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STEAMTEACH Austria: Towards a STEAM Professional Development Program

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Abstract

The STEAMTEACH (STEAM Education for Teaching Professionalism) project works with teacher trainers to develop a program of Transcultural STEAM Professional Development for in- and pre-service teachers. Following a literature review, a semi-structured questionnaire then interviews approach was used to elicit current practice, challenges for teachers and recommendations from Austrian teacher trainers. These recommendations were then compared with and supported by STEAM academic literature. It was found that none of the institutions offered a STEAM approach and it does not appear in the curriculum. Indeed, this fact is the primary challenge to overcome. Recommendations were that teachers should work in multidisciplinary, supportive, collaborative groups and networks. Problem and project-based learning were identified as key learning methodologies. A mix of physical and on-line working synchronously and asynchronously was recommended for online professional development because teachers can participate irrespective of time and place. Educational technology can support collaboration, and also 'plug and play' technologies including game-based learning can be inserted into an overall STEAM approach. The affective factor was judged essential for students and teachers.

Introduction

The implementation of STEAM (Science, Technology, Engineering, Arts and Mathematics) education requires the successful integration of content from the aforementioned disciplines (e.g., Egyptian architecture using arts, mathematics, science, and engineering) over a school program (Diego-Mantecon et al., 2021). This is not a trivial challenge, as reported by Haas et al. (2020, p.?) "in practice teachers may stay rooted in their core subject expertise and not have confidence to embrace a wider approach". Yet, Kang (2019) found that experiences with integrated STEAM are effective for cognitive and affective learning and coaching in classroom practices, within a teacher development program, increases confidence in teaching the integrated approach. This suggests a need to focus on the development of the STEAM teaching programs from both a cognitive and affective perspective. McDonald (2016) critically reviewed 237 papers focused on STEM literacy, students' engagement, effective pedagogical practices, and the role of teachers in STEM education. He suggests many pedagogical practices that have been shown to be effective in promoting student engagement and achievement in STEM disciplines, including inquiry-based learning, digital learning, and computer programming and robotics. But, even if they have confidence in their ability to deliver integrated STEAM, Thibault et al (2018) state teachers also need to be willing to invest time and effort.

The success of the Erasmus+ Project KIKS (Kids Inspiring Kids in STEAM) ref. 15/0100-KA2SE/136AA was in no little part due to the enthusiastic and expert contribution of our teachers. This highlighted the importance of teachers including the need to also engage those less confident and/or less enthusiastic about STEAM. Hence the focus of a follow-on project STEAMTEACH (STEAM Education for Teaching Professionalism) is the teachers themselves and how we might work with teacher trainers and others to develop a programme of Transcultural STEAM Professional Development for in- and pre-service teachers.

STEAMTEACH is a collaboration between Spain, Hungary, Finland, Greece and Austria. The transcultural aspect offers a key contribution to STEAM education for two reasons identified in the project proposal: Firstly, the development of STEAM material which can be used across cultures, for example GeoGebra Maths and STEAM which has a global audience of more than 100 million; Secondly, continued collaboration between cultures initiated in our case by the KIKS project to jointly develop STEAM material for all.
Therefore, the challenge for teacher training is to give teachers confidence and desire to use appropriate methodologies and tools.

This document is the first iteration of designing a transcultural professional development framework starting from the Austrian requirement. A semi-structured interview approach elicited the insights of five Austrian teachers. This was used to derive a professional development framework meeting the requirements of Austrian teachers. The research objective was to establish STEAM current practice, challenges for teachers and recommendations for STEAM professional development.

Method

This activity consisted of interviewing five Australian teacher trainers on-line using Zoom for thirty minutes. A questionnaire was given to the five experts prior to the interviews and their initial written responses captured online. The same questions were used for the on-line face-to-face interview and their previous written responses used to suggest supplementary questions. The eight questions addressed their views on current practice, challenges for teachers in implementing STEAM and recommendations. Their combined written and verbal responses recorded on video were captured in their entirety and then used to provide the Austrian view.

Current Practice

The first two questions address the teacher trainers' current practice, for example:

What methodology are you applying for delivering STEAM education to secondary school teachers?

The following three questions compare answers to the above with what they would actually recommend in order to identify any gaps or differences, for example:

What methodology or approach would you recommend for delivering STEAM education? Why?

Challenges

The next three questions concern the challenges faced to implement STEAM and the best methodologies to overcome these, together with their pros and cons, for example:

Generally speaking, what are the greatest challenges to effectively teach and implement integrated approaches to STEAM education?

Recommendations

The final two questions asked for recommendations for pre-service and in-service teachers respectively:

What recommendations for pre-service education could help teachers better integrate STEAM subjects?

What recommendations for in-service or continuing professional development would help to support integrated STEAM education?

Results

Our five Austrian subjects are all experienced in teacher training, aged between 28 and 42, of doctorate level, knowledgeable about STEAM (with one exception) and with related research interests. They have between 4 and 6 years STEAM experience (with one exception: The self-proclaimed non-STEAMer nevertheless provided valuable insights into what STEAM approach/support might be required). The teacher/institution providing purely on-line training, conforming to the same Austrian curricular requirements and accreditation as for the other institutions, also provided valuable insight to the pragmatic requirements of on-line STEAM.

Current Practice

None of the institutions offers an overall STEAM approach or framework, perhaps because this is not part of the curriculum. Our subjects are therefore referring primarily to their individual activities. Three offer limited STEAM modules e.g. "How does the ear work", 3-D printing, augmented reality with knowledge and materials, which could be implemented in the classroom. Project based learning and gamification were both mentioned once. One institution plans to offer an on-line workshop course on "Implementing augmented reality in STEM education". MOODLE and ZOOM and H5P were mentioned by two institutions.

In asking what STEAM methodologies they actually use, our expert STEAM teacher trainers responded with Problem and project-based learning, inquiry based, flipped classroom and a mix digital and physical learning activities. Additionally, both synchronous and asynchronous online learning can increase availability of the above. Finally, direct instruction has its place, especially if teachers have little/no pre-knowledge.

In asking what subjects they offer, combinations cited were all maths plus social science and/or geography or biology and statistics, often marginally. This was reflected in the fact that Austrian teachers are trained in TWO subjects. It also suggested that therefore a group of Maths teachers might well together have second subject expertise to address rich STEAM when working together. One teacher trainer had a subject independent role to help teachers to use technology in their subject/classes. Hence, a technology module such as 3D printing might attract a group of teachers with complementary expertise

Challenges

Clear challenges posed by the Austrian educational system are led by the fact that STEM/STEAM is not a curricular requirement and PTD is subject-based. It is hard to convince math teachers that STEM/STEAM is of positive benefit. Concerns are: meeting the subject curriculum requirement, time spent in STEAM development, assessment and student-perceived benefit. Teachers do not implement STEAM projects because it is not teaching for the exam. Teachers have to deal with ready-made exam questions and they cannot make their questions.Problem and project-based learning reoccurred as the appropriate methodologies with the proviso that they have 'very much potential to fail: if students have/find no problem or issue to be discovered (or they do not want to find it), teaching and learning does not start'. Similarly, teachers have to 'spread an atmosphere of curiosity and open-mindedness so that students do not just focus on fulfilling the minimum for their (single subject) grades'.

Recommendations

The previous questions set the ball rolling so that the final two questions concerning pre- and in-service teachers unleashed many recommendations that can be considered together. Responses were essentially the same as previous questions but now in much greater depth. Also, it is important to note from the above that the experts were able to 'practice what they preach' ie they were able to deploy the same as they recommended. This gives us confidence that recommendations are doable.

Collaborative Groups and Network

Teachers should work in multidisciplinary, supportive, collaborative groups. Teacher issues should be addressed head-on at the start with a group meeting. The teacher's perceived benefit and confidence appear key: 'Address teacher issues head on: In an online live meeting teachers' preconceptions regarding STEM education could be tackled and discussed'.

It is essential to convince teachers of the value of STEAM, demonstrating that it could work - i.e., use it in preand in-service education as a teaching approach. Evidence based information on project-based learning can demonstrate to teachers that students learn more with the STEAM approaches. The STEAM approach needs to be introduced to teachers with particular regard on how to integrate among STEM subjects within the curriculum. They should believe that students can learn both the topics of the curriculum and meet the exam as well.

The key to progress is to: 'Work in groups: The project should collaborate with other teachers. The biggest problem is they still work alone, not in a small group for their projects'. This can start with a familiar subject that the teachers really know then connect with other subjects combining the expertise of the different teachers. Teamwork and multidisciplinary is really important. In Austria there is potential for a combination of subjects because secondary level teachers are trained in two subjects. They mostly have math and physics, sometimes geography or sports. This means we can create an interdisciplinary learning. It is really fruitful if teachers can see that they see interdisciplinary between subjects: geography, physics, arts, language, and etc. Teachers need to know the real-world connections, benefits to students about their professional life in the future, and networking thinking such as problem solving and other more problem-based approaches.

Collaboration between teachers should also help the teacher take it out into their school. Regular meetings are needed but with a sensible schedule for the teachers. Teacher education programmes are in need of promoting cooperation among groups. Instructional design and doing projects with teachers and schools to create an interdisciplinary team. It is essential to reach out to schools. School development is important, developing learning culture in schools. Give teachers the tools to do this and that in their own schools.

Problem and Project-Based Learning

Problem and project-based learning were identified as key learning methodologies. Appropriate scaffolded design-based learning rather than pure discovery learning or pure experiential learning is necessary to get a deep understanding of content to be able to apply the knowledge in new situations. Evidence-based learning materials combined with well-designed instructional designs really help learners learn. Design-based learning is important to introduce the teachers with 21-century technologies. The best strategy is to give examples. From the TPACK papers written by Mishra and Koehler, it says that so far the teachers training program is just talking. It would be better to do real workshops for their projects. Design-based learning should address the goals of the TPACK model. Designing pedagogical and technological framework should address how to teach with technology or in technology related subjects

Mix of Physical and On-Line

A mix of physical and on-line working synchronously and asynchronously was recommended for online professional development because teachers can participate irrespective of time and place. Educational technology support can support collaboration, interesting 'plug and play' technologies including game based learning. Synchronous and asynchronous physical and on-line activities can be mixed and matched. Teach teachers on how they can create good educational learning materials and thus convince them that the technology is a good tool for teaching and teach them how to use it. Project and Problem based approach supported by appropriate scaffolding and best practice, proven "plug-and-play" modules and games can be easily inserted into an integrated STEAM approach. Additionally, one expert emphasized addressing concrete problems/issues faced by teachers. Open, student-driven activities should be carefully supported with structure/scaffolding/support by design-based learning of pedagogical and technological frameworks on how to teach with technology or in technology related subjects. Best practice, practical plug-and-play modules need practical ways to practice STEAM Education and so teachers get inspired.

Affective Factor

Some experts addressed the affective factor for students and teachers (learning that relates to the learner's interests, attitudes, and motivations) including gamification. To reach out to the affective and cognitive sides, problem and project-based learning can be motivating and make learners learn. A good structure motivates learners and they perform better compared to the control group. There is a positive correlation between affective and cognitive factors. Gamification should be combined with problem-based learning. One subject recommended linking pedagogical and psychological perspectives in particular the "Affective" factor. Game-based learning or gamification can be used to enrich experience in the online professional development course.

Discussion

The research objective was to establish STEAM current practice, challenges for teachers and recommendations for STEAM professional development. Current practice and challenges reveal that none of the institutions offer STEAM, teachers work on an individual basis and, perhaps most challenging of all, STEAM does not appear explicitly in the Austrian curriculum nor in exams and assessments. To overcome this, the expert recommendations of our teacher trainers can be examined to see how far they are supported or otherwise by STEAM academic literature. From this, four main recommendations are presented below.

Collaborative Groups and Network

To deliver STEAM into the classroom, teachers require the mutual support and expertise to work in multidisciplinary groups reaching into the school. A teacher working alone learning STEAM will be unlikely to succeed. As Thibault et al (2018) previously cited, it is essential to convince teachers of the value of STEAM and give them confidence and this implies a teacher's perceived benefit of STEAM (Weinhandel et al, 2020).

Working in teams, especially with teachers having two subjects, helps foster an integrated approach and also mutual support. Teachers can appreciate interdisciplinarity, real-world connections and educational and future life benefits for students. The collaborative problem solving and project-based approach is supported by the network of teachers. Supported by the collaborative network group, STEAM is taken into schools undertaking projects. This hopefully engenders school development and a learning sculpture in schools.

There is much literature support for collaborative problem solving in both school and industry, and can be for both pupils and their teachers. Rojas-Drummond et al. (2006) describes creativity and co-construction in primary school children's collaborative activities. Similarly, Lavonen et al. (2014) describe creative and collaborative problem solving in primary school teacher education. Both can be enhanced by student peer-to-peer teaching and collaboration (Lander 2016). The creativity and co-construction features are mirrored in industry. Wiltschnig et al. (2013) describe product development as co-evolution heightening creativity describing intensive problem-solving coevolution as *'the 'engine of creativity in collaborative design'*. Thus, in addition to its educational value, student experience in CPS will be valuable in his or her future career.

Problem and Project-Based Learning

STEAM related collaborative problem solving is a way of supporting an interdisciplinary approach and has been undertaken in both school and industry. From a school student educational perspective, the IB Curriculum (2020) states: 'Educational approaches should feature creative problem solving challenges including societal factors/needs'. The industry approach supports the EU drive to encourage students to experience STEAM activities as a preparation for their future careers.

Problem and project-based learning, scaffolded design-based learning as described by the teacher trainers is supported in the literature by TPACK theory (Mishra and Koehler 2009). Edelson et al. (1999) describe inquiry-based learning as the pursuit of open questions and inquiry-based learning as developing inquiry abilities leading to improved understanding. In line with the expert views, the Inquiry based approach faces the challenges to support where needed the individual learning paths of the students as they address the challenge, and at appropriate points provide expert help/tuition, and provide assessment mechanisms which both assess attainment and identify learning gaps which need to be filled. Similarly, flipped learning gives teachers and students time to explore together and work is student-driven, learner determined and concerned with the development of something new. This (classroom) "group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter' (Association of Flipped Learning Network, 2014).

Mix of Physical and On-Line

The possibilities and flexibility of working both synchronously and asynchronously were highlighted during the imposed restrictions of COVID-19 when much valuable learning was achieved on-line. Our experts advise that it is important to convince teachers that technology is a good tool for teaching and teach them how to use it. Indeed, Edelson et al (1999) stated that: All of the fundamental properties of computing technologies offer benefits for inquiry-based learning. Weinhandl (2021) describes how learning basic logical competencies is enhanced when utilising technologies and real-world objects. This has become more and more evident with tools such as social media, GeoGebra maths software, Gaming, Augmented Reality, 3D printing and also learning from COVID restricted education.

More fundamentally, physical and virtual can be used together in hands-on experience and experimentation. GeoGebra and Tracker (movement capture and tracking software) were used to allow students to study their sporting movement in"Analysing Sporting Performance" and also those of sports stars (Houghton et al 2019) . Lieban (2019) describes how students redesigned games and puzzles digitally using GeoGebra and then explored them with 3D printed versions. This combination enhanced their spatial reasoning and also creative process and problem solving. Weinhandl (2021) describes how learning basic logical competencies is enhanced when utilising technologies and real-world objects. MathCityMap is an easy-to-use App which lets the user create a math trail in the local environment. The trail leads to a number of real-life objects such as a church, playground which are chosen to explore maths problems (https://mathcitymap.eu/de/tutorials/.

Our experts advocate a Project and Problem based approach supported by appropriate scaffolding and best practice, proven "plug-and-play" modules and games which can be easily inserted into an integrated STEAM approach. For example, Haas et al (2020) adopted an Integrated STEAM approach featuring problem solving and content skill domains from the (Luxembourg) national curriculum.

With the COVID-19 pandemic, the physical/online balance appears to have changed: Weinhandl (2020) has made an extensive study starting with a survey of flipped-classroom, student-centred, individually paced learning and concludes from interviews with teacher trainers that courses should permit more such flexibility in both formal and informal learning especially in the light of COVID. Much of the COVID learning experience has been on-line, and the considerable experience and confidence gained by teachers as well as students suggests, as an example, that more of the "group space" dynamic, interactive experience can be provided on-line via videoconferencing than may have previously been thought.

Affective Factor

Our experts advise to focus on the affective factor for students and teachers. This concerns learning that relates to the learner's interests, attitudes, and motivations (Picard, 2004). Real life problem and project-based learning can be motivating and contribute to the affective factor within an appropriate structure Lieban (2019) and Weinhandl (2021).

Gamification is an emerging educational initiative to enrich learning engagements and experiences. The simplest and most familiar definition of gamification is the application of game-design elements and game principles in non-game contexts (Deterding et al., 2011; Huotari & Hamari, 2012; Robson et al., 2015). The use of gamification may provide learners with richer learning activities, behaviors, and experiences through several elements of games such as feedback, goals, badges, point system, leaderboard, and user levels (Huotari & Hamari, 2017). Rahmadi (2020) reports that user-generated microgames for supporting learning may result in higher take-up. The idea of user-generated microgames for supporting learning in general could be extended to support STEAM learning with so-called learner-generated microgames; students create their own microgames within integrated STEM subjects. Creating games can support integrated learning for science, technology, engineering, arts and mathematics (STEAM) education, acting as a bridge between subjects (G.A.STEM, 2019).

Conclusion

STEAM is increasingly recognised as having global importance for the well-being of nations and individuals, and school students in their education and future careers. Huge amounts of STEAM material is constantly being developed. STEAMTEACH aims to contribute to the successful and efficient exploitation of this material by providing a transcultural framework so that it can be used by all. The Austrian requirement is for Multidisciplinary, supportive, collaborative-networked groups. These would engage in problem and project based scaffolded learning featuring a mix of physical and on-line working synchronously and asynchronously with plug and play modules. These would have an affective factor to engage the learner's interests, attitudes, and motivations driving learning and cognitive development.

However, this requirement is driven at least in part by the fact that STEAM does not appear in the Austrian curriculum, teachers are not trained in STEAM, and neither teacher nor student is assessed in STEAM. In other cultures, STEAM does feature in the curriculum and the next steps will be to examine results from the different cultures to define a transcultural framework meeting the (overlapping) requirements of these different learning environments. For this, continued collaboration between and within cultures is essential for this to happen. This took place in the KIKS project, will take place within the STEAMTEACH project, which could be a driver to foster global collaboration.

Recommendations

Teachers should work in multidisciplinary, supportive, collaborative groups and networks. Problem and project-based learning are the key learning methodologies. A mix of physical and on-line working synchronously and asynchronously supports online professional development can support collaboration and also provide ‘plug and play’ capability including game-based learning that can be inserted into an overall STEAM approach. The affective factor is essential for students and teachers.

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