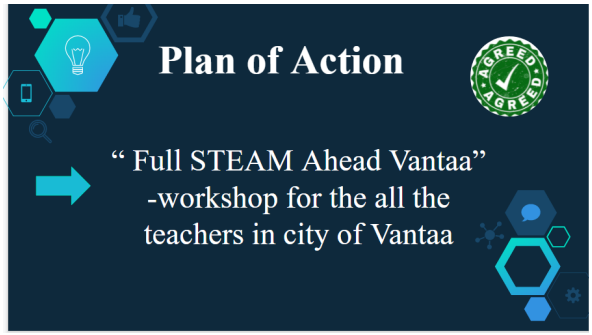


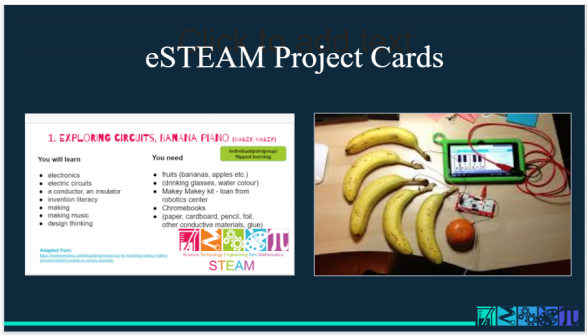




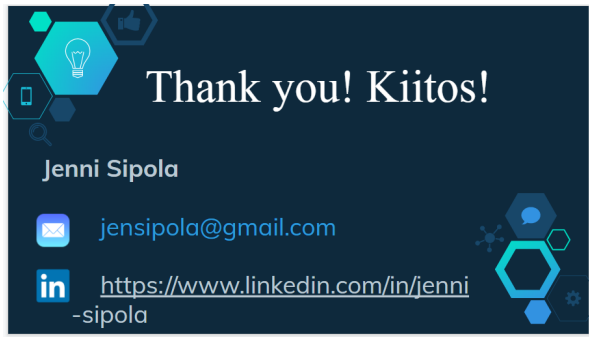

STEAM-education in Oulu is done in collaboration between different actors with great enthusiasm.


Current Educational Condition
Teachers teach STEAM related subjects in separate silos


Plan of Action
AGREED
" Full STEAM Ahead Vantaa"
-workshop for the all the teachers in city of Vantaa


eSTEAM Project Cards
1. EXPLORING CIRCUITS, BANANA PIANO
You will learn
You need
STEAM


Click to add text
Erasmus+


Thank you! Kiitos!
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