TeachME PROFESSIONAL DEVELOPMENT
CEUs for Teachers and Educators

Introducing STEAM Learning

Introduction

The purpose of this course is to explore the components of STEAM-based learning, which is a strategy that helps students gain skills that will enable them to be successful in a myriad of careers in the future. This course has been designed to help educators understand the history of STEAM, its importance, and how it can be effectively used within their classrooms. This course will allow educators to: (1) define STEAM and identify its components, (2) analyze ways in which STEAM can be incorporated into the daily curriculum through both face-to-face and virtual learning, and (3) determine the benefits of utilizing STEAM for learners, educators, and within the community.

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The History of STEAM [1,5]

STEAM focuses on the intentional integration of learning in science, technology, engineering, the arts, and mathematics, and it helps to prepare learners for life and enriching careers outside of the classroom. STEAM lessons utilize higher-level thinking and problem-solving, emphasize project-based learning (PBL), and make strong connections to the real world. (1)

- In recent decades, educators have realized the need for and importance of addressing curricular topics from multiple disciplinary perspectives. This has come about because real-life and highly-complex problems simply cannot be understood and solved by one single learning approach. (1)
- The pandemic led to a further need to strengthen core learning within the sciences, as a solid foundation in sciences is beneficial as our world shows a true need for an understanding of multiple disciplines in regard to numerous problems that require care and solutions across the world. These include health, climate, and technology facets. (5)

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STEM's Evolution to STEAM [2,3,4]

- STEM centered upon science, technology, engineering, and mathematics, and was introduced by the United States National Science Foundation in 2001. (2) Originally, the acronym SMET was used to refer to career fields utilizing those disciplines, but then biologist and assistant director of education and human resources at NSF, Judith Ramaley, reordered the letters to become STEM. The curriculum then extended past the United States and was utilized in Australia, China, France, South Korea, Taiwan, and the United Kingdom. (2)

- The need for STEM learning came about because multiple published studies and reports emphasized important links between the knowledge of science and technology and successful careers in related disciplines. Studies showed that without being properly prepared, the United States would surely fall behind in the global economy due to failures in the workforce. International studies revealed much of the same, and a push for better learning opportunities among a wide variety of disciplines was born. STEM competence covers the what - the knowledge, attitudes, and values related to the disciplines, and the how - the skills to apply that knowledge. (4)
- STEM education evolved into STEAM education, beginning with researcher Georgette Yakman in 2006. (3) Her educational experiences led her to feel strongly about the benefits of incorporating creativity and innovation into STEM learning opportunities.
- In 2007, Yakman began utilizing a STEAM curriculum and also began training educators to do the same. By the beginning of 2019, approximately 3,000 United States teachers had been trained to effectively use STEAM in their classrooms, and upwards of thirty-eight countries now utilize STEAM for student learning purposes. (3)
- Concepts similar to STEAM have been seen for centuries, as prominent artists such as Leonardo DaVinci saw real value in combining artistic and scientific knowledge together. (3) STEM learning has grown in alignment with the expansion of and specialization in the fields of biology, chemistry, physics, applied sciences, and mathematics. Some fields have fused with higher education to make new disciplines that reflect the needs of various careers, such as courses in biochemistry, rather than separate learning opportunities in biology and in chemistry. (4)
- STEAM's integration has caused some critics to believe that it might lead to fewer students pursuing postgraduate studies in common STEM fields. However, a study conducted by the National Endowment for the Arts found evidence that suggests the opposite. Learners who completed a STEAM curriculum in high school were tracked and these learners were found to be 21% more likely to attend college in

comparison to those who lacked an arts education, but they were just as likely to pursue a STEM major and career. (3)

The Components of STEAM

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- The components of STEAM include science, technology, engineering, the arts, and mathematics. Keep in mind that almost all career fields relate to STEAM in some way. By taking a look at each of these disciplines, we can understand the importance of ensuring that students have adequate opportunities to experience them and connect them to one another and to the outside world.
    - **Science:** The main branches of science include geology, chemistry, biology, biochemistry, physics, and astronomy.
    - **Technology:** Technology components include looking at past, present, and future technologies and their relations to identifying and solving potential

problems, meeting the needs of individuals all over the world, and focusing on continued advancements over time.

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- **Engineering:** Some of the main branches in engineering include computer science, chemical engineering, mechanical engineering, electrical engineering, electronics engineering, informational technology, and civil engineering. However, numerous and more specified branches also exist such as marine engineering, telecommunication engineering, and structural engineering.
- **The Arts:** The humanities, social sciences, and physiology disciplines all account for this category. Examples include world languages, fine, visual, and performing arts, philosophy, psychology, anthropology, history, politics, and international relations.
- **Mathematics:** Mathematics components include numbers and operations, algebra, measurement, geometry, data analysis and probability, problem solving, reasoning and proof communication, trigonometry, and calculus.

- Utilizing STEAM in your classroom will offer the chance for students to engage, explore, hypothesize, plan, prepare, conclude, and share. Students will utilize higher-order thinking skills by engaging in hands-on problem-based lessons, and can benefit from the use of STEAM across all grade levels.

Benefits of STEAM [2,4]

- Educational policies, programs, and curriculum should focus on the future needs of learners and their potential career involvement. In order to prepare leaders, citizens, and future workers, it is necessary that opportunities exist for both young and older learners. (4)

- STEAM experiences are ideally made available in many school settings and through community events. In a report in *Science, Technology, Engineering, and Mathematics (STEM) Education: A Primer*, STEM education was defined as: "Teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels—from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings." (2)

- In order to prioritize STEAM, educators began utilizing project-based activities that required specific knowledge and the application of certain skills. This often occurred in the classroom, but also was incorporated through team competitions, as after-school extra-curricular learning. Additionally, students were provided with opportunities through internships and job-shadowing events. (2)

Values [3]

STEAM provides value to learners through various facets. These include: (4)

Curiosity: Students develop an interest toward the environment, self-directed initiation for exploring concepts further, and searching for information and materials through independent and collaborative research.

Integrity: Learners act with integrity, show honesty while reporting specific observations and environmental discoveries, and while accurately reporting and validating data.

Objectivity: Students record data as observed. These observations are unchanged and unaffected by their feelings and hopes for specific results. Observations are explained rationally.

Open-minded: Learners remain open-minded. They are able to accept the opinions of others. STEAM learning opportunities help them realize that their positions should change only when based on evidence. Students avoid prejudice and they are flexible.

Diligence and perseverance: Students are eager and willing to repeat experiments when applicable. They show a determination in carrying out a specific job. Learners are ready to respond to questions and accept critics and challenges. They persevere to overcome problems when needed, and they move on to continued learning.

Systematic: Students carry out activity in a systematic way. Their experiments and problem-solving techniques are well-planned and fall within necessary time parameters as decided in advance. Students are aware of deadlines and follow orderly steps.

Cooperative: Learners work together collaboratively as they carry out activities, experiments, and creative processes. They take on natural roles within their teams, but everyone plays a vital role in the STEAM process. These roles may change and develop over time as students take on new qualities, receive feedback, and build confidence in their learning.

Responsible: Students are responsible for the safety of themselves, peers, teachers, and the environment. They understand that consequences exist, and they carefully weigh the ramifications of their actions.

Precision: Students conduct experiments carefully and precisely in order to collect accurate data. They have a respect for precision in regard to measurement, and are careful with using applicable measurement tools and techniques, as well as careful data recording, to ensure accurate results.

Appropriate Risk-Taking: Students are willing to try different ways of collecting data. Each opportunity might require something unique and learners are willing to explore new areas in STEAM.

Ethical Decision-Making: STEAM learners evaluate and choose among processes and experiments in a manner that is consistent with ethical principles, consulting the teacher for help when needed.

Appreciation for STEAM: Students and educators alike realize the importance and benefits of STEAM learning, and they recognize that STEAM and its thinkers are helping to make large impacts across the world. Students create and utilize inventions responsibly, and they uphold strong STEAM ethics.

STEAM Outcomes [3]

To understand the effectiveness of STEAM, educators can look for evidence through several different outcomes. They are as follows:

Intentional Connections: STEAM education is highly-beneficial as it integrates multiple concepts together to allow students to learn ways to make important connections. Across the curriculum in STEAM subjects, standards overlap and relate in numerous ways. For example, two standards that call for demonstration, may be linked together and taught at the same time.

Inquiry-Based: STEAM learning focuses on the use of problem-solving methods and processes. These can translate to various scenarios. By using questions to gain answers, students will be engaging in a critical part of the STEAM method. They will work to find the best process to explore and answer each unique question.

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Integrity: It is critically important that the art component portion of STEAM has its own identity, rather than being used simply to explain various pieces of STEM. Art requires out of the box thinking and a great deal of creativity and innovation, and these pieces need to be present in lessons to fully support STEAM concepts and lessons.

21st Century Skills: Collaboration, communication, creativity, and critical thinking make up the skills of the century in which we live, and these are non-negotiable for students in today's world. Engagement opportunities that take place in any STEAM lesson help to ensure that these critical skills are taking place in learning.

Assessment: Assessment of a lesson requires intentional connections that students are expected to make during the learning experience. This helps to see whether or not students were successful in doing so.

Making Meaning: Connecting lesson and course content to real-world applications and standards is essential. This allows students to become excited about their learning, and the potential possibilities with future careers and in-demand skills. Essentially, this helps to show them that what they are learning in the classroom will transfer to life skills that they might employ for years to come.

Incorporating STEAM Effectively [4]

In order to incorporate STEAM into learning, it is important to understand the concept of big ideas and to be able to use it effectively. Big ideas are the foundation for all fields of study. A big idea is central to a concept at the core of a particular learning field, and it helps to link various elements of understanding within that discipline. (4) These ideas can span across multiple subject areas and they can help us make better sense of the world around us. (4)

- In order to utilize STEAM effectively, teachers should connect and relate content to these big ideas and to the world around them in order to create meaningful, substantive, impactful lessons. In this manner, students can develop an understanding of various disciplines and career fields. (4) Strong and numerous connections will directly tie to their level of understanding. Students will eventually realize that disciplines are interconnected, rather than separate entities, and this can help them form more meaningful knowledge. (4)

STEAM Related Skills [4]

Numerous STEAM related skills include cognitive, manipulative, technological, creative, collaborative, and communication skills.

- **Cognitive:** These skills refer to the mental process of understanding through thinking and various experiences. Cognitive skills can range from information management, which includes identifying, collecting, processing and using relevant data to make informed decisions, critical, creative, and analytical thinking, problem solving, scientific investigation, creativity, and computational thinking. STEAM focuses on a strong reliance on scientific evidence to assess the validity of any findings or arguments. Therefore, the conclusions that are reached with STEAM must be the result of sound critical and analytical thinking. Critical thinking requires objective evaluation, while analytical thinking requires conceptualizing a problem and a solution. Analytical thinking also requires mathematical principles and knowledge of numeracy, and an understanding of data. Through analytical thinking, a student will use representation, communication, problem solving, reasoning, and make strong connections. (4)

- **Information Processing:** In the twenty-first century, data plays a large role in our world, therefore making it imperative that students have strong informational processing skills. These types of skills are used to find, collate, organize, and select valid and pertinent information for set tasks. This can help learners to then understand, interpret, analyze, and utilize data, as well as test its authenticity, reliability, and validity. Students will also display these findings in effective ways through the use of a variety of resources, often with the use of technology. It is critical that students can make decisions based on sound data, rather than their own feelings or opinions. This will ensure that they find the best solution to the stated problem. While these skills are necessary for careers within the field of STEAM, these skills are also pertinent and necessary for making informed life decisions as well. (4)

- **Manipulative and Technological:** Manipulative skills are psychomotor skills that are needed to correctly and safely use scientific and technical equipment. This is especially true for electricians, engineers, technologists, and technicians. Technology changes rapidly, and the needs of a society evolve often. Therefore, vocational and technological skills are pertinent for learners and should be a prominent piece of educational instruction. Vocational and technical learning institutions must constantly evaluate the changing needs and goals, and ensure that appropriate learning opportunities are available for their students as they move toward successful careers in the world around them. This can be challenging, but is possible.

- **Creative:** Creativity is encouraged through design thinking which provides a structured framework to encourage innovation and creativity among learners. It involves visionary processes and strategies to create products and solutions without the necessity of a sequence of rigid and orderly steps or rules. It values creative thinking and is guided by a learner's inspiration, empathy, and ideas. Design thinking utilizes critical and creative thinking through brainstorming, trial and error, review, redesign, refinement, testing, and implementation. This can be effectively applied directly to careers in STEAM. (4) Creative thinking uses the imagination, and a creative individual offers various perspectives by finding hidden patterns and sharing connections to unrelated concepts. Innovation is more tangible and involves making changes and/or improvements to current processes, products, and systems. Both creativity and innovation can be fostered by asking open-ended questions, encouraging learners to view ideas from different perspectives, and sharing different models of the same concept. (4)
- **Collaborative and Communicative:** Effective collaboration and communication skills must be developed and do not usually occur naturally. They need to be explicitly developed and through complex tasks which require effective teamwork rather than individual effort. Effective collaboration offers all team members the chance to participate and communicate ideas while also having a shared responsibility. Having common goals offers team members valuable reasons to work together and make an impact. Working both independently and in teams and being able to share information with other team members effectively are fundamental and important skills for all learning members. (4)

The STEAM Process [3]

STEAM-centered classrooms are valuable for both educators and learners. By following six sequential steps, students can develop a process for learning and educators can engage in teachable moments.

1. **Focus:** During this first step, students identify an essential question or a problem that requires a solution. Teachers should ensure that they have a clear understanding about how these essential questions correlate to learning goals and educational standards.
2. **Detail:** The second phase then centers upon discovering the key elements that created the essential question or problem to start with. This step is an important

facet of the process because it will allow you to notice some of the knowledge and skills that students already possess which will enable them to work toward the solving portion of the process.

3. **Discovery:** The third step focuses on bringing together research and deciphering what fits and what doesn't with the problem in mind. This often helps to identify gaps in research, and it allows students to learn new skills and utilize different processes.

4. **Application:** The application step enables students to gather the information and answer their original question or solve a problem. Learners may begin to understand how they can create a dynamic solution by using the tools and research that they have collected thus far.

5. **Presentation:** The presentation step allows students to express their findings in a creative way. Often they might use a variety of technology tools and present in unique ways. Classmates can gain further understanding about the topic at hand. Students in the learning community will also gain and receive feedback through this step in the process.

6. **Link:** The sixth and final step brings the project together as it is along with the additional feedback given, and then reflects further. Learners can then choose to revise their work if needed and incorporate what they have learned from their peers and teacher's evaluation. (3)

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There are several STEAM practices that may take place during a lesson, including the following: (4)

1. Ask questions and define problems. Students inquire and share explanations of how the world works and decipher which components can be tested. Students ask questions to clarify. They also determine the criteria needed for successful solutions and identify constraints to solving problems and clarifying ideas.

2. Develop and use models. Students may form replicas, diagrams, or representations through graphs, formulas, analogies, and simulations.

3. Plan and carry out investigations. Students plan experiments and conduct investigations based on inquiry.

4. Analyze and interpret data. Students collect, analyze, interpret, and present data. This is necessary so that their audience can understand the information. They can also then apply what they have learned and replicate it or utilize it to continue the learning process as applicable.

5. Use mathematics and computational thinking. Students use mathematics through logic, geometry, and calculus skills to represent variables and show relationships. This helps with making quantitative predictions. Learners use computational thinking to design strategies as well. This can help them to locate data, organize data, design algorithms, form simulations, and develop various systems.

6. Construct explanations for science and design solutions for engineering. Students reflect on their understanding through words, graphics, and formulas. Students systematically design in order to attempt to find a solution to problems that are based on scientific knowledge and models of the world. They balance functions, feasibility, cost, safety, aesthetics, and compliance, and look at how well the proposed solutions meet criteria and constraints.

7. Engage in arguments from evidence. Students argue and reason based on evidence. This helps them to identify the best explanation for an occurrence or the best solution to a problem. Students listen, compare, and evaluate competing ideas and methods based on sound evidence.

8. Obtain, evaluate, and communicate information. Students do this through the use of diagrams, graphs, equations, and writing. Learners critique and communicate ideas individually as well as in groups through extended discussions.

Models of STEAM Integration [4]

There are different models used to integrate STEAM successfully. One or more of these might be the perfect fit for your learning schedule and space. One way is to teach all of the disciplines individually, and another consists of focusing on teaching all five disciplines but focusing most on one or two of them. A third way is by integrating one of the disciplines into the other four. For example, engineering might be integrated into science, technology, and mathematics classes. A comprehensive way is to infuse all of the disciplines into one another and teach them in an integrated way.

Discipline-Specific: A discipline-specific approach is often used in primary schools, and sometimes is incorporated in secondary schools. Most primary students learn the subject areas of math and science, while Technology, Design, ICT, and Engineering are offered as electives, especially at middle and high school levels. In this approach teachers still teach their optional subjects. The links between the subjects might not be explicit and the overall desired competencies may not be gained.

To encourage more students to study STEAM and embark in a STEAM career, individual STEAM subjects might be combined together to provide indicators to students on subjects that best fit their interests, needs, and goals, allowing them to take appropriate steps in becoming prepared for involvement in STEAM opportunities in the future.

Integrated: Integrated STEAM education, or interdisciplinary STEAM education, is a combination of the five components, and the focus of learning is not the individual discipline, but rather on solving real world problems and issues. There is a need for multi-faceted and integrated competencies in alignment with the changing needs of our world.

This approach allows students to think outside the box and identify problems. They can then construct solutions. This often provides opportunities for more relevant and less-fragmented experiences for learners. Students often find this approach to be stimulating and exciting, and it encourages them to be better problem-solvers, inventors, innovators, and logical thinkers. Additionally, students are often more technologically literate and are motivated to learn and do well in school. If this approach is not feasible with a learning schedule, subjects may be taught separately, but connections must be made through student and teacher reflections.

STEAM Through Pedagogical Approaches: Various inquiry-based and problem-solving approaches can also be used to integrate STEAM learning into the curriculum.

Students will focus on real world authentic problems in real world contexts with the chance for them to make connections across subjects and develop problem-solving skills. Critical thinking skills including research, hypothesizing, analysis, synthesis, and deductive reasoning to discover applicable solutions to real problems are all very important in STEAM learning. These skills can be nurtured and expanded through this approach, while learning is grounded in authentic situations and within relevant context.

Possible ways to accomplish this include placing an activity at the beginning or conclusion of an assignment so that students are challenged with applying acquired STEAM knowledge. Project-Based Learning (PBL) allows students to conduct research and apply knowledge and various skills to find viable solutions to specified problems. The selection of specific problems and the availability of support to guide the learning process and debrief at the end of a learning experience is critical to Project-Based Learning. The teacher supports the process, but he or she does not give information related to the problem. Students are expected to work and solve.

Another method that incorporates STEAM, is known as inquiry-based learning. This is similar to project-based learning, as the learning activities are organized around achieving a shared goal. However, the role of the instructor, as both a facilitator of learning and a provider of information, is stronger, whereas the learner's role in setting the goals and parameters for the investigation is less defined. If done well, by skilled teachers, these activity -based approaches help students to make personal meaning of their learning experiences. This likely will increase the probability that what is learned will be retained and can be transferred for later use.

A challenge in utilizing integrated approaches in schools is the readiness and willingness of teachers who have already gone through specific disciplinary training as they worked toward their degrees in teaching colleges and universities. It is highly challenging for STEAM teachers to master all STEAM knowledge. Therefore, professional development needs to focus on interdisciplinary themes and pedagogical approaches which encompass a broad range of content, methodologies, and practices. This can be slow-going, but it is worth the time as the rewards for students are immense. Therefore, it requires a long-term perspective and careful planning. An additional challenge is the ability to teach STEAM knowledge within the amount of time allocated in a school day and schedule. Lastly, there is a need to keep STEAM knowledge relevant. This will help avoid the potential that it becomes outdated and therefore unusable.

Incorporating STEAM into Face-to-Face Learning [3]

Incorporating STEAM can begin with some small changes, but it will take time and resources to integrate it fully and successfully. However, small progress is better than no progress, and as time continues you will likely find that it comes more naturally and easily. The following ideas will help you use STEAM effectively in your classroom or in a dedicated space like a makerspace where students have access to a variety of materials and experiment tools.

1. Get others on board by discussing your plan and the importance of STEAM in your classroom and within the school. Other teachers, administrators, parents, and community members will be important assets to utilizing STEAM effectively. Consider asking other educators in local districts to share how they have been able to use STEAM in their face-to-face classrooms.

2. Be willing and excited about problem solving. A critical piece of STEAM learning is the ability and desire to solve potential problems in sound and creative ways. Implementing this new teaching style will likely be met with some challenges. Take opportunities as they come your way and learn on the fly as you go. Each plan you make will not likely play out perfectly, as it is on paper. That is okay, and is all a part of the process.

3. Patience pays off and time is a virtue. Becoming a successful STEAM teacher will not happen overnight, and having realistic expectations that match this fact will allow you to enjoy the process and take on problem-solving opportunities as they come your way. Your students will look to you as you react when things might not go as planned. Carry on and remember that as time goes on, your STEAM lessons will improve.

4. Allow students to take on leadership roles. Sometimes students are better equipped and more familiar with various types of technology, so letting them take the lead often pays off. This also gives them the opportunity to think outside the box. Students might be familiar with ways to use technology tools that you have not considered, and they will essentially be able to teach you! In years that follow, you will have this knowledge in your back pocket, and you will be able to share it with your future learners too. If a potential solution does not work out, remember to treat it as a teachable moment to problem solve and show students why it might not have been the best fit at that time and/or in that situation.

5. An art teacher is a fantastic asset. If your school has an art teacher, ask that individual to partner with you on some lesson planning. This is an essential part of STEAM learning, and students will gain an appreciation for the artistic process. By engaging in these lessons, students will understand ways in which the artistic process can enhance their learning across other disciplines.

6. It is okay to fail. Some processes and lessons simply do not go as planned. A lesson that you had high hopes for might be a complete bust, or you might get to the conclusion of the lesson and realize that your learners did not follow along with a particular method or concept as you had imagined. This will likely happen sometimes, but it is important that a situation such as this does not deflate you. Take good notes about what worked and what did not to use for future reference, and then simply move on.

7. Create a feedback system for STEAM learning opportunities. Ask students how they feel about the process and consider asking a colleague to observe a lesson or two. This can help provide guidance for future lessons and experienced teachers might have some suggestions for ensuring your lessons run smoothly. Simple tips can make all the difference. Be sure to continue connecting with other educators, assisting them as well, as you become more versed and knowledgeable about utilizing STEAM effectively.

Incorporating STEAM into Virtual Learning [3]

STEAM brings together multiple academic disciplines and standards, and educators may feel intimidated by the idea of teaching complex lessons through distance learning. Finding and utilizing online resources that have been designed to be tailored to STEAM education can be challenging, and most teachers do not have the time or resources necessary to create applicable ones for their students to use. Collaboration, communication, creativity, and critical thinking are important and necessary 21st century skills, and allowing students to focus on these through STEAM learning is important for helping them to grow academically. Consider some of the following ideas to utilize within your online learning community.

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- **Online Museums:** Museums and various historical spaces have created online self-guided tours which allow visitors the ability to experience their collections. Hosting virtual museum tours with your class can allow them to see STEAM in action.
- **Virtual Field Trips:** Virtual field trips are also great learning opportunities and can be used as components of learning goals. Zoos, the Great Wall of China, and the planet Mars all have virtual field trip options. Think about the conversations you might have with your learners while discussing the ways in which the Great Wall of China might be improved. It makes the perfect STEAM-based learning opportunity!
- **Smithsonian Science Education Center:** At this site, resources are organized by grade level, type, and topic. These are helpful for allowing learners to explore scientific innovations from their computer screens.
- **PBS Design Squad:** PBS has created a myriad of activities that can be used either online or offline, and many encourage students to build objects with existing things inside their homes. Allow students to work independently and then report back live to show off their creations, findings, and discoveries.

- **Challenger Lessons:** Lessons and activities have also been created by the Challenger Center. These also offer additional chances for STEAM concepts and self-discovery from home or through online lessons. They can be found at: https://www.challenger.org/stem-resources/#elementary_school

Case Study [7]

The growing interest in STEAM can lend itself to more resources and lessons that are readily available for young learners than it does for secondary learners. This can pose a problem to secondary educators, who are often subject specialists. Additionally, they would be tasked with looking at ways to make STEAM work within their rigid school building schedule that offers little flexibility most times. Curriculum integration has occurred in various ways in primary settings, but it is almost unheard of in high schools and other secondary environments. A case study examining the role of STEAM programs with teen learners was conducted in New Zealand and Japan, and it focused on the five STEAM components. Researchers considered the potential connections between concepts of cross-curricular inquiry and ways to take practical steps to implement a STEAM program into secondary learning on a more consistent basis. (7)

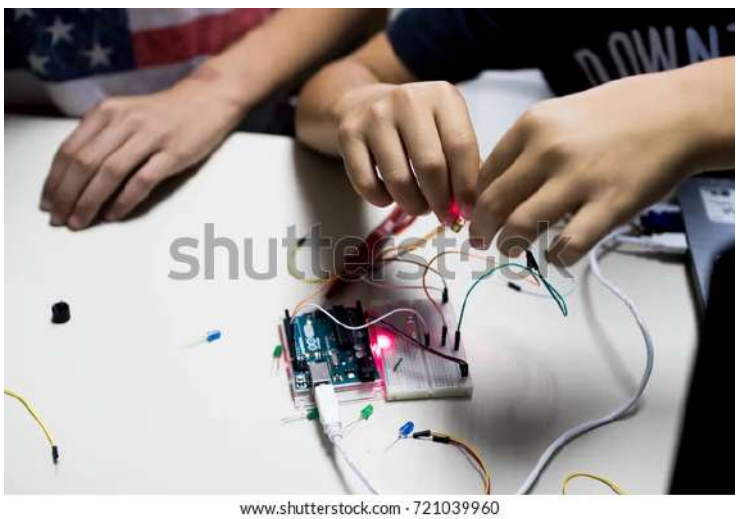
The study involved two schools and took place over a six-week period. "36 students at the New Zealand secondary school were taught by three teachers, and 44 students at the Japanese school were taught by seven teachers. The classes had three lessons of 75–100 minutes in duration per week, and the teachers had curriculum specialism in science, technology, health, social studies and mathematics. Qualitative data were gathered through the use of audio recordings of the meetings, which were transcribed and analyzed in identified themes." (7)

Although the study was short in time, and looked at only two groups of students, teachers felt that its findings were significant. They believe that the STEAM experiences were advantageous for their teaching practices and goals, and for their students as well. Their positive findings are summarized here:

- Facilitated the collaboration of STEAM teachers to the advantage of each of the separate subject curricula.
- Increased engagement of students and the development of STEAM competence.
- Allowed for the promotion of solution-oriented active learning in the classrooms.

- Promoted science and technology as possible careers.
- Increased collaboration of students working effectively together.
- Increased confidence and skills of students to collaborate effectively with people such as scientists and technologists.
- STEAM created opportunities for learners to take on social perspectives. (7)

This case study reveals that potentially any attempt at incorporating STEAM into a classroom, whether it is face-to-face or virtual, can provide numerous benefits to educators, students, parents, and the community. Educators should consider the ways in which they can make STEAM work for their students, and utilize resources, including their peers, to help in doing so successfully.



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Conclusion

- STEAM learning has developed due to the necessity of being able to focus on real-life and highly-complex problems that cannot be tackled by singular approaches. STEAM consists of science, technology, engineering, the arts, and mathematics.
- The majority of all career fields relate to STEAM in some way, therefore making it critically important that students have adequate opportunities to experience these skills and can then connect them to one another and to the world around

them. STEAM provides value to learners in multiple ways and the beneficial outcomes that result have been key in showing the success of the STEAM learning process.

- STEAM requires the use of resources, including the knowledge of peers that have previously helped learners to engage in the process. An open mindset and willingness to focus on teachable moments rather than cut and dry lesson plans is also an important component of utilizing STEAM successfully. Educators often learn as much during the STEAM process as their learners.
- The STEAM learning process incorporates the four necessary skills for the 21st century: collaboration, communication, creativity, and critical thinking. It also enables students to take on various independent and collaborative roles, including in leadership.
- STEAM is an ongoing potentially ever-changing process that can be tailored in ways that best fit with your space, learning schedule, student needs, interests, and goals. Being flexible and enjoying the process will help to ensure that STEAM becomes a regular component of and an enjoyable experience with huge benefits for years to come.

Key Terms

STEM – refers to the grouping of the academic disciplines science, technology, engineering, and mathematics

STEAM - refers to the grouping of the academic disciplines science, technology, engineering, the arts, and mathematics

Inter-Disciplinary – describes interrelated branches of knowledge

Makerspace – refers to a collaborative workspace inside a school, library, or community building in which learners are provided opportunities for creating, sharing, and exploring.

Project-Based Learning (PBL) – a teaching method in which learners are actively engaged in real-world problems and projects that reflect their personal interests and goals.

Design Thinking – a process for solving problems with a focus on prioritizing consumer needs.

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