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Finding the T and E in STEAM: A lesson taught and learned

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Abstract

This study illuminates the challenges of making technology (T) and engineering (E) concepts visible within a STEAM task. During a course in technology education for pre-service teachers, students were tasked with creating short films to express their perspectives on technology. The study adopts a descriptive approach, using aesthetic learning processes as a tool and employing Pierre Bourdieu's theoretical framework of technological capital to examine the technological knowledge embedded in these films and how it relates to teaching and assessment. The results found that students did not use their subject-specific knowledge as expected. Instead, their focus leaned more towards the creative process of filmmaking, diverging from the primary objective of communicating their views on technology. Nonetheless, the films can be seen as successful from an aesthetic perspective. Findings underscore the need for another kind of time investments and a focus on technology content knowledge when teaching the T and E in STEAM. The discussion offers insights into these complexities of technology and engineering in an interdisciplinary setting. It also highlights the gains of aligning an aesthetic learning process with technology subject matter to ensure a holistic understanding of technology among future educators.

Keywords

STEAM education; Swedish technology education; STEM education; technology education; aesthetic learning processes

Introduction

This article is centred on the education of pre-service technology teachers within a STEAM environment. Teaching technology education within an interdisciplinary realm is complex (Lewis, 2006; Sanders, 2009). This complexity might be connected to STEM education's struggle with identity (Hsu & Fang, 2019). A shifting identity depends on how the subject context is presented since the STEAM disciplines are not always related to each other, in content or pedagogy (e.g., Hallström & Schönborn, 2019; Liao, 2016; Herro et al., 2019). STEAM subjects are primarily taught isolated from each other (e.g., Bautista, 2021; Kelley & Knowles, 2016). Generally, STEM stands for teaching where Science, Technology, Engineering and Mathematics integrate. By integrating the STEM subjects, students' understanding and learning are assumed to benefit, as the combination supplies opportunities to apply interdisciplinary knowledge in everyday life or design exercises (Allen et al., 2016; Breiner et al., 2012; Bryan et al., 2015). A too narrow expression of technology can increase the gender-stereotypical image of technology and affect learners' image of their technical abilities (Sultan, 2018). Educators can create more inclusive learning by teaching with a broader perspective of what technology is. One criticism against STEM has been that it can lead to Technology (T) and Engineering (E) often being downplayed in favour of foremost Science (S) (Hallström & Ankiewicz, 2019).

In our teaching experience, fitting Swedish technology education into the STEM package is challenging. Today, technology education in Sweden is an interdisciplinary subject that includes crafts, engineering science, and technology history. The Swedish National Agency for Education (2022) describes it as having a role in shaping our future by developing technological skills and literacy by raising awareness of various dimensions of technology, a subject already in line with STEM but at the same time finding it hard to find its place within it. Alternatively, even more, finding it hard to take its place.

Hallström & Ankiewicz (2019) point to design, as found in technology and engineering, as the most promising in unifying the STEM subjects. Integrating Art (A) with STEM further emphasises the importance of design, creativity, and innovation when learning STEM (Bautista, 2021). However, despite STEAM education gaining popularity, little empirical data exists, and even less is known about the challenges associated with teaching (Herro et al., 2019). Therefore, we wanted this descriptive study to lean into the integrated STEAM more than STEM and explore issues when teaching technology education in relation to STEAM.

Research setting

This study is set in the first week of a five-week course in technology education. The first week centres around exploring the concept of technology. It includes readings about topics such as the philosophy of technology and didactics. However, before the students had gotten into the course readings, they were asked to create a movie about technology. It could be about an artefact, an idea, a system, or anything connected to the students' view of technology.

The students were pre-service teachers at a university level. The course is positioned during the programme's third semester, and the students were engaged in compulsory courses covering subjects like Biology, Chemistry, Physics, Sustainable Development, and Technology. An aesthetic learning process influenced our subject teaching, and creativity was vital to the course sessions. Technology education made up 7.5 credits out of a total of 30.

Methodology

We have chosen to do a descriptive study. "Descriptive studies often represent the first scientific toe in the water in new areas of inquiry" (Grimes & Schulz, 2002, p. 145). In our study, the method is used to learn more about the possible issues when teaching technology education in relation to STEAM. The data was collected through an observational session that provided information about the technological content in the students' movies about technology. The descriptive research also aimed to reveal issues in the relationships between technological content and STEAM. The rationale of the data collection was to describe more *what* than to understand *how* or *why* students did what they did. This choice was made with an ambition to add to our research field but also to teaching practices' understanding of what can happen with the T and E in a STEAM classroom. We used descriptive categories such as science, art, and technological content and understanding to sort and analyse the data and conclude the implications of the findings.

The T (and E)

To explore the students' technological content, we chose to be inspired by Bourdieu's thinking of symbolic forms. Using a Bourdieusian perspective gave us a vehicle to see technological knowledge embedded in the students' projects and helped us unpack the T and E in their choices. Bourdieu's thinking presents technology as mainly a result of invention, implementation, use, and cultural transmission (Bourdieu, 1979). Romele (2021) described a Bourdieusian perspective showing that technologies are entangled in social and cultural dynamics of classification, separation, and eventual exclusion and discrimination. In other words, technologies are more than artefacts. Bourdieu (1979) put forward the technological capital as being in three states:

- Objectified – All technologies owned, used, or designed for actor/group.
- Institutionalised – Some actors can use technological artefacts in a certain way or have access to them, while others cannot.
- Embodied – Actors/groups allow or prohibit the use of technological artefacts in a particular way.

We found adding definitions of technology close to teaching and assessing valuable to broaden the technological capital. Valuable in the sense of connecting the study to classroom practices. We use, inspired by Parayil (1991), Nordlöf et al. (2022), and Norström (2014), the categories *technical skills*, *technological scientific knowledge,* and *socio-ethical technical understanding* when sorting technical understandings. In Nordlöf et al. (2022), technical skills are described as understanding not *why* things work but *that th*ey work. Activities can include making, sketching, and drawing. Technological scientific knowledge is knowledge gained using a general scientific approach and understanding *why* things work. Socio-ethical technical understanding is understanding the relationship between technology and the human world. Knowledge *about* technology.

Aesthetic learning process

An aesthetic learning process is a representative method of learning. Symbolic expressions are characterised by representation, for example, perception of the world, and experience, an emotion, or an object. However, a learning process can only happen when practical knowledge, reflection, and relations to the earlier experiences meet the new knowledge gained. The aesthetic learning process used in this paper is creativity scaffolding, a socio-cultural collaboration between the students instead of just being an individual trait (e.g., Bergfeldt, 2022; Horh, 1998). Hohr (1998) stresses that an aesthetic activity can be used to express the unspeakable. The learning experience becomes an aesthetic learning process when it develops into knowledge. In our study, while creating a stop-motion movie, the students learned to work with clay, build environments, and use art to communicate while learning about technology. The relationship between what students did and what they understood creates depth and width in an experience far beyond an unreflective "doing". The difference between "just making a movie" and the learning process that results from the students' work with animation is the students' awareness of the relationship between what is produced and their reflection.

In this study, in the acronym STEAM, the "T" stands for tool use, such as iPad, iMovie, photos, and digital media. "E" means making structures and the intellectual capital of technology, such as knowledge and ideas. "A" stand for visual arts, storytelling, and auteur-ship. An auteur is a person who influences the whole creative process—from idea to making to finished product. We are zooming in on the S, T, E and A in this STEAM-related activity, focusing on the T and E as we see them most closely to technology education as we teach it in this specific course. By introducing stop motion movie as a tool, the goal of the course session was to give teachers a practical tool to use in-service and provide an understanding of what technology is.

Stop motion as a tool to gain data

Figure 1. Stop motion session.
Note. Example of a small table studio made by the students. The students used an art print by Danish painter PS Kröyer as a background. In front of it, they positioned the clay figures. They photographed the setting with an iPad, set in 3D printed holders. A black holder is seen on the table in front of the students.

Stop motion is a programme where you take single-frame photos of an object. In the frame on display is a shadow of the object visible. With a shadow of the object on display, it is possible to find the last position. That makes it possible to move the object a little bit. Removing the object, changing it a bit, and then putting it back into the same position is possible. Therefore, minor changes between each shot are possible. Clay is an easily re-shaped material and is often found in classrooms. It is cheap and requires minimum pre-experience to manage. Orraryd (2021) stresses that one of the limitations of using clay models is that it is time-consuming but facilitates potentially meaningful learning. In this study, the students were asked to manifest what technology meant to them using clay and stop motion.

Course sessions

The day before the movie session, the focus for our data, the students were given a homework assignment. They were asked to go out and look and take photos of technology in their surroundings. Indoors and outdoors. The following day, they had a three-hour session that started with the lecturers randomly grouping the students into four groups. One lecturer then presented the basics of traditional western storytelling, for example, starting with "Once upon a time …" and continuing to describe the setting and characters, delivering waypoints and a clear ending. In short, the dramaturgical tricks used in stories.

The students showed their photos to the group and discussed and reflected on the previous day's technical findings. Next, the students decided how and what they would like to present as technology from the discussion. The group then agreed on a technological story to exemplify through "stop motion"—stories such as "the lever", "trampoline", and "space trap". These stories shifted and evolved during the production. Finally, when students decided on their story, they designed and built a background, which could be anything, as seen in Figure 1.

Figure 2. Making the characters.
Note: Example of students' creating main characters. Balls of clay lie on the table, and in the foreground, an iPad can be seen in its holder.

Figure 3. Shooting the movie.
Note: An example of students making the movie. The students took three shots in every scene (movement) to make the movie run smoothly.

When all the scenes were shot, they transferred the raw material into iMovie. In iMovie the students cut scenes and set sound effects and background music. Students then orally presented and premiered their movies on the big screen using a projector in the study hall. The audience, including lecturers and students, commented on the moviemakers through the assessment method—two stars and a wish. Example:

- Interesting story (star)
- Nice waypoint (star)
- Lighter (wish)

Most of the feedback was on the movie's narrative. After the assessment, the students and lecturers watched the movies again, intending to see new things by revisiting the movie a second time after being made aware of how someone else perceives it. The finished movies became our data to study the students' understanding of technology.

Results

This section presents a concise description of the movies we have studied. We offer frames from each movie for insights into visual expressions. The frames stand for each movie's beginning, middle, and ending. Movies 1 and 2 have four frames, and Movie 3 is represented with six frames. After each result, we will present our analysis. We analysed the movies plus stills from the movies using inductive analysis. The movie was watched numerous times. First, in the data managing sessions, authors silently watched them and took notes. Then we discussed the movies from the different subject traditions we come from. Finally, we sorted the movie content after our specific subject knowledge.

Table 1. ***Example of Subject Sorting***

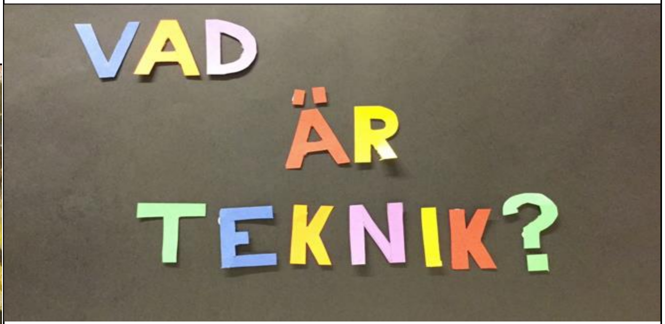
Movie	**Science content**	**Art content**	**Technological content and understanding**
No 1	Ladybug, fly agaric (poisonous woodland mushroom), poisoned, death	Ladybug and fly agaric, background	Fork, incline plane, problem solving, technical skills
No 2	Minerals, rocks	Barren lunar landscape	Watch, trap, socio-ethical understanding, technical skills
No 3	Sky, clouds, organisms, sun, forces	A blue sky with small woolly clouds and a sun, Ball-shaped clay figures, vehicle identified as an ambulance	Radio communication, ambulance, trampoline, social-ethical understanding, technical skills

The authors re-watched the movies again after sorting and discussing the content.

Descriptions of movies

Table 2. ***Movie – The Inclined Plane***

Frame 1 (top left)	Frame 2 (top right)
A fly agaric is in the centre of the picture. A fork on the ground to the left side of the mushroom.	A ladybug sees a fly agaric and walks towards it. (A walking sound is heard). The ladybug tries to climb the mushroom cap using the stem/stalk. It cannot climb up.
	

Frame 3 (bottom left) Walk towards the fork, pick it up and use it as an inclined plane. When on top of the cap, takes a bite, dies, and falls. 	Frame 4 (bottom right) End text – what is technology? 

Using the three states of the technological capital (Bourdieu, 1979), we learned that Movie 1 showed how the actor, the ladybug, could use the fork as an inclined plane. Therefore, being in an institutionalised state, the fork was also objectified, used by someone else and left for the ladybug to use. Technology was not embodied. The students show technical skills by making the ladybug use the fork to solve the problem of not being able to reach the mushroom hat. There could also be aspects of socio-ethical technical understanding (Nordlöf et al., 2022) since an ethical aspect can be added to the movie—is technology always helping? The solution of using the fork also led to the death of the ladybug.

Whilst working with the animated movie, the students learned to use different image sections, angles, and photographs in long sequences to create a narrative image. If we look at the movies from an aesthetic perspective, for example, the ladybug does not correspond to reality, nor does the red fly agaric, but they are appealing from an aesthetic point of view. Therefore, we interpret the picture as a ladybug and fly agaric, even if not true to reality.

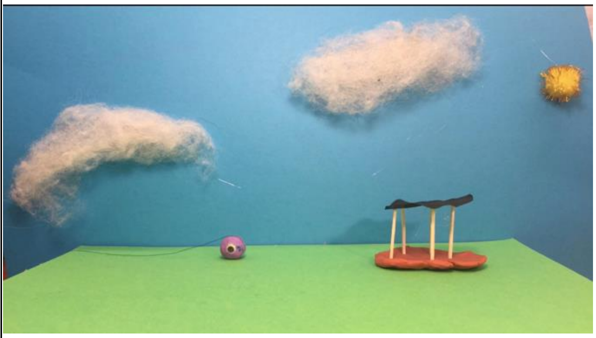
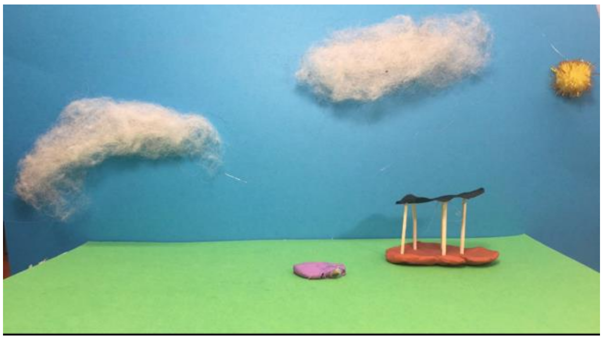
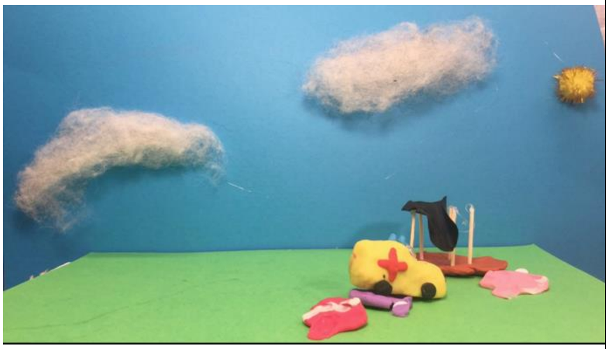
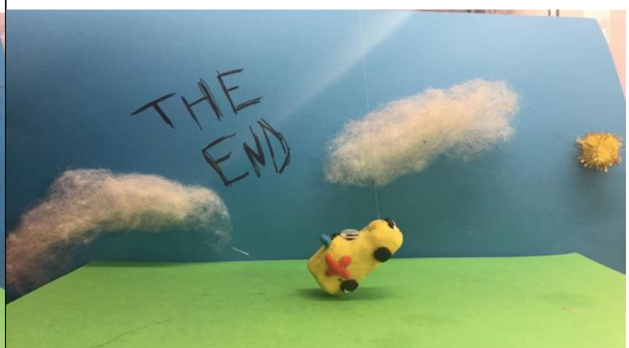
We looked at biology and physics using a science perspective and science-related attitudes, values, and dispositions. We learned that natural science does not automatically come into action. For example, the fly agaric foot is not correct, and the colour of the foot is not right. The ladybug is not correctly built. It lacks a thorax. The number of legs is less than six, and the position of the legs is wrongly placed. In addition, the fly agaric does not grow during summer. The trace body grows mainly during autumn. The trace body is outgrowth mostly during autumn. The ladybug is seen during summer. Therefore, the ladybug and the fly agaric cannot be seen simultaneously in nature.

Table 3. ***Movie – The Watch***

Frame 1 (top left) Scene setting. Stone and mineral landscape. Cave in the centre of the picture. 	Frame 2 (top right) The wristwatch moves in from the right of the picture towards the centre. (Music playing in the background.) 
Frame 3 (bottom left) Watch is heading towards the cave. 	Frame 4 (bottom right) The watch goes into the cave and closes. It was a trap. The movie ends with a narrator saying, “Don’t forget to insure your watch.” 

Using the three states of technological capital (Bourdieu, 1979), we learned in Movie 2 that the actors are the watch or the trap and that someone owns it. This we learn from the narrator's voice reminding us of getting insurance. It is also institutionalised as it is something that can be used. It is not embodied except for being portrayed as a living organism, yet at the same time, it can be seen as objectified since the insurance is put in focus. The students show us their technical skills by having a trap in the movie. They are not giving us any information as to why the trap worked but that it worked by it closing, and you get reminded to insure your watch. From the aesthetics perspective, we see an abstract environment where a dark background, metal, glass balls, and litter from pencil sharpeners form a freely created environment, which we interpret through the aesthetic eye as a form of a barren lunar landscape. Adding a science perspective, we see in the second movie that the landscape is built on different stones of rocks and minerals.

Table 4. ***Movie – The Trampoline***

Frame 1 (top left) Scene setting. Trampoline to the right of the picture. Blue sky, sunny day. One ball-shaped clay figure enters the scene. It enters from the left. 	Frame 2 (top right) Figure sees the trampoline and begins to jump on it (springy sounds). Falls. It becomes flattened as it hits the ground. 
Frame 3 (middle left) The ambulance enters from the left. Sirens on (communication radio sounds). Two ball-shaped ambulance personnel jump out from the back of the vehicle. Help the flattened figure. 	Frame 4 (middle right) Ambulance personnel and the figure jump on the trampoline together (happy sounds). 
Frame 5 (bottom left) They all fall off the trampoline and become flattened—the ambulance drives over them. 	Frame 6 (bottom right) Movie ends with an ambulance driving out of the picture, and the words “The End” appear. 

Using the three states of the technological capital (Bourdieu, 1979), we learned that Movie 3 presents technology as objectified. It is used and designed for a specific purpose for a specific actor—someone hurt, injured, or sick. This also means the technology is institutionalised. Only certain actors, such as above, can access the ambulance. Also, the trampoline is institutionalised. Only an able-bodied character can use it. Here, using the categories of Nordlöf et al. (2022), we find the students showing us having technical skills as they present *what* more than *why* of the technical activities. They also show a socio-ethical technical understanding that deals with the relationship between technology and the human world, for example, the use of ambulance care and its sociological and ethical aspects as the personnel unexpectedly jump with the care receiver and the ambulance driving over them. In frame six, the end, the ambulance is seen doing something that could be seen as a sign of victory—reared on its two back wheels. This adds tension to the dualism of the expected role and objectified symbol of the ambulance. The embodied state is not visible in this movie.

From an aesthetic point of view, we can see a blue sky with small woolly clouds and a sun, where a ball and a trampoline are actors. Because of the red cross and the yellow colour of the vehicle, we identify it as an ambulance. Both clouds and the sun are an alternative to nature, a way of seeing things. In the third movie, we can see from a science perspective an organism that is ball-shaped and has one eye—an organism that does not exist in the natural world. Despite the outlook of an eye, the scene is like humans who meet each other, but it is not a human. In the background, we can see a blue sky and clouds. These aspects are the closest to an actual science perspective.

Discussion and implications

When focusing on the technological content, we found that little technology was expressed, even when this was the focus of the course session. We were unaware of this issue when the data was collected, but when analysing it, it became clear that the students focused on making the movie itself. This research is limited to a specific setting and concerns a small scope, but a few conclusions can be drawn. Using Bourdieu (1979) and concepts of technological knowledge, we could see what the student did not initially show us. The students showed us examples of having technical skills and socio-ethical understanding, yet technological knowledge was narrowly expressed. Using a Bordieuan eye (1979) the movies represent objectified, embodied, and institutionalised artefacts from a western and more modern notion of technology. What surprised us was that the technological content was not broader or more profound, even after a day of preparation. This raised thoughts about how students think about and define technology and how it affects our future teaching and learning.

Using the perspective of an aesthetic learning process (Bergfeldt, 2022), we have learned that the expression of the movie changes through different image sections, camera angles, and the number of images. The multimodality is enhanced via sound and light in the animation. In the aesthetic learning process, aesthetic expression is central to providing knowledge and understanding and asking and answering questions like what have they done, how have they done it, and why? Creating a learning environment that offers creative teaching. Aesthetics help us combine diverse ways of expression and can allow students to communicate in the way they wish. The moviemaking experience created what seemed to be a fun lesson but needed to develop into STEAM knowledge and make it an aesthetic learning process. Aesthetic learning processes can be a tool for understanding students' existing and emerging technological capital but making it a tool for learning requires a different approach. As in Orraryd (2021), we agree that subject content is essential to consider before the process of stop motion animations, but we saw that even if doing so, the content can be lost. We discovered that science and technology content knowledge did not transfer into stop motion movies. This was a surprising find. The students, high achievers in earlier courses with proven science knowledge, did not apply this knowledge in the movie. Even though the students were instructed to make movies about the technology, they did not. We needed to add a theoretical framework to unveil the technological content. This taught us that teaching STEAM poses a time challenge for teachers who do not have the recourse to share time with the data as we have been fortunate to do.

Conclusion

This study found that making technology and engineering visible whilst doing a STEAM task was more challenging than we expected. We were surprised that the students were not using their subject knowledge as we expected. The students focused more on making the movie than following the task of showing what technology is for them. Nevertheless, from an aesthetic point of view, they did great. We learned that not only is the subject easily lost, but teaching STEAM requires more time and content knowledge from the teacher.

Recommendations

To make a STEAM lesson like ours successful for the students and teachers, we suggest preparing a clear and articulate task, active student preparations, moviemaking, analysis of the movie, and reflection on how they can improve the subject knowledge, then revisiting and editing. For example:

- Extended session to understand and reflect on what is happening, more than the three hours we had in our example.
- Draw and write a storyboard to help students put their thoughts into words before the movie is made. The storyboard may have a maximum of 10 frames. Together we can then speak about the storyboard they created and help the students reflect on their choices and how they can be presented.
- Scaffolding the students to communicate with art and highlight what they think is relevant to bring forth a message in the movie.
- Orally present their thoughts on the finished result.

The examples above can give a deeper understanding of what technology is and can be as we spend more time reflecting before, during, and after the movie. In agreement with Hallström and Schönborn (2019), we see a challenge in designing classroom activities that integrate two or more STE(A)M subjects. Transfer of subject knowledge does not happen automatically. Since transfer is easily lost, we advocate for an "outer disciplinary" approach when the students reflect on the content of the movies—sorting subject by subject. This is to make the students aware of each subject's role in the movie, as we did when analysing the results in a table. We, therefore, believe teachers like ourselves can benefit from support in choosing content areas and teaching materials when engaged in interdisciplinary teaching. The experience we describe in this paper shows that in STEAM, it is easy to lose the T (and E) if you do not know what to look for.

References

Allen, M., Webb, A. W., & Matthews, C. E. (2016). Adaptive teaching in STEM: Characteristics for effectiveness. *Theory into Practice*, *55*(3), 217–224. https://doi.org/10.1080/00405841.2016.1173994

Bautista, A. (2021). STEAM education: Contributing evidence of validity and effectiveness (Educación STEAM: aportando pruebas de validez y efectividad). *Journal for the Study of Education and Development*. https://doi.org/10.1080/02103702.2021.1926678

Bergfeldt, B (2022). Salinas väg till kunskap In I rörelse: Estetiska erfarenheter i pedagogiska sammanhang (pp. 149–164). Södertörns Högskola

Bourdieu, P. (1979). Symbolic power. *Critique of Anthropology*, *4*(13–14), pp. 77–85. https://doi.org/10.1177/0308275X7900401307

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3–11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Bryan, L. A., Moore, T. J., Johnson, C. C., & Roehrig, G. H. (2015). Integrated STEM education. In C. Johnson, E. Peters-Burton, & T. Moore Eds.), *STEM road map: A framework for integrated STEM education* (pp. 23–37). Routledge. https://doi.org/10.4324/9781315753157-3

Grimes, D. A., & Schulz, K. F. (2002). Descriptive studies: what they can and cannot do. *The Lancet*, 359(9301), 145-149.

Hallström, J., & Ankiewicz, P. (2019). Laying down the “T” and “E” in STEM education: Design as the basis of an integrated STEM philosophy. In S. Pulé & M. J. de Vries (Eds.), *Proceedings PATT 37: Developing a knowledge economy through technology and engineering education*, 3-6 June 2019 University of Malta, Msida Campus (pp. 187–194). Msida: University of Malta.

Hallström, J., & Schönborn, K.J. (2019). Models and modelling for authentic STEM education: Reinforcing the argument. *International Journal of STEM Education*, *6*, 22.. https://doi.org/10.1186/s40594-019-0178-z

Herro, D., Quigley, C., & Cian, H. (2019). The challenges of STEAM instruction: Lessons from the field. *Action in Teacher Education*, *41*(2), 172–190. https://doi.org/10.1080/01626620.2018.1551159

Hohr, H (1998): *Opplevelse som didaktisk kategori*. NTNU.

Hsu, YS., & Fang, S.C. (2019). Opportunities and challenges of STEM education. In Y. S. Hsu & Y. F. Yeh (Eds), *Asia-Pacific STEM teaching practices*. Springer. https://doi.org/10.1007/978-981-15-0768-7_1

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM education*, *3*(1), 1–11. https://doi.org/10.1186/s40594-016-0046-z

Lewis, T. (2006). Design and inquiry: Basis for accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching, 43*(3), 255–281. https://doi.org/10.1002/tea.20111

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education, *Art Education*, *69*(6,) 44–49. https://doi.org/10.1080/00043125.2016.1224873

Parayil, G. (1991). Technological knowledge and technological change. *Technology in Society*, *13*(3), 289–304. https://doi.org/10.1016/0160-791X(91)90005-H

Orraryd, D. (2021). *Making science come alive: Student-generated stop-motion animations in science education* [Doctoral dissertation, Linköping University]. Linköping University Electronic Press). https://doi.org/10.3384/diss.diva-173038

Nordlöf, C., Norström, P., Höst, G., & Hallström, J. (2022). Towards a three-part heuristic framework for technology education. *International Journal of Technology and Design Education, 32*, 1583–1604. https://doi.org/10.1007/s10798-021-09664-8

Norström, P. (2014). Technological knowledge and technology education [Doctoral dissertation, KTH Royal Institute of Technology]. Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-144875

Romele, A. (2021). Technological capital: Bourdieu, postphenomenology, and the philosophy of technology beyond the empirical turn. Philos. *Technol. 34*, 483–505. https://doi.org/10.1007/s13347-020-00398-4

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher*, Dec-Jan, 20–26.

Sultan, U. (2018). Flickors teknikintresse i fokus. In Naturvetenskapernas och teknikens didaktik: Vol. 2018:2. Teknikdidaktisk forskning för lärare : Bidrag från en forskningsmiljö (pp. 31–40). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-146028

The Swedish National Agency for Education (2022) *Läroplan för grundskolan, förskoleklassen och fritidshemmet*. Skolverket. https://www.skolverket.se/getFile?file=9718