10. Using self-made automata to teach STEM in early childhood teacher education[1]

Oliver Thiel, Rolv Lundheim, Signe Marie Hanssen, Jørgen Moe, Piedade Vaz Rebelo

We let the student teachers build their own automata to promote a better understanding of STEM.

Introduction

Many early childhood education and care (ECEC) professionals are reluctant to teach STEM (Fenty & Anderson, 2014; Parette, Quesenberry, & Blum, 2010; Timur, 2012). One reason for this might be little experience with STEM. In a recent study by Chen, Huang, and Wu (2020), pre-service ECEC teachers who had STEM

[1] This case study is published in the *Journal of Learning Development in Higher Education*, Issue 18 at https://journal.aldinhe.ac.uk/index.php/jldhe/article/view/601

teaching experience, were interested in STEM, or had participated in STEM-related activities, showed more STEM-related self-efficacy. Park, Dimitrov, Patterson, and Park (2017, p. 285), however, found that about 70 % of the pre-service ECEC teachers in their sample did not believe themselves to be ready to teach STEM, regardless of their teaching experience.
We attempted to tackle this problem in how to address STEM in ECEC teacher education, in an engaging, motivating, and practical way that showed students appropriate ways to teach STEM in a playful and child-centred way. **AutoSTEM** aims to develop and share an innovative approach in early STEM education and ECEC teacher training. In this case study, we focus on learning development in higher education (Hilsdon, 2011) by presenting an object-based teaching unit for ECEC teacher education.

The research questions are:

1. How did the ECEC student teachers view our innovative approach?
2. How did the ECEC student teachers reflect on the content that they learnt?

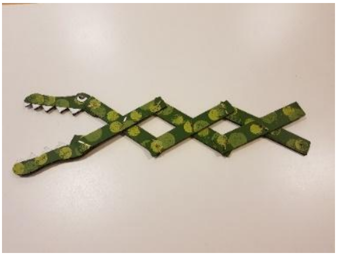
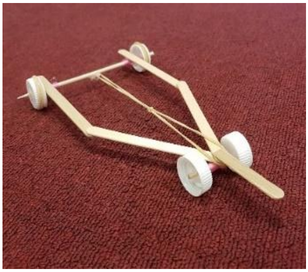
Context, approach, and implementation

We use a relational play-based pedagogy. This pedagogy is situated between the extremes of free play without adult intervention, and adult-led teaching. ECEC teachers use their professional knowledge and skills to interact with the playing children to extend children's thinking and learning (Hedges & Cooper, 2018). Following Broström's dynamic learning concept, it is the ECEC teacher's task to prepare a play environment that challenges the children and encourages them to create new meanings and understandings (Broström, 2017). One way for ECEC student teachers to learn this is to experience it by themselves. This corresponds with Dewey's pedagogical theory of 'having an experience' (Dewey, 1934, p. 35). This theory was further developed by Kolb (2015) into Experiential Learning Theory (ELT). ELT is used in early STEM education and ECEC teacher education (Thiel, Severina, & Perry, 2020, p. 192) as well as in learning development (Kukhareva, Lawrence, Koulle, & Bhimani, 2019, p. 4) because of its relationship to constructivist learning and the scientific process (Dennick, 2015, p. 53). Kolb (2015) describes a learning cycle with four steps: concrete experience – having an experience while doing something; reflective observation – reviewing what you have experienced; abstract conceptualisation – concluding and learning from the experience; and active experimentation – trying out what you have learnt, which leads to a new concrete experience.

Concrete experience

This object-based learning approach (Hardie, 2015) was undertaken with a class of 31 Norwegian ECEC student teachers in the third year of their bachelor studies. A short introduction was followed by three parallel 45-minute workshops each repeated three times. In the first workshop, with an art teacher, a group of students built a crocodile or dinosaur with a scissor arm mechanism. In the second workshop, with a mathematics teacher, they built a car with a rubber band engine. In the third workshop, with a science teacher, they explored a self-made wind turbine attached to a winch to pull objects (see Figure 1). After each student had attended each workshop once, the lesson ended with a 30-minute session with the whole class.

Figure 1. The automata that we used with the ECEC teacher students: a crocodile with a scissors arm mechanism, a rubber band car, and a wind turbine that powers a winch

Reflective observation and abstract conceptualisation

Schön (1983) distinguishes between reflection-in-action and reflection-on-action. During the workshops, we encouraged the students to reflect in action by asking questions. For example, 'what will children learn here about physics?', 'how can you support a child that has difficulties with this task?', 'how does your experience now affect your feelings about mathematics?' In the plenary session after the workshops, students reflected on the action that they just had experienced. The students reflected on the following questions: 'what do you think about this activity?', 'is this applicable to young children?', 'what would you have done differently?', 'do you have ideas for other automata?' The students then had to carry out a written task in the months after the lesson: 'Choose an automaton. Describe the toy briefly, preferably with a picture. Explain what young children learn about STEM (mathematics, physics, biology, or …) while making and/or playing with your automaton.'

Active experimentation

Four weeks after the seminar, all students attended a five-week practical placement, each one in a different ECEC institution. Here, they had the opportunity to apply what they had learnt with children.

Data collection and analysis

In this case study, we analyse data from two sources. At the end of the half-day seminar, we asked the students to complete a questionnaire including ten items from the two subscales, interest/enjoyment and perceived usefulness (Deci, Eghrari, Patrick, & Leone, 1994), from the Intrinsic Motivation Inventory (IMI). An expected learning outcome on the syllabus is that the student has developed an attitude towards STEM that includes students viewing STEM as an important tool in aesthetic learning processes and as a source of play, learning, and education (Queen Maud University College, 2019). Twenty-six students responded on a 7-point Likert-type scale spanning from (1) 'not at all true' to (7) 'very true'. They gave their informed written consent for us to use the data.

Furthermore, we analysed the students' answers to the written task mentioned above. Eighteen students gave their informed written consent. We coded all utterances in the students' texts descriptively. Afterwards, we categorised the utterances according to the expected learning outcomes. The syllabus includes learning outcomes related to

- **Pedagogy**: The students has
  - extended knowledge about children's exploration, wondering, experimentation,
  - creative enthusiasm related to science and arts,
  - can foster curiosity and scaffold children's processes of wondering and creative activities;
- **STEM content**: The student has knowledge about STEM phenomena that one could explore together with children of any age;
- **Other subjects**: The student has knowledge about the use of arts and crafts in STEM (Queen Maud University College, 2019)).

We subdivided these three general categories into more specific subcategories, for example, STEM was divided into the four STEM subjects, and then each subject into the STEM phenomena related to that subject. Figure 2. shows an overview of all categories and subcategories. After we categorised the utterances, we counted different things:

1) How many utterances belong to each category?
2) How many utterances in this category did every student on average make, at least and at most?
3) How many students made utterances in this category?

Challenges

This is just a small-scale case study with an opportunity sample. We did not use a pre-test post-test design, and we did not have a control group. The presented seminar was only a small part of a larger STEM course including theoretical lectures as well as other hands-on activities. Thus, we do not claim that our findings can be generalised or that the work with automata alone contributed to students' learning. This case study aims to share our experiences with the object-based teaching approach that we have developed. It worked well with our students, but in different contexts, adaptations might be necessary.

Results

Enjoyment and perceived usefulness

The mean of the subscale 'interest/enjoyment' was 5.9 (SD = 0.6, MIN = 4.8, MAX = 6.8) with a reliability (Cronbach's alpha) of 0.84. The item with the highest score was 'this training is fun to do'. The mean of the subscale 'perceived usefulness' was 5.7 (SD = 0.8, MIN = 4.0, MAX = 7.0) with a reliability (Cronbach's alpha) of 0.89. The item with the highest score was 'I believe that this training is useful for working with STEM in kindergarten and/or primary school'. The reliability of both scales is good even though the sample size is rather small. All students enjoyed the half-day seminar and perceived it as interesting and useful for their future work. Along with Deci et al. (1994, p. 132), we found that the two scales are strongly correlated ($r = 0.78$, $p < .001$).

Students' reflections

We counted a total of 355 utterances. The minimum was 12, the maximum 35, and the average 19.7 utterances per student. Every student made at least four utterances about STEM. One student made as many as 24 utterances that were related to STEM. The average was 11.4 utterances per student. This category contained 58% of all utterances. Another 36% of all utterances were about pedagogy. The remaining six per cent were about other subjects: arts and language. Not every student wrote about these subjects. 56% of the students wrote about arts and 39% wrote about language. The following example mentions arts and language in the same utterance: 'Children learn a lot through STEM activities. They learn language, practical artistic skills, and social competence' [Utt84].

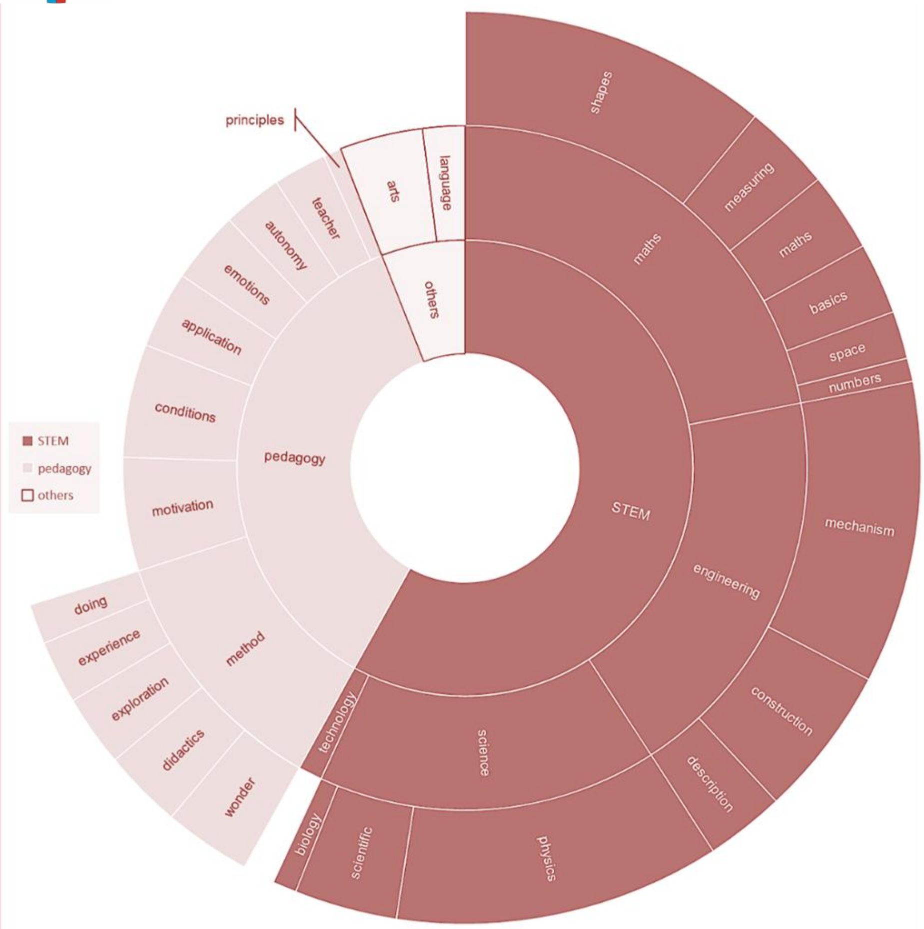


Figure 2 Categorisation of the students' utterances in the written task

. shows the utterances' distribution between the different categories. Most of the STEM-related utterances were about mathematics, followed by engineering and science. We found only four utterances about technology, and these were very general, not directly related to the automata. The utterances about engineering, on the other hand, were mostly about the automata, how the automaton works, how it is constructed, or a more general description. Within mathematics, the following topics were covered: shapes, measuring, basic methods like classification and comparing, space, and numbers. In addition, ten utterances were about maths in general without referring to specific content. Most of the science was about physics, for example, force, energy, and power:

> 'When children use this mechanical toy, they will learn about physics. Children will soon understand that if this toy shall catch something, one must apply a force. In physics, force is an influence on an object that can change the state of motion of an object. I do not think the children think about this much when they play with this toy, but I think most of them will understand that you must apply a force to make this toy work' [Utt313].

All the biology statements came from three students and were related to the automaton with the scissors arm mechanism.

Thirteen utterances were about general scientific methods, ideas, and principles. They did not mention specific physical or biological concepts. An example of a general scientific method is testing a hypothesis:

> 'Before the race starts, you can talk with the children about who they think will win, then the children will gain experience in experimenting. They will make a hypothesis that means they will guess who they think will win the race. The hypothesis will be tested and either confirmed or refuted' [Utt330].

Most of the pedagogical utterances were about methods. The most mentioned method was that of wondering: 'We could

have used the automaton when we wonder together with the children about the planet Earth and space' [Utt191].
Exploration was followed by experience and learning by doing. In the category 'didactics', we have collected other methods like teamwork, project work, and presentation. Nineteen utterances were about motivation. The ECEC student teachers reflected on children's interest, curiosity, and desire to learn. They wrote that the activity is meaningful and enjoyable and that a self-made toy has an intrinsic value. Another 19 utterances were about conditions. The students reflected on the preparation work, the time, and the tools that are needed as well as the children's prior knowledge and fine motor skills. Most utterances in this category, however, referred to the ECEC curriculum. Eight students reflected on applications. They described possibilities, variations, and their experiences when they made automata with children in the practical period. About half the students reflected on the children's emotions and autonomy, and the teacher's role in scaffolding children's explorations. Only three utterances from two students were about general pedagogical principles: 'According to Leontiev, an activity is meaningful when there is a match between the goal and the motive, as in play' [Utt238].

Discussion

The high scores in the two IMI subscales show that all students enjoyed the activities and perceived the seminar as useful. In early childhood teacher education, it is an important goal that prospective ECEC teachers develop positive attitudes towards STEM. Teachers need positive attitudes to inspire the children to discover STEM phenomena in nature (Karp, 1991). This suggests that hands-on activities as proposed here help reach this goal under certain conditions. The activity should be closely related to what an ECEC teacher actually can do with children and enough time should be given to complete the activity, including reflection-in-action and reflection on possible applications and variations.

The Norwegian National Curriculum for Early Childhood Teacher Education claims that prospective ECEC teachers shall be able to explore nature, conduct experiments, and reflect together with children (Norwegian University Counsel for Teacher Education, 2018, p. 18). The students' reflections have a strong focus on these methods. All students were aware of opportunities for teaching STEM content in a participatory and inspiring way as well as the **AutoSTEM** project's pedagogical possibilities and challenges. None of the students wrote about traditional teacher-led methods like explaining and demonstrating. Furthermore, the curriculum demands that the students are able to choose and use different materials, techniques, and tools in practical work with children and make use of local natural resources (Norwegian University Counsel for Teacher Education, 2018, p. 18). Admittedly, most students chose the materials and techniques presented in the workshop, but their reflections show that they understood how to use these in practical work with children. According to one of the most import curriculum goals, students shall be able to create an inclusive and varied play and learning environment for STEM exploration and to guide, lead, and critically reflect on early STEM teaching (Norwegian University Counsel for Teacher Education, 2018, p. 15). To reach this goal, the practical period was essential. One of the students expressed his experiences like this:

> I used the crocodile in the practical period. The children's wonder and commitment was great. I guess it was not immediately obvious to the children how the mechanism made the crocodile close its mouth. I agree with Broström and Frøkjær (2016, p. 50) that children's wonder and questions are a good foundation for learning. What makes

the automaton operate in such a way? Even for toddlers (one-year-olds) who do not have advanced verbal language skills, I see the value of exploration and wonder. Besides, I think that the automata's aesthetic expression plays an important role. I guess many children thought my 'snapping crocodile' was tough since it looked like a kind of crocodile monster that caught the children's interest more easily than a grey pair of scissors would have done. This can motivate children to play with the toy, which can then help influence the inner motivation. Broström and Frøkjær (2016, p. 46) point out that children's desire to learn is greater when they are intrinsically motivated. 'The snapping crocodile' is therefore in many ways a simple entrance ticket into the scientific world because it is based on principles that are not too complicated. At the same time, it provides many opportunities for the children to design it in creative ways. The possibilities are endless if competent and supportive teachers help and support the children in the creative process.

Applications and future work

This case study showed that the students understood that using automata in ECEC teacher education as interesting and useful. Their reflections showed that they learnt a lot about STEM and the acquired skills that are needed to teach early STEM in an engaging way. We are now working on the development of a free online course, which will be available in several European languages. The aim is to equip ECEC teachers with the tools to use automata construction for teaching basic STEM skills and concepts as well as promoting motivation for STEM.

References

Broström, S. (2017). A dynamic learning concept in early years' education: a possible way to prevent schoolification. *International Journal of Early Years Education, 25*(1), 3-15. doi: 10.1080/09669760.2016.1270196

Broström, S., & Frøkjær, T. (2016). *Realfag i barnehagen : barn og barnehagelærere undersøker naturens lovmessigheter* [STEM in kindergarten : children and early childhood teachers explore the laws of nature]. Oslo: Pedagogisk forum.

Chen, Y.-L., Huang, L.-F., & Wu, P.-C. (2020). Preservice Preschool Teachers' Self-efficacy in and Need for STEM Education Professional Development: STEM Pedagogical Belief as a Mediator. *Early Childhood Education Journal*. https://doi.org/10.1007/s10643-020-01055-3 doi:10.1007/s10643-020-01055-3

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of Personality, 62*(1), 119-142.

Dennick, R. (2015). Theories of learning: constructive experience. In D. Matheson (Ed.), *An introduction to the study of education* (4th ed., pp. 36-63). Milton Park: Routledge.

Dewey, J. (1934). *Art as Experience*. New York: Putnam.

Fenty, N. S., & Anderson, E. M. (2014). Examining Educators' Knowledge, Beliefs, and Practices About Using Technology With Young Children. *Journal of Early Childhood Teacher Education, 35*(2), 114-134. doi: 10.1080/10901027.2014.905808

Hardie, K. (2015). Wow: The power of objects in object-based learning and teaching. *Innovative pedagogies series*. https://www.heacademy.ac.uk/system/files/kirsten_hardie_final.pdf

Hedges, H., & Cooper, M. (2018). Relational play-based pedagogy: theorising a core practice in early childhood education. *Teachers and Teaching, 24*(4), 369-383.

Hilsdon, J. (2011). What is Learning Development. In P. Hartley, J. Hilsdon, C. Keenan, S. Sinfield & M. Verity (Eds.), *Learning Development in Higher Education* (pp. 13-27). Basingstoke: Palgrave Macmillan.

Karp, K. S. (1991). Elementary School Teachers' Attitudes Toward Mathematics: The Impact on Students' Autonomous Learning Skills. *School Science and Mathematics, 91*(6), 265-270. doi: 10.1111/j.1949-8594.1991.tb12095.x

Kolb, D. A. (2015). *Experiential learning. Experience as the source of learning and development* (2nd ed.). Upper Saddle River, NJ: Rearson Education.

Kukhareva, M., Lawrence, A., Koulle, K., & Bhimani, N. (2019). Special Collections as a catalyst for flexible pedagogical approaches: three case studies. *Journal of Learning Development in Higher Education,* (16). https://journal.aldinhe.ac.uk/index.php/jldhe/article/view/549

Norwegian University Counsel for Teacher Education. (2018). *Nasjonale retningslinjer for barnehagelærerutdanning* [National curriculum for early childhood teacher education]. Retrieved from https://www.uhr.no/_f/p1/i8dd41933-bff1-433c-a82c-2110165de29d/blu-nasjonale-retningslinjer-ferdig-godkjent.pdf

Parette, H. P., Quesenberry, A. C., & Blum, C. (2010). Missing the Boat with Technology Usage in Early Childhood Settings: A 21st Century View of Developmentally Appropriate Practice. *Early Childhood Education Journal, 37*(5), 335-343. doi: 10.1007/s10643-009-0352-x

Park, M. H., Dimitrov, D. M., Patterson, L. G., & Park, D. Y. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research, 15*(3), 275-291. doi: 10.1177/1476718x15614040

Queen Maud University College. (2019). BHFOR3590 Realfag i leik og læring. Retrieved 22 Sept 2020, from https://studier.dmmh.no/nb/emne/BHFOR3590/652

Schön, D. (1983). *The reflective practitioner*. New York: Basic Books.

Thiel, O., Severina, E., & Perry, B. (2020). Reaping the benefits of reflexive research and practice in early childhood mathematics education. In O. Thiel, E. Severina & B. Perry (Eds.), *Mathematics in early childhood. Research, reflexive practice and innovative pedagogy* (pp. 189-202). London: Routledge.

Timur, B. (2012). Determination of Factors Affecting Preschool Teacher Candidates' Attitudes towards Science Teaching. *Kuram ve Uygulamada Egitim Bilimleri, 12*, 2997-3009.