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Relevance of the SAM Project for K-12 Education

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Additive Manufacturing (AM), commonly known as 3D printing, has emerged as a cutting-edge technology that revolutionizes physical object creation. By layering materials to build component parts, AM provides infinite design freedom, material versatility, and a streamlined production process [1]. While its applications in various technical fields are well-known, 3D printing is also making significant inroads as an educational tool in K-12[1] settings. By enabling the production of tangible objects that facilitate learning, 3D printing holds the potential to enhance comprehension and engagement across various school subjects, such as: chemistry, mathematics, sports and others. [12]. Additionally, it helps to facilitate learning and recall by addressing multiple senses [13], for example a study shows that using 3D printing activates the sense of touch via producing materials and makes abstract concepts more concrete [15]. For this reason, 3D printing provides advantages to support learning in subjects like mathematics [4], science [5], engineering [6], and social studies [7]. It also supports learning with a new approach to teaching complex subjects [6], harmonizes multiple curriculums, and enhances students' higher order thinking and learning skills [8].

When compared to the traditional didactic approach, 3D printing offers revolutionary and innovative methods of learning and understanding of complex subjects [6] by visualizing theoretical concepts [2], as well as improving students' higher order thinking and learning skills [8] by integrating theoretical and practical knowledge [2]. The major benefits of using 3D printing in education can be sorted as (1) creating excitement among students by allowing them to involve in the study and design phase of the models, (2) preventing students from being passive in the learning process instead of consuming information they can actively involve in the creation of objects related to the subject topic, (3) providing new learning possibilities to students by visualizing the topic learned, (4) promoting students' problem-solving skills due to printing objects correctly they will have to learn to face and solve practical problems [2]. Figure 1 summarises education subject areas where 3D printing can be used as supporting didactic approach.

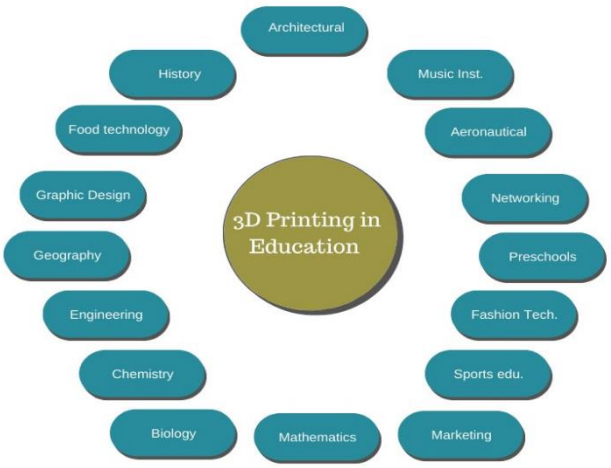

Figure 1: Aspects of where 3D printing can be used in education [12]

[1] *K-12 refers to the educational journey that encompasses kindergarten (K) through 12th grade;*

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Despite 3D printing having advantages, meaningful integration is still very limited [9]. Even though some schools have 3D printing equipment, a high percentage of schools still do not fully utilize these technologies for education [10]. This is because most teachers have limited knowledge and experience of the benefits of 3D printing and the use of the equipment [11]. Studies show that teachers get frustrated with the use of 3D printing software and hardware. They also have trouble understanding 3D file types, and some technical aspects such as printer calibration, modelling, and design [11]. When knowledge, support and resources are made accessible to teachers, they are more likely to engage in the use of 3D printing [14]. Therefore, training for teachers will be beneficial to have positive attitudes toward using 3D printing in education and reduce their resistance to integrating this technology into education [11].

Perception of teachers about SAM TECH4KIDS activities

Over the course of the project lifecycle, SAM project partners conducted a systemic raise awareness campaign involving the planning and implementation of dedicated activities with schools from early childhood to high school levels. . These activities were conducted under the **Tech4Kids** framework that includes developing educational materials, such as: comic series, videos, banners, quizzes, and an 3D printing kit for teachers to implement 3D printing activities. Tech4kids activities were carried out in Germany, UK, Spain, France, Ireland, Italy, and Portugal.

The awareness campaign has been launched to attract young people to the 3D Printing industry. To achieve this goal, SAM focused on students and teachers in K-12 education. Since teachers are one of the main actors in designing the learning process, if they are aware of the AM technology use and benefits, they can encourage students' learning as well, thus ensuring a multiplier effect. in terms of impact with K-12 target group, SAM project approached 86 different schools and involved nearly 3400 children and youngsters. Among the great number of participants, this paper will focus on the results achieved with two specific activities conducted in Portugal. The first activity aimed to engage a wide range of students, from early childhood to high school grades, over a period of five full days. Customized materials developed in the Tech4kids program were utilized for each grade level. For example, one activity designed for early childhood grades involved a recycling game where children matched 3D printed materials with the correct recycle bin. Following the game, the children were introduced to the 3D printed materials and machine, and a discussion was held to explore their benefits for sustainability.

For primary school students, a comic series was presented, followed by the SAM Basic quiz. They also had the opportunity to participate in the recycling game and learn about 3D printers and shredder machines. A discussion on sustainability and 3D printing concluded the session.

Secondary school students were exposed to a presentation on 3D printing and its application areas. They enrolled in a hands-on experience investigating 3D printers and shredder machines. A recycle game was incorporated into their session as well, followed by a discussion on the relationship between 3D printing and recycling.

In the second activity, the target audience consisted of high school students. They were presented with information about 3D printing technologies and potential career opportunities in AM. The focus was to educate and inspire the students about the possibilities offered by 3D printing and its relevance in various industries.

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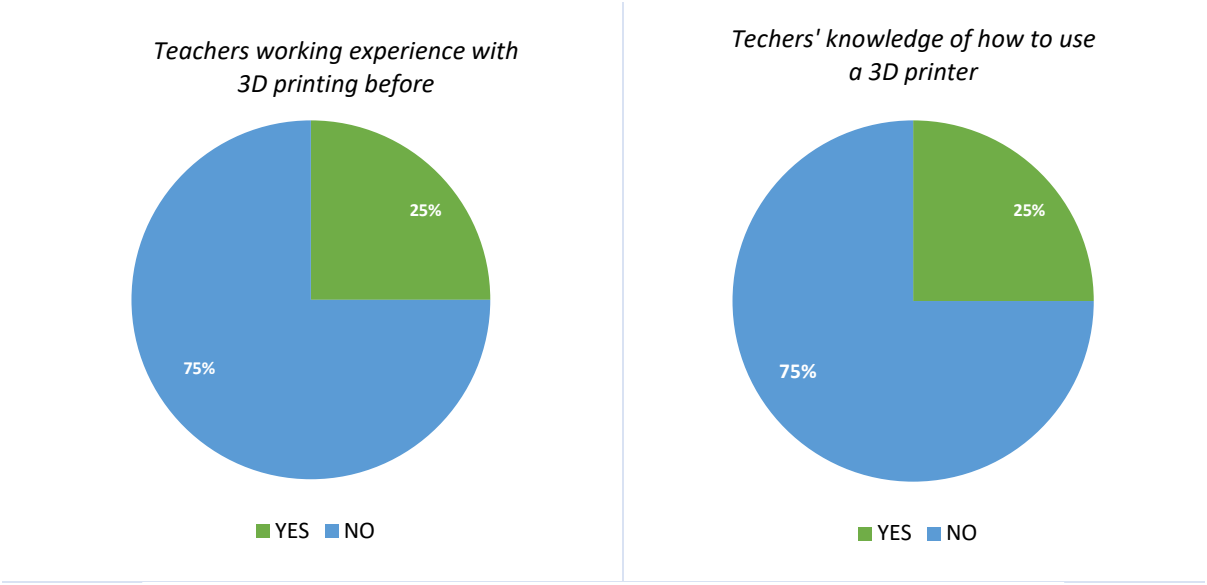
Throughout these activities, teachers were also encouraged to attend the sessions. This allowed for a collaborative learning environment where both students and teachers could engage in the activities and discussions, fostering a deeper understanding of 3D printing and its connection to sustainability.

At the end of both activities, the views of the teachers were sought. Four teachers voluntarily filled out a feedback questionnaire. The teachers' names were kept anonymous and referred to as T1, T2, T3, and T4. The background of these teachers with 3D printing is shown below.



In conclusion, we can say that most of the teachers have not had knowledge and experience with 3D printing before the Tech4Kids activity.

In response to the question of the type of 3D printing activities they would like to apply in their classes. They responded as:

- "It does not apply to the subject I teach." (T1)
- "Production of 3D models for Natural Sciences, Physics, Chemistry, Mathematics, Geography, Visual Education (etc.)." (T2)
- "Presentations, prototypes." (T3)
- "Prototyping characters or interfaces." (T4)

In general, and despite non prior knowledge about the technology, teachers are interested in using 3D printing for prototyping and visualizing concepts.

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Another question was asked about the necessary teaching resources and support to integrate 3D printing into school projects or classroom settings. Their responses were:

- "Training, appropriate technology." (T1)
- "Experiences." (T2)
- "Funding." (T3)"3D scanner and printer." (T4)

Teachers indicated that they need to access the printer first and then get training and experience to use these technologies. Then, their opinion about the benefits of 3D printing in education was asked. They answered that:

- "Making learning more hands-on in science." (T1)
- "The participation of students and the production of unique pieces or models in the most scientific areas." (T2)
- "Creativity." (T3)
- "A fast relationship as a prototype. Connecting the virtual to the real.
- Connecting the digital to the analogue." (T4)

According to their response, it can be concluded that 3D printing in education has the potential to increase interaction in the classroom and bring innovation to education. This is done by visualizing materials and increasing hands-on learning opportunities. In addition, it provides examples that illustrate the use of digital technology in real life situations. When they were asked them what the less positive side is of using 3D printing in education, they replied that;

- "It cannot be used in quantity and is a time-consuming process." (T1)
- "Cost, investment." (T3)
- "Costs." (T4)

Their responses reveal that the cost of equipment is one of the barriers in applying 3D printing technology within the different school education levels. Additionally, it is a time-consuming process and challenging to integrate into limited class time. This answer might be linked to their lack or limited background knowledge regarding 3D printing. Finally, we asked teachers from the Teach4Kids activity whether they were enlightened about how to implement 3D printing in the classroom context. All of them responded with "yes".

Conclusion

The integration of 3D printing in education has the potential to revolutionize the learning experience by providing tangible and interactive tools for K-12 students. The benefits of 3D printing, such as enhanced engagement, visualization of concepts, and the development of problem-solving skills, make it a valuable addition to classrooms across various subjects. However, the limited integration of 3D printing in education highlights the need for accessible training, appropriate technology, and support for teachers. Overcoming these challenges will pave the way for a more widespread adoption of 3D printing in educational settings. Through the experience and opinions of some of the teachers involved in the SAM project, it becomes evident that 3D printing has the potential and capability to enrich education and empower students as active participants in the learning process. The desire of teachers to incorporate 3D printing in producing prototypes, visualizing concepts, and fostering creativity underscores the potential impact of this technology in the classroom. While cost and time constraints remain as challenges, advancements in technology and increased availability of resources are expected to mitigate these limitations over time. As the benefits of 3D printing in education become more

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evident, it is crucial to invest in teacher training programs and provide the necessary infrastructure to support the integration of this innovative technology. To meet these needs, the SAM project developed Tech4Kids interactive education materials addressing early childhood to high school education. Additionally, a free and open-access 3D printing kit for teachers was developed to support and guide teachers in integrating 3D printing into their education environments (https://skills4am.eu/3dprintteacher.html).

In conclusion, 3D printing holds great promise for transforming education by facilitating hands-on learning, visualization of abstract concepts, and the development of critical skills. Despite the lack of knowledge about 3D printing and the constraints in accessing a 3D printer. The SAM project has contributed to increase teachers' awareness of 3D printing and its applications. As well as created the necessary resources to support the teachers in future activities. As found in the study, before the Tech4Kids activity, most of the teachers had not contact with 3D printing. However, now they have a new vision and also supporting guidance materials to facilitate 3D printing in their educational environment.

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