Case Studies

Co-funded by the Erasmus+ Programme of the European Union

Contents

INTRODUCTION

AutoSTEM is an EU project supported by Erasmus+ Programme with the goal of providing pre-school and primary school teachers, educators and any other stakeholders with a series of tools and materials that will allow them to use automata for STEM autonomously, by making and using automata toys.

The project team includes representatives of five EU countries – Portugal, Norway, Italy, Bulgaria, UK, from the areas of teaching methodology and school administration. The project-based team focussed on developing ideas for teaching and learning, which integrates automata toys step by step into STEM lessons.

Beginning with simple, guided, Automata and then to independent constructions, learners and teachers are introduced gradually to applications of mathematics, engineering, mechanics and science in the classroom.

The case studies report on some of the findings from workshops and teacher training by the project partners in their countries. There are twelve case studies included these are categorised in three broad areas:

Case Studies with a target audience of learners aged 4-12

- Including an **AutoSTEM** activity in an annual classroom project 'The garden' - ITALY
- The Travelling (Jelly)Bird - ITALY
- The Ulysses' boat
- When two hands are not enough: spontaneous cooperation between children when constructing automata - PORTUGAL

- Children's engagement and learning in a moving toys workshops in a primary school - PORTUGAL
- Integration of the **AutoSTEM** project in the curriculum. Making an Acrobat - BULGARIA
- Development of skills for problem detection, choice of work strategy, decision making, activity planning - BULGARIA
- From guided play to creativity: metamorphoses and stories of a bird - PORTUGAL
- Using Automata in an after-school Science Club - UK

Case Studies with a target audience of teachers

- Using self-made automata to teach STEM in early childhood teacher education - NORWAY

Case Studies with a target audience of SEN students

- Outcomes of Automata for STEM activities with cognitive and physically impaired people - ITALY
- Hearing and touch for seeing: Instructions to promote mental representation of geometric shapes in visual impaired people when constructing a moving toy - PORTUGAL

The **AutoSTEM** team would like to thank all the teachers and pupils involved in the workshops, training and case studies and wishes all those interested in STEM subjects fun when working with the **AutoSTEM** ideas and project materials.

Case Studies with a target audience of learners aged 4-12

1. Including an AutoSTEM activity in an annual classroom project 'The garden'

Corinna Bartoletti and Susanna Rossi

This case study illustrates how the **AutoSTEM** approach can be included within a wider project that involves more than one classroom.

Introduction

The case study shows how the teachers used the ideas learnt from **AutoSTEM** to create new automata prototypes to answer the project goals. It also shows how **AutoSTEM** activities can be used successfully with children of different ages.

Context, approach, and implementation

The workshop took place at the Pre-primary School Scuola dell'Infanzia *V. Trancanelli* – Petrignano – I.C. ASSISI 3

The schools interest to the world of STEM was designed in conjunction with the theme of Childhood-Primary Continuity, to include logic-mathematics and educational robotics. The School's Vertical Department of Childhood-Primary Continuity designed the project basing on a larger scale task related to real life 'An arranged garden ' and included 4 related tasks in which **AutoSTEM** was included, they are:

- Vegetable garden with Dani
- Vegetable garden...in a box
- An ecosystem in a bottle.
- Automata for STEM...learning science while having fun.

The project focused around a vegetable garden which already existed in the garden of the school, so the children already had a basic knowledge of the various parts of plants. The main goal was to have a first approach to STEM subjects by children aged 3 to 5 year-old.

The activity was carried out by the 3 to 5-year-old children of sections A and B of the 'V. Trancanelli' school in Petrignano di Assisi (PG). The activity was carried out by the section's teachers who had help from colleagues from other sections of the school.

The activity of making the Automata and the final performance lasted 6 hours, the other 3 tasks listed above took 4 hours.

'Ortoliamo con Dani', is a story about a farmer devoted to looking after his garden. Suddenly, coloured flowers, birds and insects, including butterflies, appear. The teachers linked the automata to the 'Appearance of butterflies and flowers'.

The construction of the automata had three distinct phases:

- Phase one: the teachers showed the children how the automata is constructed and answered their many questions;
- Phase two: the children were given cards with photocopied shapes (templates) of the parts of the automaton (butterfly) that they then cut out;

- Phase 3: the children stuck together, with glue, the different pieces. The children had to remember the presentations of the teachers. At this stage, the teachers only gave advice and did not intervene in the construction**.** The children chose what colours to colour their butterfly.

To build the automata flower, an origami technique was used.

Challenges

Although there were no children with special educational needs, the group was not homogeneous: some were able to respect the assigned times for the completion of the work, others needed more flexible time and clearly the levels of learning abilities were quite different.

The most complex phase was the gluing of the different parts that had to take into account precise distances in order to be able to slide the mechanism of the automata in a linear way. Some children used too much glue while others used too little glue that led to the pieces coming apart.

Results

The **AutoSTEM** workshop was very well integrated into the previously planned annual project. The **AutoSTEM** toy 'The Jellybird' was modified as a butterfly (see **Error! Reference source not found.**), and a new automata design, "The Swinging Flower" was created by the teachers (see

). The collaborative approach in the construction of the Automata allowed the successful inclusion of different ages and abilities in to a single project.

All the participating children were very interested and while they watched the automata (butterfly or flower) taking shape, started asking questions, particularly about the next steps.

The collaboration among the teachers allowed the successful integration of **AutoSTEM** into an already planned project format and led to the invention and design of new Automata toys by the teachers.

Figure 1 the butterfly

Figure 1. The Swinging Flower

Discussion

The teachers said that the areas of experience that were most involved were:

- The body and movement
- Knowledge of the world

And it was easy to see how the activities have actually opened up additional ways to use the methodology in most areas of experience.

Given the curiosity and interest shown by the children, the teachers are convinced that this activity should be repeated. The construction of the automata engaged the children in STEM as active participants, giving them a greater sense of control and responsibility in the learning process: they saw, listened, touched, measured, they 'put their hands on the subjects'.

2. The Travelling (Jelly)Bird

Author: Cinzia Macchiaioli (teacher), Corinna Bartoletti

Combining STEM and Intercultural education

Introduction

The project "The travelling bird" was initiated by a story composed by a teacher, the tutor of the workshop and the **AutoSTEM** teachers guide to making a JellyBird

The pre-school is part of a unified group of local schools in a region (Istituto Comprensivo *Giovanni Paolo II*) that range from pre-primary to upper secondary. The Istituto Comprensivo is in a rural area of Umbria. The region has a significant migrant population and poorly integrated families. The social context is complex as there are families with high economic-social levels and others that are disadvantaged. The presence of psychosocial problems affecting students is often not supported within the families.

The Istituto considers it particularly important to promote intercultural awareness and citizenship education from the earliest age, plus the strengthening of mathematical, logical and scientific skills.

The project the Travelling Bird was aimed at promoting STEM content and the development of active and democratic citizenship skills through the enhancement of intercultural and peace education, and respect for differences and dialogue between cultures.

23 children aged 4 and 5 (section A), of which 5 are from immigrant families and two have disabilities completed the project.

Context, approach, and implementation

The project started at the beginning of January 2020 and lasted until the end of February. The Jellybird Automata was used. The project followed a series of steps and followed the principles of cooperative learning.

1. Storytelling

The teacher told the children the story of the Travelling Bird. The JellyBird Automata represents a bird that is travelling over the whole world. In the story, other birds each with a specific colour inhabit each country. The travelling bird goes from country to country and is given different coloured feathers from each bird that he meets. The children engaged with the story, suggesting to the teachers which countries were visited by the Travelling Bird.

2. Cooperative Working

The class was divided into 5 mixed age groups (4 and 5 years old). Each group represented a country and built a different coloured Jelly bird from each other group. The teacher guided the children to look at the materials available, paying particular attention to the use of appropriate terms to expand their vocabulary. Within each group, the different tasks are decided by the children (who colours, who cuts out the pieces). The construction is carried out step by step according to the teacher's oral instructions. At each step, the children pass on the Jellybird to other children in their group, so that at the end they have all been involved in the building of the birds.

3. Research

To complete the story of the Travelling Bird the teacher and the children agree on the need to research relevant information. The children who suggested countries (most of whom named their country of origin) are given paper to take home to write down the results of a short "interview" with their families.

4. Sharing

Each child presents information about the country they represent to all the class. They are helped by a simple Power Point presentation on an interactive whiteboard prepared by the teacher.

5. Individual Work

Each child makes their own bird and a visual chart summarising the information about each country that that bird lives in.

6. Story's Dramatization

The children return to working in groups and representing a country with their coloured jelly bird. The teacher played the role of the travelling bird that goes from country to country, receiving feathers from each bird he met and being told about the country. Within each group of children they decided what and who would say things about their country to the travelling bird (teacher)

In another classroom, a group of 3 year old children were invited to watch the drama. At the end of the play, the performing children approached the younger children to show them how the Jellybird works.

7. Taking action

Following the example of the travelling bird who keeps in touch with his friends by communicating, the children also decided to look for "distant" friends. They made bracelets out of clay. Each child "dedicates" his bracelet to a child from another section of the school. With the help of the teacher the children wrote a nice letter to introduce themselves and went to the Post Office to send it.

8. Follow up

A series of follow up activities were organised:

- Comparison of the countries' cultural icons (flag, typical dishes, etc.).
- Walk through the village of Costano with a map of the places seen (shops, church, monuments, schools)
- Creation of a floor map on which to retrace the path using educational robotics.

- Reflections on cultural differences and similarities with appreciation of diversity.

Challenges

The cooperative learning approach helped to solve most of the potential difficulties that younger children might have in the course of the piloting. This approach allowed the inclusion of children with special needs in the whole process.

Results

Objectives set/objectives achieved

The objectives achieved were in line with those set. Thanks to the ability to combine elements of mechanics, craftsmanship, manual skills and storytelling, it was possible to encourage the technical and manual skills (cut, paste, fold, slide), mathematical skills (dimensions, topological concepts), engineering skills (observing and making mechanisms), as well as incorporating citizenship and intercultural education objectives such as:

- To know and compare different cultures
- Valuing differences
- Stimulating a sense of belonging to the community
- Stimulating a sense of friendship and solidarity.

Figure 2 Cooperative work

Discussion

The use of the automata greatly stimulated the children's interest from both a narrative and technical point of view. The construction of the Jellybird in the first group was very effective in enhancing individual skills and collaboration towards a common goal.

Once the steps were clarified as a rotation between the children in the same group, they showed a spirit of collaboration and above all autonomy of work that amazed the teacher. The construction of the second, individual Jelly bird strengthened the technical skills of the children who were then able to build the automata almost without guidance, and consolidating their knowledge of some specific terms.

The presentation part (firstly of the information gathered for their own class group and then during the dramatisation for the other section) stimulated the self-esteem of all the children, who felt an indispensable part of a single project.

The whole workshop was characterised by strong interest and participation, so much so that the teachers decided to make the most of it by continuing with other activities planned for citizenship education and STEM education.

The experience was very positive.

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https://cercalatuascuola.istruzione.it/cercalatuascuola/istituti/PGAA84302P/costano-giovanni-paolo-ii/valutazione/sintesi/

3. The Ulysses' boat

Authors

Combining STEM with the promotion of fine motor skills and large-scale collaborative learning.

Introduction

The STEM micro-project "The Ulysses' boat" has been included within a wider didactic unit called "Ulysses and the storm".
The adventures of Ulysses can be very engaging and stimulating for young children. The didactic unit "Ulysses and the storm" seemed very apt to include the construction of the automata called "The Ulysses' boat challenging the waves".
For the Ulysses boat it was decided to use the "Crocodile" mechanism, with the aim to promote:

- Mathematical concepts: quantity, numbering, length, width, size, shapes.
- Familiarity with mechanisms: in particular connections between objects.
- Science concepts: the atmosphere

The workshop involved all the 3 to 5 year old children of the school that are a heterogeneous mix.
The activities took place in each of the school classes of 23/24 children, in February 2020 over the course of about 2/3 weeks. The group of pupils included 6 children with special needs, 5 of them with different types of disabilities.

Context, approach, and implementation

All the children of the school participated to the different phases of the workshop. The workshop used different pedagogic strategies that were tailored to each child, respecting their individual learning rhythms and characteristics. The main learning objectives were:

- Development of fine motor skills
- Encouraging participation within the group
- Stimulating curiosity, attention and interest.

The teachers prepared an automata model beforehand to enable the children's to see and build their curiosity. From the presentation of the automata to the final dramatisation, the steps were:

STEP 1; Presentation of the automata,
Presentation of the automata by the teacher, the children could explore the toy and share their reflections on the functioning of the mechanism, materials needed, and build hypothesis of its construction.
They were also allowed to observe the materials, previously prepared by the teacher, who also stimulated questions and encouraged an exploration of shapes, quantities, sizes, types of connections.

STEP 2: Making the automata
Each child individually coloured and cut out some elements of the automata (boat and sail); they worked as a small group for assembling the various elements under the verbal and/or physical guidance of the teacher.

STEP 3: Preparation of the setting
To create the drama ''The Ulysses' ships in the storm, on the journey back to Ithaca a physical scenario was constructed. This included a blue cloth for the sea, that is held up by the children; balloons for the sound of the sea and rain; bottles, tubes, salad spinner for the sound of the wind. Before making the drama, the children were asked to recognise the sounds produced.

STEP 4: -Dramatisation:
In this workshop, the STEM activities were about the weather. The dramatisation was carried out by groups: one group performed the soundtrack and the other group performed the dramatisation with the children behind the cloth, moving their automata, represented Ulysses' ships in the storm.

Challenges

The individual work phase took a long time, given the large number of children. This difficulty was overcome through the involvement of both teaching and non-teaching staff across the school classes.

Results

Figure 3. The scenario of the representation

Discussion

The workshop was held through the support and the enthusiasm of the entire teaching staff of the school, who invested time and resources in the various stages of implementation. This deep involvement was the factor, which ensured the success of the project together with the enthusiasm, the participation, interest and curiosity of the children. The complexity of the activity required the child to apply many different skills. These innovative activities in STEM education were also positively evaluated by some parents.

4. When two hands are not enough: spontaneous cooperation between children when constructing automata[1]

Introduction

This case study focuses on the analysis of spontaneous cooperation between children who participated in four **AutoSTEM** project workshops. Since one of the transversal competences that were intended to be developed with the activities of the project consists of cooperation, although cooperative learning

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[1] [1] This case study is part of the article:
Bidarra, G., Santos, A., Vaz-Rebelo, P., Thiel, O., Barreira, C., Alferes, V.,, Almeida, J., Machado, I., Bartoletti, C, Ferrini, F., Hanssen, S., Lundheim, R., Moe, J., Josephson, J., Velkova, V., Kostova, N. (2020). Spontaneous cooperation between children in automata construction workshops. In Pixel (Ed.). *Conference Proceedings. 10th International Conference The Future of Education Virtual Edition* (pp. 525-528). Filodiritto Publisher. ISBN 978-88-85813-87-8 ISSN 2384-9509. DOI: 10.26352/E618_2384-9509

strategies have not been introduced, we tried to observe how spontaneous cooperation forms emerge and how they can be suggested by the dynamics of the proposed activities, the habitus (habits), culture and classroom arrangement, guidance of the educators and the children's age.

Cooperation is a form of interaction between two or more individuals. What distinguishes cooperation from other forms of interaction is the fact that it takes place according to an objective common to these two or more individuals. In this way, cooperation emerges as a way to achieve a goal that individually could not be achieved (Warneken & Tomasello, 2007). Indeed, cooperative learning is now advocated as a form of high-impact instruction (Knight, 2013), which refers to various strategies used in the classroom, designed to create active learning and involvement among students. These strategies are based on principles and procedures, which are different from ordinary group work, constituting an alternative to competitive and individualistic structures, contributing to better cognitive learning and the development of social skills. Assuming different structures and syntaxes, which individualize them, they have different designations as jigsaw, cooperative scripting, learning together, and group investigation, among others.

Hargreaves (1994), a defender of these strategies, considers that these should be included in the repertoire of teachers, however they should be used with flexibility and discretion, recognizing that their introduction in schools and classrooms constitutes a safe simulation of the forms of collaboration more spontaneous that are possible among students, which have been somehow eradicated by the school and teachers, through discipline control and assessment practices. These forms of spontaneous cooperation are of great value and unpredictability since the locus of control of cooperation is in the student.

One of the components of cooperative learning consists of positive interdependence, which assumes several modalities, namely, the interdependence of purposes, when group members work towards a common purpose, of the task, when "two hands are not enough", of resources, (scissors, paper, glue, etc.), and the environment/space where the group works, which can become a unifying element (Johnson & Jonhson,1999). Therefore, the objective of this case study is to describe spontaneous forms of cooperation among children who participated in the automata construction workshops, without having been instructed in this type of learning.

Context, approach, and implementation

In this case study four workshops are included. The general pedagogical method followed in all the workshops involved the presentation of automata and children being challenged to plan and construct their own automata. Workshop 1 and 2 had a very similar structure, each had 22 2nd grade students from a elementary School, the children were between 7 and 8 years old. Each workshop's sessions lasted two hours. In both sessions a friction drive mechanism was used, with different narrative parts.
Workshop 3 took place in a classroom with 24, 1st grade children ages 6 and 7 years old. This workshop was about linkages and the lever automata. Each child built two automata. The workshop lasted three hours.

Workshop 4 had two sessions, for a total of three hours. There were 21 children in the first session and 19 children in the second one. These children were between 9 and 10 years old. In this workshop different automata were presented including ones with a friction drive mechanism, with a lever and linkages.

However, there were some differences between the workshops, in three of them, a poem about the earth was read; one of the workshops took place in a library, while the others where in a classroom. The classroom arrangements changed according to the workshop, with children seated in pairs, at round tables or in a presentation format. In addition, in the classroom workshops the teachers scaffolded the process by offering instructions, while in the library workshop there was a minimum of instruction. The class teacher was not present at the library workshop. In all the workshops, from the instructions about how to construct the mechanism to the final product, several processes took place where spontaneous cooperation between the children emerged.

Data was gathered through participant observation, registering field notes, photos and videos. At the end of the workshop, children answered a short questionnaire about motivational issues and perception of learning. At the end, a report was completed for each of these sessions, which accounted for all the data collected and analysed.

Challenges

Being that cooperation was one of the transversal skills that the project intended to develop; the principal challenge was to recognize the forms of cooperation that emerged among children during the activity, although no instructions have been given in this regard. During the different workshops, spontaneously various forms of cooperation appeared among children, so it was a challenge to understand what could had led to this situation and which factors have enhanced and allowed this cooperation.

Results

Content analysis of different types of data identified four categories of spontaneous cooperation: Modality, Dimensions, Influencing factors and Outcomes,

Modality of spontaneous cooperation points to different ways of organizing this cooperation:

- One: where there is a decision to construct a unique automaton for the whole group;
- Two: where each child constructs its own automata but developed strategies of cooperation.

One: where children spontaneously decided to cooperate and build a group automaton, there is a type of cooperation with a common goal and task that could be considered a modality more similar to formal cooperative learning with convergent involvement between pairs (Figures 1, 2 & 3).

Figures 1, 2 & 3. Children cooperating to develop an automaton for the whole group.

Two: When each children develops their own prototype while cooperating in an informal way with colleagues. In this case, there were no properly shared goals or tasks, so the cooperation that emerged can be considered as a divergent or not convergent cooperation (Figures 4, 5 & 6).



Figures 4, 5 & 6. Children cooperating while developing their own prototype.

Another category identified was Dimensions of spontaneous cooperation, that includes dimensions that appear in both the modalities identified or only in one of them

Some dimensions, transversal to both working modalities, can be: informal distribution of tasks, sharing materials, mutual observation of the work and the assistance in the construction. These can then be considered the core dimensions of spontaneous cooperation. There are then transversal indicators that appear in the workshops analysed that can be considered core dimensions of spontaneous cooperation (Figures 7, 8 & 9).

Figures 7, 8 & 9. Core dimensions of spontaneous cooperation: observing and learning from each other and sharing materials.

Working on the same project involves interdependence of purposes, coordinating actions, shared tasks and all ideas of the participants are considered and included in the automaton. Specially the interdependence of purposes and coordinated actions are characteristics of cooperative learning. This group of dimensions charactherize convergente spontaneuous cooperation.

Working on separate projects includes the indicators: imitating and being inspired by the colleague's work, and the selfless willingness to help a colleague (Figure 10). These indicators can be considered as dimensions of divergent spontaneous cooperation.

Figure 10. Selfless willingness to help a colleague.

Influencing factors were related to workshops characteristics as: children's age, guidance, teacher's class presence, seating arrangement. In fact, 6-7 years old cooperated while developing their own project and 9 years old decided to work on the same project. When a teacher or educator guided the workshop, children cooperated while developing their own project, but when they had more autonomy, the class teacher was not present and the children were seated at round tables, the children decided to work on the same project. The, seating arrangement, in pairs or presentation, was associated with children cooperating while developed their own project.

The Automata produced were analysed as outcomes and had the following types: similar to the one presented, automata 'in pairs', predominance of an idea.

These types of automata are associated with the workshops above. In fact, in all the workshops analysed some of the automata were very similar to the ones presented. However, there were also instances where children sat next to each other produced similar automate, this was interpreted as a typical class working routine (Figures 11, 12 & 13).

Figures 11, 12. & 13. Examples of automata that are a similar to the ones produced by the colleague seated at the same table.

In one of the workshops, the children produced automata very similar to each others, although each children worked on their own construction (Figure 14).

Figure 14. Similar automatas built in one session.

When children decided to work on the same project, the automata produced included differences from the automata initially presented. This was interpreted as evidence of creativity.

To the question 'What did you learn in this workshop'?, There is evidence that most of the children learnt how to construct a simple mechanism, how to make a moving toy and also about the topic of the narrative initially presented. Children also refered to other competances including how to cooperate or to solve problems.

Several emotions were also registered. In general, children expressed joy and satisfaction with the work that they developed, some said they felt proud of their work. These emotions could be observed both when a child developed their own automata (Figure 15) or when they developed a 'shared automata' (Figures 16 & 17).

Figure 15. Children were influenced by each other while developing their own automata

Figures 16 & 17 Happiness and pride when developing unique automata.

Evaluation

In summary, data analysis indicated that despite the characteristics of cooperative work not being formally established, spontaneous cooperation between the children emerged. This spontaneous cooperation can take different forms including deciding to work on the same automata or to develop their own automata while cooperating in an informal way with colleagues. In this case, cooperation can be seen in:

- Observing each other work,
- Sharing materials,
- Helping with the construction,
- Imitating and being inspired by a colleague's work.

Spontaneous cooperation also varied according to:

- The children's age,
- The dynamics of the workshop, e.g. the seating arrangement,
- The context where it took place,
- The presence of class teacher,
- The guidance of the educators.

The automata mechanism used did not seem to be associated with the characteristics of the cooperation.

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5. Children's engagement and learning in a Moving toys workshops in a primary school[2]

A.Santos, P. Vaz Rebelo, O. Thiel, G. Bidarra, V. Alferes, J. Almeida, C. Barreira, I. Machado, F. Rabaça, M. D Dias, P. Pereira, N. Catré, F. Ferrini, C. Bartolleti, J. Josephson, N. Kostova

Introduction

This case study analyses children's engagement and motivation in **AutoSTEM** project workshops. The **AutoSTEM** project aims to analyze the potential for building automata or "Moving toys" as a motivational strategy for learning in the subject areas of science, technology, engineering and mathematics (STEM), it is important to to understand how this is done and whether it is having the desired results.

The motivation and engagement of children and young people in science subjects continues to be a challenge for contemporary education, and there is evidence of the importance of its promotion in the earliest years of schooling (e.g. Campbell, Punello, Miller-Johnson, Burchinal & Ramey,

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[2] This case study is published in the *International Journal of Developmental and Educational Psychology*., 2(1), 115-124. doi: http://www.infad.eu/RevistaINFAD/OJS/index.php/IJODAEP/article/view/1820

2001). The importance of this highlights the need to understand the dimensions that characterize motivation or engagement, and strategies that can promote them. Both motivation and engagement are multifaceted and interconnected constructs.
In particular, the concept of intrinsic motivation can take on dimensions related to autonomy, interest, sense of competence, stress, perception of value, among others, and complex and subtle dynamics between these various dimensions (Deci & Ryan, 2000). Since "intrinsic motivation results in high-quality learning and creativity, it is especially important to detail the factors and forces that engender versus undermine it" (Deci & Ryan, 2000, p. 55).

Several dimensions for engagement have been proposed, for example, at affective, behavioral, cognitive levels. Thus, it is possible to say that engagement is a "multidimensional construct that unites affective, behavioral, and cognitive dimensions of student adaptation in the school and has influence on students' outcomes" (Veiga et al., 2012, p.118). In short, the affective dimension is related to the child's emotional experiences during the learning process; the behavioral dimension is related to the child's effective behavioral participation in their learning process; finally, the cognitive dimension concerns the child's mental orientation during learning (Gonçalves, 2017).

In the **AutoSTEM** project the automata used consist of two parts, , a narrative part and a mechanism, These allow, a playful approach, with activities related to the planning and construction of the automata toys to enhance the interest and engagement in the STEM subjects listed above. Particularly in the knowledge and construction of simple mechanisms, understanding of their functioning and / or the narrative they represent, and skills such as observation, problem solving and creativity.

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Context, approach, and implementation

In this case study 30 children in the1st, 2nd, 3 rd and 4th grades of a primary school in Portugal between 6 and 9 years old, participated in two workshops. In Workshop 1 were twelve students, two from the 1st grade and the remaining ten from the 3rd grade. In Workshop 2 were eighteen children, six from the 2nd grade and twelve from the 4th grade.

These two workshops kept the classroom arrangement in the school and were three hours each. The two sessions followed the same structure and processes for the children, involving:

- The observation of automata with different mechanisms and narratives,
- The planning and construction of their own automata,
- The presentation of their finished automata and reflecting on what they have done

The activity began with a short presentation about the project and some examples of automata with a rotation mechanism, linkages, and a lever. Next a poem was read about the environment, related to the school network theme and closely related to the science and citizenship curriculums. Children looked at the automata, explored the available materials that had been made available, and planned their own automata (Figures 1, 2 & 3).

The children had total freedom to create their own automata based on the mechanisms that they were shown (Figures 4, 5 & 6).

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Figures 1, 2 & 3. Children working on their automata.

Figures 4, 5 & 6. Children building automata.

After the time allocated for construction time was complete, children showed their automata to the class and then answered a questionnaire (Figure 7).

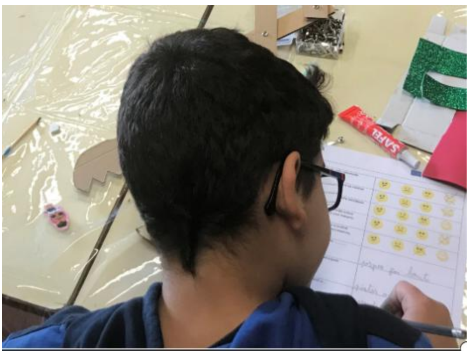


Figure 7. Child answering the questionnaire

To evaluate these two workshops both a questionnaire and participant observation were referenced. The questionnaire included statements and open questions about motivation, perception of learning, experienced difficulties, and suggestions for improvement. The observation guide included indicators on engagement: behaviour - affective, and cognitive; children's expressions of satisfaction and products developed in order to analyse learning and creativity.

The indicators considered in the engagement analysis were:

- Behavioural engagement analysed through participation in the activity, to plan a project and to work on it.
- Cognitive engagement, analysed through the areas of observing with attention, being curious about the movement and mechanisms, exploring materials, making a project and adapting procedures to develop it, asking questions, solving problems.
- Affective engagement analysed considering expressions of interest, during the session, and in the answers to the questionnaire. In the final considerations, it is possible to see if the child shows pride in what he/she built.

Learning was analysed based on the answers of children to the questionnaire, as well as the analysis of the automata produced. The indicators considered were the parts of the automata:

- That the automata have mechanical and narrative parts
- That the automata has been produced with at least one part that is functioning.

For creativity, the indicators involved the use of materials or the characteristics of the automata produced:

- That it is a copy of the one presented;
- That is has new mechanisms;
- That it has new narratives.

Challenges

A challenge was that a variety of automata with different mechanisms, were presented simultaneously to the children, that required the children to make decisions about what they wanted to make, as well as requiring the preparation of a plan. This needed the children to feel sufficiently involved, with the motivation necessary, for its implementation.

Results

The various data collected has been analyzed into three general sections:

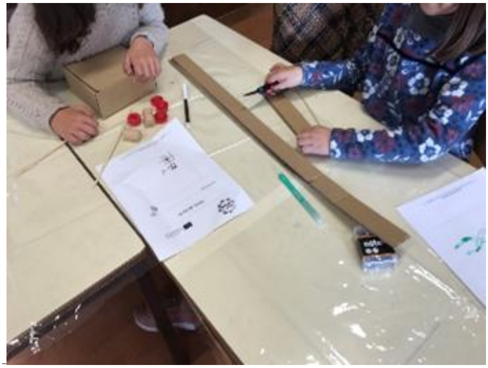
- For engagement and motivation,
- For perception of learning
- For critical incidents.

In each section below, the results will be presented separately and interpreted as two sessions, Workshop 1 and Workshop 2.

Engagement and motivation

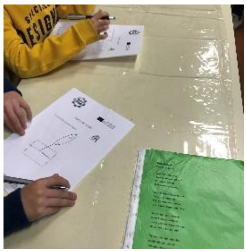
Initial plans In Workshop 1, taking in to account participant observation, the children were very engaged and enthusiastic during the workshop. They immediately started to analyse the automata available, showing curiosity about their functioning.

To develop their own project, the children started to imagine their own automata and how they would make adaptations and test it. This process can be seen as evidence of cognitive engagement as the children were curious enough to want to start their own projects, as soon as the challenge was launched. An analysis of the plans showed that most of the children drew something that was similar to the automata that they had been shown, but in two of the children's logbooks, we couldn't understand the child's idea (Figures 8 & 9).



Figures 8 & 9. Children working with their initial plans

Workshop 2, was similar to what has been described for Workshop 1, the children showed strong engagement and enthusiasm. They wanted to start to analyse the automata available, the materials, and to plan and work on their own project (see Figures 10, 11 & 12).



Figures 10, 11 & 12. Children working on their initial plans.

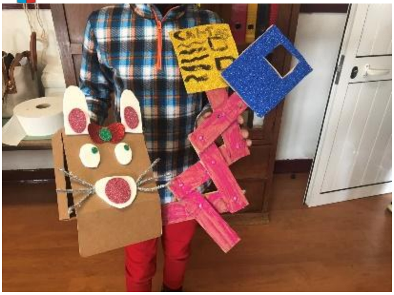
In this session, there was a interesting case of a child who drew a new kind of mechanism. In this child's logbook, we can see an adaptation of the rotation mechanism by putting a lever inside the box unlike the two rods and the wheels in the displayed example. This case shows us how engaging the activity can be, since this child by exploring the presented prototypes and the available materials, was able to create his own innovative project, which can be a cognitive engagement indicator.

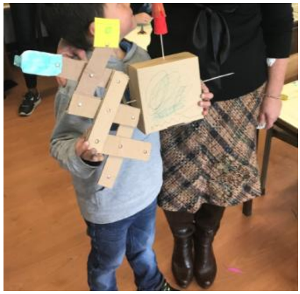
In conclusion, in both workshops, children were actively engaged in the activity either observing the examples, planning their own, exploring the materials that are cognitive indicators of engagement. They were inspired by the examples presented but at the same time, more ideas emerged.

Automata produced.

The automata produced took in to account the automata and mechanisms presented to the children, but also inspired new ideas. In Workshop 1, most of the automata produced were with the lever mechanism, most of the children built recycling bins, similar to one shown them at the beginning, where each box has a lever with similar colour to the box. There was one child that built a talking animal toy with the box and the lever (Figures 13 & 14). Another mechanism used widely was the linkages, there were six children that built toys with linkages, some were theme related, with recycling bins, and others were not. One rotation toy with a small doll was built; by the youngest child after it had built a linkage toy, (Figure 1). This single case will be presented later in the critical incidents.

In this session, two children planned to build two toys each and described them in their logbooks, one with the lever mechanism applied in recycling bins, and another one with the rotation mechanism. This can be seen as an indicator of engagement.





Figures 13 &14. Children presenting their automata.

It is also important to know that in this session there were children from different age groups. All of them were shown all the toys regardless of the individual difficulty for each child. In this way, it was possible for us to see that the younger children, in the first grade, chose the simpler linkage mechanism. This is the one normally given to children of this age in sessions in which only one of the mechanisms is presented and built (Figures 15, 16 & 17).

Figures 15, 16 & 17. Children presenting their automata from Workshop 1.

In Workshop 2, the automata produced used the mechanisms of the automata presented, but also brought in new ideas and proposals. Most of the automata produced used the linkages next in popularity were the rotation ones. Three lever toys were also built, two were related to recycling and the final one was a new adaptation that a child made of the rotation mechanism by putting a lever inside a box and not the usual rods and wheels (Figure 1). This case will also be described in the critical incidents below.

In this session, it was clear that the children respected the theme since almost every toy made had something to do with the environment. The children were very committed to decorating their toys and by analysing the final projects it is very clear how much effort each child put in to their toys.

It is important to mention that in this session as the children were older, they chose more difficult mechanisms to build, such as the rotation one. In dealing with the difficulties encountered, two children mentioned the assembling of the linkages, they said that they didn't have detailed instructions how to do it (Figures 18, 19, 20, 21 22 & 23).

Figures 18, 19, 20, 21, 22 & 23. Some automata produced in Workshop 2.

In conclusion, all the children constructed their own automata correctly, as all the products had mechanisms and functioned. Children had original ideas and were very creative in what they built. Children also invested a lot of effort and imagination in the narrative part of their automata. In Figure 24 the mechanisms constructed in the sessions are shown.

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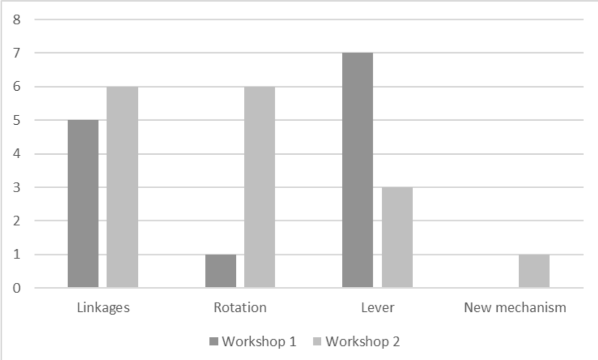


Figure 24. Chosen mechanisms in the two workshops.

The successful conclusion of the activity, with some children even building more than one toy is a behavioural engagement indicator since the children fully engaged with the activity and exhibited active participation. They progressed through all the planned stages from curiosity, to analysis of the presented prototypes, planning of their own toys, assembling and a final reflection.

Participants' satisfaction

During the sessions and when completing the questionnaires, children expressed satisfaction with the activity. In Workshop 1 all the children responded that they enjoyed the activity very much and that they would like to repeat it. Regarding the children expectations, most of them concluded they had reached them successfully with only two participants reporting not being completely satisfied. As for feeling nervous, it can be seen that most of the participants did not feel nervous during the making of the automata; however, there were three participants who distanced themselves from the rest, saying that they felt very nervous. Most of the children recognized the importance of these kinds of activities to learn about moving toys and mechanisms, with only one child disagreeing. Finally, all the children thought they were able to build automata and they were good at it. In response to the open question about what they most liked, the majority said that the workshop was fun, and they enjoy activities where they can use artistic expression. Some children also answered that they enjoyed the activity because they like to build toys.

At the end of the Workshop 2, children also answered a questionnaire and the results also showed that they enjoyed the activity very much and that they would like to repeat it. Most of them thought that the activity is useful to learn about mechanisms and toys that move and they are good enough at building moving toys. This is interesting, as it allows us to understand their motivation for these kinds of activities. Concerning the open question about what they most liked, the majority said that the workshop was fun, and they enjoy activities were they work with their hands. Some children also said that they enjoyed the activity because they were able to learn about new things like how to build a moving toy, and working with recycled materials. Something that also pleased the children was that they were able to use many materials as paints and glue.

In conclusion, the results showed that in both workshops, there were high levels of satisfaction and interest, pointing to affective engagement. In Figure 25, are the results from both sessions.

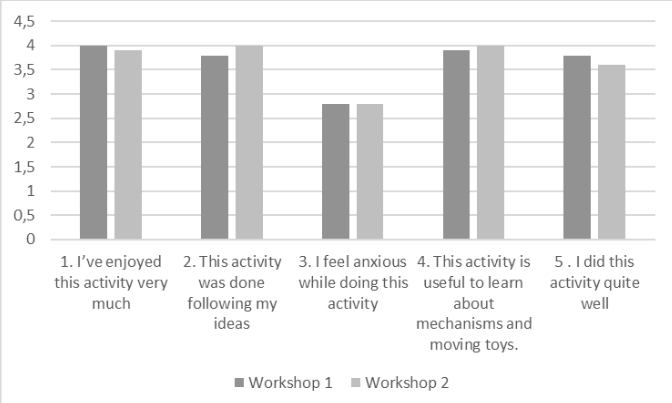


Figure 25. The results of questions related to the intrinsic motivation.

These results can be an indicator of affective engagement since the children's appreciation for this type of activities is clear because all of them answered that they have enjoyed it. During the sessions, it was also possible to notice a high level of enthusiasm and the pleasure with which the children completed the tasks. In addition, it was clear the pride with which they presented the pieces they had built.

Perception of learning

Learning outcomes. In Workshop 1, the children answered the open question on the perception of learning that the primary learning is related to their skill in building toys, only one child mentioned moving toys. Some children also answered that they learned about the environment and how to recycle, and two of them answered that had learned about mechanisms and how to paint.

In Workshop 2, the results from the same open question about perception of learning showed that the children thought that their primary learning is related to their skill in building moving toys and using recycled materials. Some children also answered that they had learned about new things and learned to work with more different materials.

Perceptions of difficulties and improvements

In Workshop 1, the biggest difficulties were the assembly of the toys in general, and the mechanism. It was also mentioned that the painting was difficult and a few children also mentioned cutting, decorating and obtaining materials as a difficulty.

In Workshop 2, most of the children in this session answered that they did not have any difficulties during the activity, although some mentioned a few obstacles. Some children said that they had difficulties in getting the mechanism to rotate, or to assemble the linkages, in measuring and one child answered that his difficulty was his nervousness (Figure 26).

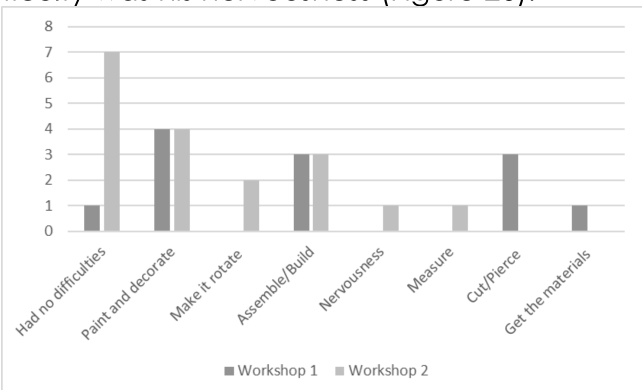


Figure 26. Difficulties felt during the sessions.

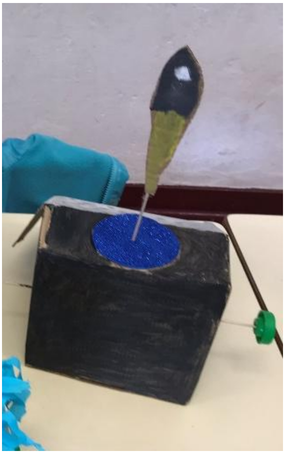
When asked to for suggestions, the children in Workshop 1 answered that there was nothing to improve. Some of the children suggested that it would be interesting to have more materials and to build more and different toys. Some children also suggested that would be nice to have more people helping.

Concerning improvements to the project, in Workshop 2, one of the children suggested to think faster, which could be a suggestion for himself and not to the project in general. Other than this child, there were no other suggestions for improvement.

Critical Incidents

In Workshop 1, one of the youngest children, from the 1st grade, that built two toys, one with the linkages mechanism and the harder one with the rotation mechanism, which is usually used in activities with older children. Observation during the activity and talking to this child's teacher, we understand that this child is usually easily distracted. In this session, there was a behavioural change since he was really committed and engaged in the activity. The child started by building a simpler toy, the linkages one, and even found time to decorate it. After that, the child wanted to start a new toy and he was told he could if he wanted to, so he chose the rotation one. Even though he had help to build both toys, especially the rotation one, The motivation and engagement for the task was impressive. This can be a behavioural indicator as an affective measure of engagement. Firstly, the child really got into his projects and put in a lot of work to assemble both toys, secondly, the child showed a lot of interest and was proud about his accomplishments. Even the teachers were surprised by how he was focused on the task and how he completed it so well.

In Workshop 2, one child, seeing and analysing the presented prototypes and their mechanisms developed a new idea for a mechanism by combining a lever with the structure of a rotation toy. The idea was to switch the rods and wheels that make part of the mechanism by two card strips glued in a perpendicular way. Thus, by pushing the lever the child was able to make his decorative figure go up and down, in this case it was a rocket (Figures 27 & 28).



Figures 27 & 28. Automata built with an innovative mechanism.

It was interesting that the child was committed to the mechanism and to assembling the structure but not as much in decorating it. The child was enthused by the assembling and putting together all the parts to prove that his idea would work but when he had put it all together and was meant to decorate it, he was less interested. The child still completed the painting, in a less enthusiastic way but when he had to draw his rocket, he was not motivated and made a small and simple rocket. After a motivational talk with the child in which we explained to him that he had a good idea by changing the mechanism it was a pity not to put a really big and colourful rocket to add value to his amazing toy. The child eventually agreed and started a new rocket with more motivation and commitment and in the end when it was all assembled, the child was proud of his project because everyone told him that he was very original, and the toy was amazing.

This single situation can be an affective indicator of engagement, by showing how proud the child was in the end, and a cognitive one since the child was curious enough about the task and about what was presented to him to rethink it and develop a new mechanism.

Evaluation

Based on these results, we were able to recognize a convergence in all the parameters analyzed, although small differences emerged according to the ages of the participants in each session.

In both workshops, there was a high level of motivation and interest in the task. All the children showed their interest in the activity from the beginning and were quite autonomous in developing their ideas, which proved to be quite creative. Furthermore, it was only in rare exceptions that children were nervous about their ability to complete the task successfully; having, most of the time, realized their value and their ability to carry out the challenge according to their ideas. All of this was proven by the participant observations made by the educators present during the activity, and by the answers to scales about the children's intrinsic motivation.

In addition to this, the engagement in the task was also clear, during the activity, and in the responses to the questionnaires whose results are analyzed above. There were several results that show strong evidence of engagement at an affective, cognitive and behavioral level. During both sessions, the appreciation of the activity was notable as well as the satisfaction with the work developed by each child.

Generally, the children said they were happy to participate in the project and proud of the work developed. At a cognitive level, the curiosity felt by the children about the various prototypes presented and the respective mechanisms was clear from an early stage, which made them involved in the task. This was evidenced by them asking questions, exploring materials and options and developing new ideas. Finally, the behavioral engagement was equally evident since all children successfully completed the activity, having even exceeded expectations in some cases, as were the cases of the two critical incidents described.

Based on the idea that motivation and engagement are two great enhancers of learning, we can recognize the importance of activities such as those developed by the **AutoSTEM** project for the acquisition of learning in STEM subjects. These types of activities allow the development, in a playful way, of the interest in learning of STEM subjects that previously could be a challenge. In a motivated and engaged way, children ask questions and test hypotheses that they would not have asked in the past, thus developing their learning potential.

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6. Integration of the AutoSTEM project in the curriculum. Making an Acrobat

Nelly Kostova, Veneta Velkova, Ivanka Nikolova

Introduction

The dynamics of the development of modern society brings to the foreground the growing need for socially and technologically educated individuals capable of constructing their personal and professional behaviour and making decisions for the benefit of society.

This requires rethinking school education and changing attitudes from subject-oriented to competence-oriented teaching and learning, moving from encyclopaedic knowledge to dynamic perception of competencies as a set of knowledge, skills and attitudes that are developed in school from an early age and are enriched throughout life. Key competencies include skills such as critical thinking, problem-solving skills, teamwork, communication and negotiation skills, analytical skills, creativity and intercultural skills.

The modern teacher faces the challenge of motivating their students to learn and showing them the practical application of what they are learning. Combining the traditional model of teaching with innovative techniques provides a positive learning environment and turns the student into an active participant in the learning process. In addition, this promotes the development of their creative and critical thinking, increases their motivation to learn.

The STEM approach is one of the main trends in global education, which helps not only to create a connection between reality and what is learned in school, but also a connection between the individual subjects.

- The advantages of the STEM approach are: Interdisciplinary approach, which is the basis for the integration of natural sciences in the field of technology, mathematics in engineering, etc.
- Application of scientific and technical knowledge in everyday life - STEM approach through practical exercises demonstrates to children the application of scientific and technical knowledge in real life. They design, build and develop a tangible product.
- Develop critical thinking and problem-solving skills needed to overcome the difficulties that children may face in life.
- Building self-confidence - children develop and test, process and test again and thus improve their product. By solving all the problems themselves, they build confidence in their own abilities.
- Active communication and teamwork
- Development of an interest in technical disciplines
- Preparing children for technological innovations that will occur during their lives

The STEM approach is considered a prerequisite for the development of engineering thinking. The beginnings of engineering thinking are necessary for the child from an early age, as technology, electronics, and robots surround him already. This type of thinking is necessary not only for the study and for the functioning of technology. Through it, the child builds an idea of the initial modelling required for scientific and technical creativity.

The **AutoSTEM** project includes an innovative and motivating way to introduce the basics of STEM. When planning and constructing toys, children, learn about maths, geometry, mechanics, physics and improve various key competencies while enjoying the process which builds motivation and engagement for learning STEM subjects.

Context, approach, and implementation

The aim of the **AutoSTEM** project is to explore how toys can enrich children's play to promote a better understanding of science, technology, engineering, and mathematics (STEM).

A workshop with twenty five students from the third class, 9 years old, of 32 School "St. Kliment Ohridski"- Sofia, were divided into 5 teams that made **an acrobat** using the **AutoSTEM** approach.

The work began with a discussion about toys and their role in children's daily lives and gradually introduced the idea of making them themselves. The teacher presented the overall concept of the **AutoSTEM** project, showed different automata and the children chose to make an acrobat. The teacher used a video to show the functioning and manufacture of the product. (https://www.youtube.com/watch?v=a8WIwm1UDJ0)

The observation was followed by a discussion and comments on how the acrobat moves and how it is constructed, what the body parts look like, what shapes they are and how they are found. Particular attention was paid to the way of connecting the individual parts and we discussed the types of connections - movable and immovable. The possibility of using recyclable materials for the protection of nature, when making the toy, was also discussed.

The students were divided into 5 teams. Their task was to discuss what materials are needed, to distribute their roles in the team so that everyone was an active participant, to plan and organize their activities and to work as quickly and efficiently as possible. The workshop where they made and reflected on their work took place in two consecutive classes in mathematics and technology, and entrepreneurship. The students watched the video instruction again and began to work out their own construction. They applied their mathematical skills of measurement and drawing, their knowledge of the human body and its movement, and perfected their technical abilities. Some teams met difficulties in making the support or in connecting individual parts. The teacher's intervention was kept to a minimum. After completing the work and making some improvements, the toys were demonstrated to the whole class and were shown in an **AutoSTEM** exhibition in the school.

Challenges

Some students had difficulty making the supports and correlating its height to the size of the acrobat, or joining parts. The teacher's intervention was kept to a minimum - she managed the learning process not so much by informing but by advising the students. Prior preparation is key to success. The teacher must be very well prepared and know what is going to be done; to provide the necessary materials for the project; to take into account the necessary skills to perform the activities and that the children have the skills, so as not to demotivate children; to find the right way to give guidance without directly offering the solution; to specify the time it takes for each element of the project to be completed.

Results

The **AutoSTEM** activities help develop a love of learning and inspire children to discover their passions and talents while encouraging lifelong learning.

- The **AutoSTEM** approach is motivating, engaging, inspired by the real world.
- **AutoSTEM** activities are creative and adaptable, and this allows children with different interests and abilities to express themselves within a group or team. Teamwork, collaboration and communication are the focus.
- Students have the freedom to think critically, creatively and innovatively.
- Failure is an opportunity to learn.
- **AutoSTEM** lessons reduce anxiety and stress in the classroom; improve organization and discipline.

In the workshop, students showed their knowledge of individual subjects, applied different skills, showed cooperation, and assessed themselves and their classmates. As a result, the following goals were achieved:

- Gaining knowledge of physics and mechanisms, especially connections
- Development of engineering competencies for analysis and design
- Improving mathematical concepts in the process of construction and assembly
- Problem solving and creativity

Discussion

Creative STEM activities bring benefits to all students at all skill levels, creating a truly inclusive and effective educational opportunity. The biggest benefit of the **AutoSTEM** project and the workshops is that they promote a love of learning for STEM subjects. Inspiring this passion and desire to learn is the most important competence in the early years of education. Elementary students are ideally placed to embrace the integrated, hands-on learning that **AutoSTEM** offers.

The highest assessment for this is the sparkle in the children's eyes and the incessant questions: "Are we done yet?", "Can we do it again, but with a different character?", "When will we have an hour like this again?"

STEM activities are all around us, and learning can be endless fun.

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7. Development of skills for problem detection, choice of work strategy, decision making, activity planning

Nelly Kostova, Veneta Velkova, Ivelina Piralkova

Introduction

Project-based learning is a learning strategy that covers different subjects at the same time. This is achieved by the teacher encouraging students to identify a real problem through research, to develop a solution, applying evidence of support and to present the solution in an interesting and interactive way, using a set of contemporary visualization tools

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The trainers are given the task to increase the motivation for learning, to form skills for lifelong learning and social skills, etc. Many of these tasks cannot be solved through traditional teaching and learning methods. Interactive methods are successful in which students actively participate in joint or independent activities to create or discover facts and dependencies. Such teaching methods are problem-based learning, research methods (learning by discovery, learning by doing) and the application of information and communication technologies, combined teaching methods, etc.

Interactive teaching and learning methods have several major advantages over traditional methods:

- increased attractiveness of training;
- practical application of knowledge, skills and competencies to achieve certain goals;
- reducing the amount of teaching time

The development and application of modern educational models, which include interactive methods of teaching and learning, meet the current needs of improving the quality of education in mathematics, science and technology.

Context, approach, and implementation

The **AutoSTEM** project is related to the study of natural sciences, mathematics and technology at an early stage and is designed for children between 7 and 10 years. The topic of the workshop organized in 4th grade is "Project-based learning", as it is closely related to the subjects of mathematics, technology and entrepreneurship, which are compulsory subjects for primary school students in Bulgarian schools.

The project started with a 40-minute introduction to various projects made by students from different European countries and materials published on YouTube.

The participants were 21 students aged 9 years old and divided into 5 teams from the 4th grade of the 32 School "St. Kliment Ohridski" . They made a construction of a drawbridge within two consecutive lessons in Mathematics and Technology, and Entrepreneurship.

The students were acquainted with the overall concept of the project and chose the topic to work on.
As an independent task, the teacher asked them to research various bridges in Europe. The children were excited at the prospect, even as they were introduced to the project and the ideas,

Before starting their own work, they watched the instruction for constructing the toy using a video available on YouTube (https://www.youtube.com/watch?v=Ah-I88JAAaE). Thanks to it, they were able to see clearly exactly what was required and how they would work in the time available.

The students were acquainted with the overall concept of the project and chose the topic to work on.

As an independent task, the teacher asked them to research various bridges in Europe. The children were excited at the prospect, even as they were introduced to the project and the ideas. Thanks to it, they were able to see clearly exactly what was required and how they would work in the time available.

Drawbridge construction:

During the independent work, the children concentrated, diligently and carefully, especially when working with the glue gun, where they had help from the teacher.

The project helped the children to improve their organizational skills as they had limited time and resources. It also helped them develop independence and autonomy, as they were required to work with almost no outside help.

The teacher divided the children into 5 teams of 4-5 students, and each group had to make a separate structure. According to the teacher, if one part of the class is engaged in one activity and another in another, there will be chaos and the activities will not be synchronized. These groups worked with little help from the teacher and support for the math and technology problems, and the techniques they used. They determined by themselves which of the available materials to use.

They made an action plan, that included a sequence to assemble the structure and drew pictures. The children had to organize themselves and their roles in each teams in order to be able to work as quickly and efficiently as possible. They had to ensure that no one would be inactive or that one person would do all the work.

During the implementation of the project and the construction of the bridge, a competitive element appeared which is extremely important for the students in primary schools. When they compete with each other, it encourages them to work faster, more efficiently and better.

At the end of the workshop, the students corrected any problems with the bridge construction with minimal help from the teacher. They demonstrated their work to all the participating classes, and to their parents. An exhibition in the school building was organized and all the materials made by the students were shown.

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The main advantage of **AutoSTEM** is that young students work to develop and improve their creative skills and mathematical and technical literacy.

Challenges

Some of the students had a problem assembling some parts of the structure. The teacher plays a more passive role than that of the student, which is the main characteristic of project-based learning. With the advancement of technology and the digitalization of our daily lives, there is no way that the learning process will not change. The teacher should be well acquainted in advance with the steps to be followed; that the necessary materials and tools are available, that the work is planned and that there is enough time.

The teachers helped the children to correct their mistakes and the children tried again on their own. This approach - self-study and teamwork - had a positive effect on the discipline of children in the classroom. The children were more organized and motivated to work.

Results

Why does **AutoSTEM** help children learn to plan and work in a team?

AutoSTEM shows children how important it is to work in an orderly way, to plan and not to be chaotic in your actions. To make the individually assigned products, students must first plan well how they will continue, and this is where the teacher is most involved in the project, in the presentation of the idea, the presentation of a video that shows how the products are made, and giving quality, and adequate instructions for the work.

The practical implementation allows the children to be active participants and the main actors in the learning process. Unlike traditional lessons, in which the teacher takes this role, here the students are given the opportunity to judge for themselves what, when and how to do, of course following the instructions and requirements. However, this does not limit them to decide at what pace to work, how exactly to glue the individual elements of the product and who to play what role in group work. This freedom is extremely inspiring and stimulating for children and makes them act actively, dynamically and productively.

By developing students' creativity, ingenuity and technological skills, the project enriches children's knowledge and abilities in various subject areas such as mathematics, art, architecture, technology and entrepreneurship. In order for the Bridge to work, children have to calculate and measure everything they will glue, cut and assemble, which in turn is closely related to their mathematical knowledge and skills (units of length, drawing angles and sections, addition and subtraction up to 100).

It turns the lesson into a fairy tale with its own plot, an interesting story about a problem that can be solved or an activity that can be developed. Learning happens on the way to producing the solution. In project-based learning, the main role of the teacher is to teach in a way that motivates students to want to learn and to participate in creating something.

The children can show what they have learned in the different subjects or the whole section, explore the connections between the individual units, cooperate with each other, and evaluate themselves and their classmates. What they do is not just test or make a specific product, but a real in-depth understanding of the whole process.

Discussion

The method of project-based learning was used in a teaching practice with the development of various structures with moving mechanisms. This type of group work unites children and increases their motivation to participate in the learning process. Their creative thinking develops and an interest in mathematics, natural sciences, and technologies deepens.

This successful method can also motivate and involve students with a reduced interest in mathematics and technology.

All students in the class gave very positive feedback and expressed a desire for this type of lessons to be held more often.

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8. From guided play to creativity: metamorphoses and stories of a bird[3]

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Introduction

This Case Study describes a workshop developed for the **AutoSTEM** project that was designed to investigate how automata can enrich young children's play to promote a better understanding of Science, Technology, Engineering, and Mathematics subjects (STEM) and to promote the development of motivation for STEM and creative thinking.

Today the benefits of play in learning are already known, although these two principles are often presented dichotomously. To respond to this opposition, the guided-play concept emerges as a middle term between both principles. Guided-play concerns "learning experiences that combine the child-directed nature of free play with a focus on learning outcomes and adult mentorship" (Weisberg, Hirsh-Pasek, Golinkoff, Kittredge & Klahr, 2016, p.177). Guided play is only established in the presence of two key elements, the child's autonomy and the guidance of an adult.

The balance between adult guidance and the child's self-discovery is often difficult to achieve, as the concepts to be

[3] This case study is partially published in the *International Journal of Developmental and Educational Psychology*., 2(1), 221-228.
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learned become more complex, there is an increased need for scaffolding by the adult.

Therefore, the implementation of this strategy in the **AutoSTEM** project is extremely pertinent, as the concepts of STEM subjects, in addition to being important, can be extremely complex, requiring as an essential the mentoring of an adult to achieve full learning.

Given the characteristics of automata, especially that they include a narrative part and a mechanical part, they can be used within a play-based pedagogy, to implement activities related to the planning and construction of toys, and to promote competences including observation, problem solving, and creativity in STEM subjects.

This case study is based on a workshop that was developed using the construction of automata with a sliding mechanism, called the JellyBird. The JellyBird is a moving toy made from paper and cardboard that flaps it's wings like a bird when constructed. STEM subjects can be introduced when constructing the JellyBird:

- To learn about physics and mechanisms,
- To develop engineering competences of analysis and construction
- Other soft-learning goals including problem solving and creativity.

Taking in to account the Guided play concept, the workshop also aimed to analyse the relationship between the teacher's guidance during the activity, and the children's creativity.

Context, approach, and implementation

Figure 1. Overview of children working on the JellyBird.

21 children aged 7 to 8 years attended this session. During the session, university students from the Science Education Bachelor and Master courses were also present, as participant observers.

The workshop started with the presentation of the automata and the construction of JellyBird automata. Firstly, the teacher showed a model of the JellyBird. Children observed the JellyBird and made comments and asked questions about how it functions. Teachers talked about the movement in a very simple way, calling attention for the sliding motion.

Following the presentation and observation part, the children were given some instructions about how to construct the JellyBird, and then a time to decorate it, and develop a narrative about it.

As the children were building, the teacher explained the next steps. Firstly, the students cut out the geometric shapes from the supplied template that had been pre-printed, that would shape the automata (Figure 1). This initial stage was guided by the teacher, afterwards the children continued the activity, finishing the construction and painting the prototype. There was some variability in the steps described above, as some children started decorating the prototype before finishing gluing and construction it (Figure 2), while others completed the construction and only after started painting (Figure 3).

After this step was completed, the teacher asked the children to compose a story, about the toy they had made.

Figure 2. Child working on the decoration.

Figure 3. Child working on the construction.

An evaluation of the workshop was completed through:

- Participant observation,
- An evaluation questionnaire
- Analysis of products developed (the automata and the narratives).

Figure 4. Child counting the parts of the automata.

The observation guide included indicators on interest and motivational learning, experienced difficulties and creativity.

The questionnaire included statements and open questions about motivation and perception of learning. The automata produced as well as the narratives were also considered for analysis of the learning outcomes and creativity.

For analysis of the learning processes (Figure 4), perception of learning was considered but also analysis of the mechanism and its functioning of the automata.

For creativity analysis, indicators considered were:

- Is the automata mechanism a copy of the one shown /does the automata have new mechanisms;
- Is the automata narrative part a copy of the one shown/ has the automata new elements;
- Characteristics of the narrative and similarity between them

During the workshop, the trainers talked with the children, about their ideas, took some notes and made photos and videos of the constructions (Figure 5). After the workshop, children answered a questionnaire

Figure 5.Trainer talking and helping a child.

Challenges

How to reconcile the need for instructions to carry out the task without inhibiting creativity? Both aspects are necessary, the instructions are important to a feeling of accomplishing the task, but they must not be so excessive that they hinder creative expression.

Results

An analysis of:

- The observation records
- And answers to the questionnaire

show that during the construction of JellyBird, the children were enthusiastic and curious about the activity, showed interest and cooperated with everyone. During the activity there was no child who showed any resistance to participation, in general, they all showed great enthusiasm.

The main reasons for it having been an enjoyable activity have been categorized into three categories:

- The activity was interesting and fun
- That they were able to learn something new/ how to do make toy/ a bird
- Independence and autonomy" I could follow my ideas" and " my work is original"

The category with the highest number of responses was "I' learned something new/how to make a toy / a bird".

From the analysis of the responses to the question about the main areas the children had learnt, three categories were identified:

- To construct a toy / bird,
- To construct a mechanism,

- To do new things / to invent / to be creative - To cut, being the most mentioned

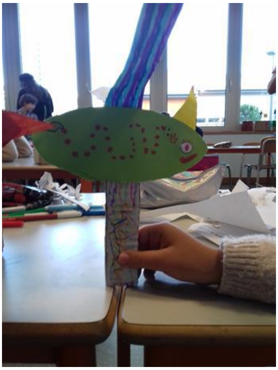
However, difficulties experienced during the workshop also centered around the mechanism construction and bringing the different parts together and sticking them.

An analysis of the automata built by the children makes it possible to note that all the participants successfully carried out the activity (Figures 6, 7, 8 & 9). At the end of the session, each child had an automaton that worked as intended. This data is in agreement with the data obtained from the questionnaire; in particular, the statement "This activity is useful to learn about mechanisms and moving toys".

An analysis of the automata produced shows that in all cases, the automata mechanism is a copy of the one the children were shown. However, some differences emerged, both in terms of the procedures followed by each child during construction, when it was painted or the toy created.

As the instructions progressed and the different parts of the automata were identified, some children chose to paint it first, while others finished the construction first.

In addition, although the instructions were given in a similar way to the class, the automata produced were all different from each other, especially in the painting and decoration. The work produced was diverse: most of the children made birds following on from the initial presentation, but there were also whales, rockets, and unicorns, and others.



Figures 6, 7, 8 & 9. Examples of some JellyBirds created in the workshop.

The stories produced by each child about their automata also show a high degree of creativity. All the stories were different, having different characters, plot, problems and the duration of the story.

Examples, can be seen just from the titles of the children's stories that included 'The spaceship and the bird' 'The sparkling bird', 'The seagull and the fish', 'The footballer bird', 'The Tonico Whale', 'The green bird', 'The paper bird', 'The bird Herb extinguishes the fire', 'The Luluu bird'. The children were very creative in their stories, and these were just some of the titles. One child, although using the same template as everyone else, chose to change his into a whale.

As an example, here is one of the children's stories, 'The spaceship and the bird', that has been chosen for its originality and creativity (Figure 10).

Figure 10. Illustration of one of the narratives made by the children.

In this story, the child tells us that there was a spaceship that did not know how to fly and therefore it felt sad to be in the middle of the other spaceships that could fly. Then, on a stormy day, a bird appeared next to the spaceship, The bird had lost his nest because it had flown away and asked the spaceship if it could take shelter inside it. The bird asks the spaceship why it is sad and as soon as the spaceship says, 'Because I don't know how to fly', the bird agrees to teach it. After much training, the ship learns to fly and becomes friends with the bird and whenever they flew in the sky, they did it together.

The booklet with all the narratives in Portuguese can be found here (Figure 11). You will need an account on Issuu to access the book. It is also available on Google at: https://docs.google.com/document/d/1J4NCo3gQCIEelHY2i1HbjYQbiQSp5WrT4eW5IGrksTk/edit?usp=sharing

https://issuu.com/home/published/cesolum_sul_-3_sesso_es._v8

Figure 11. Cover of the booklet.

From the analysis above, it can be seen that a high level of creativity and initiative emerged from the activity

Evaluation

The activity generated a high degree of interest, with all the children actively participating and building their own toy. In general, the children followed the instructions given for the construction of the automata.

However, it was also found that after an initial construction phase, some of the children preferred to decorate it, only finishing its construction after, while others followed the opposite procedure. In addition to this difference, it was also found that, despite the instructions, the built automata differed in decoration, color, accessories, etc. even with figures other than the suggested bird. However, it was in the narratives around the automata that the unique creativity of each child emerged, with diversity of characters, plots or type of text constructed.

Considering the high degree of satisfaction and the lessons learned, it seems possible to state that the instructions given were important for the successful completion of the mechanism, but in no way limited or inhibited creative thinking.

We can see that the middle ground between the child's autonomy and the adult's instructions, in this group of children had no impact on the child's creativity. In this case, the teacher's guidelines were essential, otherwise, children would not be able to assemble the toy, however, the children had complete freedom to decorate their toy and the narrative associated with it, making that part completely autonomous and for this reason, creative and diverse results emerged.

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9. Using Automata in an after-school Science Club

Joel Josephson

Introduction

Automata are fascinating mechanical toys for children, small Kinetic Art sculptures. An Automata is a construct that includes engineering, cultural awareness and artistic expression. Automata are story telling mechanical objects. Automata have fascinated children over the ages and today there are museums just for automata.

AutoSTEM uses a multidisciplinary approaches which introduces STEM concepts and competences in different subject areas at the same time, including, measurement, transfer of power, mechanics, numbers, creativity and comprehension.

This case study details how **AutoSTEM** activities were implemented in a 1-hour Science club over the course of 4 sessions.

Context

Joel Josephson (Kindersite) and Ms Bettany (general primary school teacher) at the Firs School, Chester, UK, carried out the activity.

The Firs is an independent primary school for boys and girls aged 2-11. The activity was carried out with 10 – 12 boys and girls aged 9 to 11 years.

Case

This case study looks at using **AutoSTEM** resources in an informal, context were direct learning is not the primary objective, but peripheral.

The concept of the Science Club is to introduce science areas to the upper primary children in the school in an informal and enjoyable setting and build interest and engagement with science subjects.

Approach and implementation

The workshop was organized by introducing the **AutoSTEM** project to the head teacher and her assistant. An introduction to the teachers of the school was then arranged during a regular teacher meeting. At that meeting, Josephson introduced the project and a short workshop was completed where each teacher built the JellyBird.

A meeting was arranged with the teacher who would be conducting the Science Club (Ms Bettany) who is a general primary teacher with over 20 years experience of teaching. At the meeting, a number of different **AutoSTEM** automata were shown to the teacher and an agenda was decided on of which automata would be completed each week.

Over the course of the 4 weekly meetings the desired methodology used was:

- Setup of materials and tools in the classroom prior to the children's arrival
- Reflection on previous week
- Short introduction to the task of the day
- How they wished to work individually or in groups
- Building of the automata
- Using the automata
- Roundup and reflection

The planned methodology was adapted during the course of the club in reaction to actual events and feedback.

The automata made were:

- The Balloon car
- The Dancing doll
- The Drawbridge

The children were 10 x 9 to 11 year olds, boys and girls.
Josephson also led a discussion on the physics involved in using the car. The cars are driven by blowing air in to a balloon attached to the car and the release of the air caused by the tension in the rubber balloon creates the propulsion. The discussion centred on where the energy came from and the chains in the transformation of energy to have reached the balloon. In addition, other **AutoSTEM** automata were shown to

the children so they could understand other aspects of the physics that they are based upon.

Challenges

It was found during the first club meeting that there was not enough time to complete all the steps envisaged in the initial plan and the necessity for more scaffolding and allowances for mistakes made by the children meant that the initial target of a completed and working Balloon car by the end of Club meeting one with feedback and reflection, could not be achieved. It was decided to remake the Balloon cars with adaptations learnt from week 1.

Challenges included insufficient scrutiny of the children leading to mistakes especially in the placement of the holes for the axles and straw. There was also not enough time for the children to play with their Balloon cars and engage in a discussion of their work.

The second session was also preceded by a discussion of how the children felt that they could improve their cars.

This challenge was overcome by recommencing the Balloon car in to the 2nd weekly session.

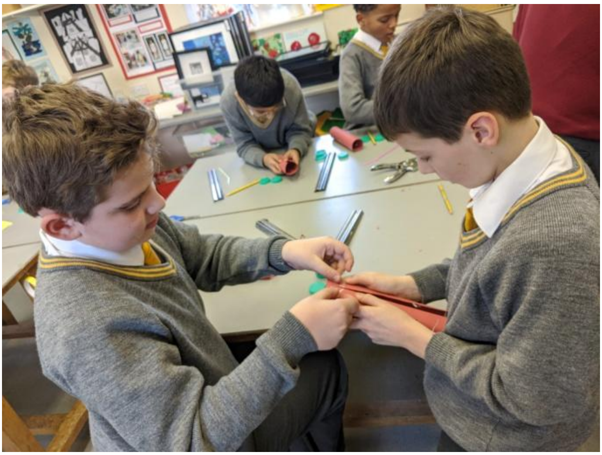
The Dancing doll automata that was developed in the 3rd week faced similar challenges.

The Drawbridge in session 4.

Successes

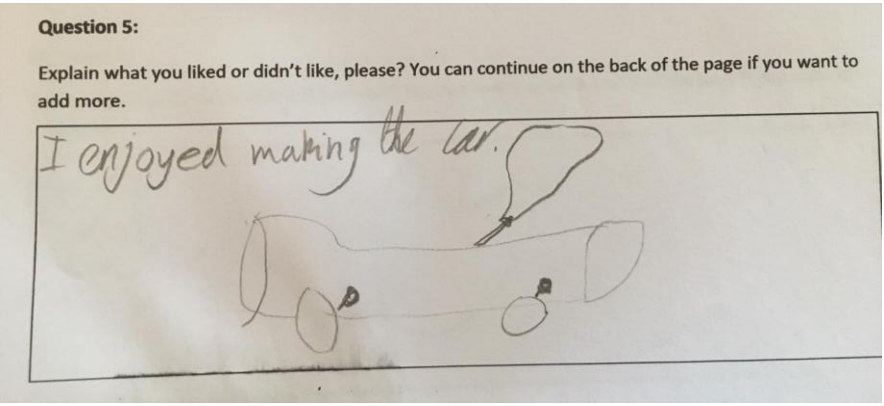
The work produced positive results:

- All participants managed to make a working automata that they were proud to share
- They gained an introductory understanding of how energy is conserved and transferred.
- They worked together and helped each other complete their tasks. The participants gained confidence in their ability to complete the tasks they were satisfied and this increased their sense of self-esteem.



- They built an understanding through the discussions and reflections of how they car's move and stop

Comments from the children include:


Question 5:

Explain what you liked or didn't like, please? You can continue on the back of the page if you want to add more.

I enjoyed making the car.

Outcome

The children very much enjoyed the challenge and making things that worked.
The workshops teachers felt the time was much too constricted and reduced the impact due to not being able to carry out enough reflection and challenge their thinking and reflecting skills.

Evaluation

This case study indicates that **AutoSTEM** Workshop activities can be adapted to alternate formulas but requires more preparation in to the methodologies to be employed, with a less ambitious agenda and more pre and post work around the actual construction.

In addition as the workshop was with older children than specifically targeted the potential to go much further in to the mechanics and physics involved are very clear and indicates that workshops can be held with older groups of children and used as a starting point for practical science instruction and experimentation with a toy that is relevant and interesting to children that have placed a stake within as they constructed the toy.

The children's questionnaires

The children completed simple questionnaires at the end of the 4 sessions with the following questions and findings:

Q1. Did you enjoy the **AutoSTEM** workshops?
75% responded that they *Enjoyed a lot*, or *Enjoyed*
Q2. Was it easy or hard to make the Automata?
42% said it was *Very easy* or *Easy* but 17% said it was *Hard*
Q3. Did you learn anything new?
67% said that they *learnt loads* or *Learnt a bit* and 33% said that *Some new but some I knew already*
Q4. Would you like to do more learning with automata?
83% stated that they would like to do more learning using automata.

Analysis of results:

An analysis of results at this level and sample size can only be indicative but appears to indicate that even though the children were older than the targeted group of the project and in a semi-formal setting, they still gained from the project pedagogically, and with engagement and enjoyment. The indication that the children would like to go further with this direction is encouraging and indicates that a future project for older children may be indicated.

Comments from the children:

Enjoyed making the car

Cool Fun Easy
My favourite was the cogs challenge
I liked the spinning doll
I quite like it
I think you should make more time. I liked the fun of making stuff
I enjoyed making the car but the ballerina was too hard but I do like my teachers
I liked everything
I liked playing with it
It was really fun
I liked the experimentation
I liked making the car and really enjoyed stuff

Evaluation from the teacher:

What went well?

- The pupils enjoyed making things and testing if they worked
- Good opportunities for collaborative work

What could be improved?

- Perhaps the pupils could have been involved in the prep rather than being handed a readymade kit requiring not enough thinking and effort.
- More sessions needed. If we had more than 4 or 5 sessions then there would have been time for pupils to prep materials and more importantly to reflect on what worked and what did not with the opportunity to better their designs and tinker with the product to improve its working, therefore challenging their thinking and reflecting skills.

What the children gained from it:

- Enjoyment, but with more sessions, they could have developed their thinking, discussed the successes and failures and improved on initial attempts.

Case Studies with a target audience of Teachers

10. Using self-made automata to teach STEM in early childhood teacher education[4]

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,

[4] 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

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 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?

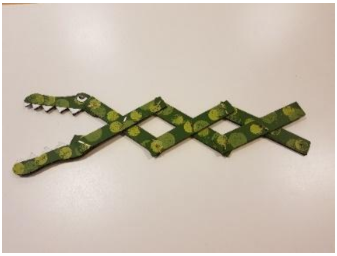
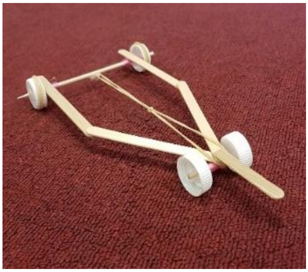
Context, approach, and implementation

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 4). After each student had attended each workshop once, the lesson ended with a 30-minute session with the whole class.

Figure 4. 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.

With the support of the Erasmus+ Programme of the European Union. The content reflects only the author's view and the European Agency and the European Commission are not responsible for any use that may be made of the information it contains.

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].

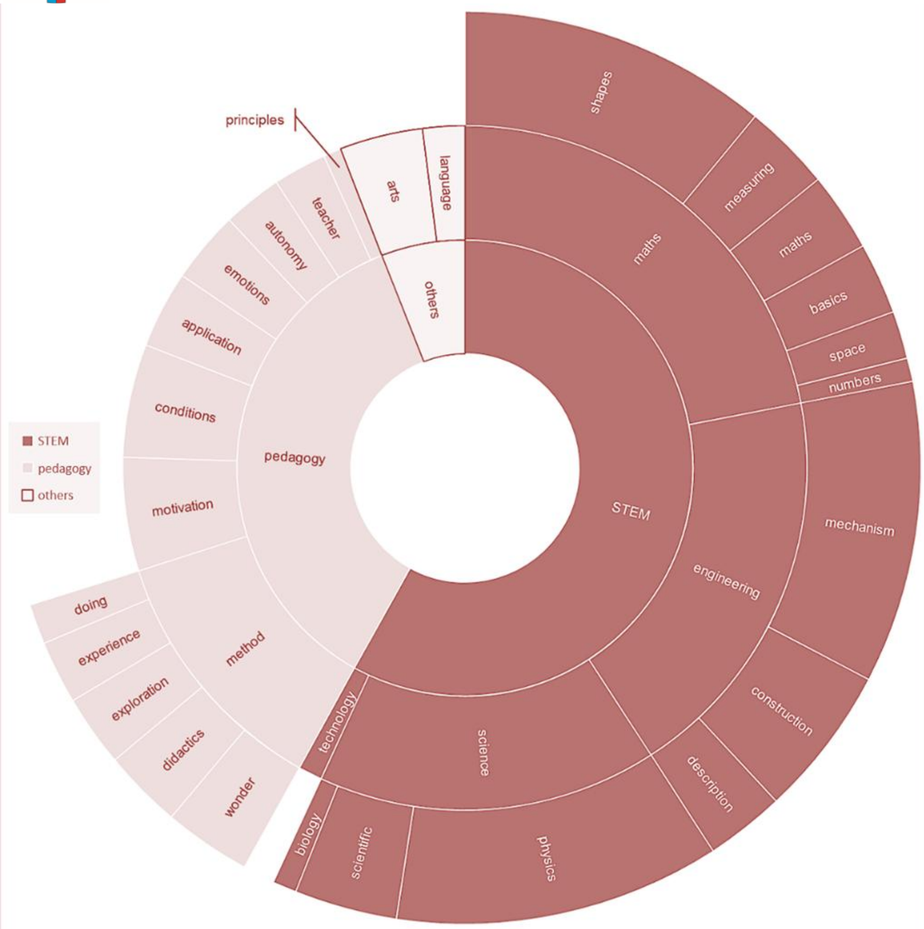


Figure 5 Categorisation of the students' utterances in the written task

. shows the utterances' distribution between the different categories. Most of the STEM-related utterances were about

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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].

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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.

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Case Studies- Case Studies with a target audience of SEN students

11. Outcomes of Automata for STEM activities with cognitive and physically impaired people

Authors: Corinna Bartoletti and Francesca Ferrini

This case study shows how an **AutoSTEM** activity can be an excellent stimulus to people who have cognitive and physical special needs, stimulating the proximal zone of development of each individual (Vygotsky, 1978), to help them discover their own inner resources and potential and deal with difficulties (C. Morosin Psicomotricità dell'adulto, Cecilia Morosini, Lina Barbieri, Laura Ferrari Carrocci Faber editori 2005i).

Introduction

Automata are fascinating mechanical toys for children, small Kinetic Art sculptures. An Automata is a construct that includes engineering, cultural awareness and artistic expression. Automata are story telling mechanical objects. Automata have fascinated children over the ages and today there are museums just for automata.

AutoSTEM uses a multidisciplinary approaches which introduces STEM concepts and competences in different subject areas while also including, measurement, transfer of power, mechanics, numbers, creativity and comprehension.

Context, approach, and implementation

Francesca Ferrini (educator, psychomotor and pedagogical counsellor) and the educators of the Arboreto Day Centre carried out this activity. Arboreto is located in Gubbio (PG), Italy. It is a centre for young adults with physical and cognitive difficulties. The workshop lasted 3 hours and 10 people participated. Francesca led the group while educators from the centre helped people with greater difficulties to complete the most difficult manual tasks.

Respecting the centre's policy and in order to avoid any distractions, no photos were taken of the participants.

This case study intends to be a starting point for any educator who works with people with special needs. It demonstrates that the use of manual skills is a great help in strengthening fine motor skills and hand-eye coordination. It also indicates that STEM contents can be spontaneously understood while experiencing them in the building process of an **AutoSTEM** automata. It also shows that the activity is a good stimulation for reasoning processes and for building a connection between different topics, leading participants to gain useful insights. Furthermore, this kind of activity encourages group work, collaboration and verbal sharing of what has been learnt.

Implementation

The workshop was organized in nine steps:

1) Explanation to the participants of what they would be doing
2) Drawing circles using compasses
3) Considering how to divide the circles into 8 equal parts and completing the task
4) Colouring the disks – the students were divided in to 2 groups: one group had freedom to follow their own imagination and the second was instructed to used only use primary colours
5) Construction of the turbine - some participants helped in the construction
6) The disks were cut, holes made in the centre, and they were mounted on the turbine
7) Turning the turbine - a hair dryer was used to make the turbine rotate. The whole group observed
8) Reflecting – the group reasoned and reflected on the mechanism that moves the turbine. They enjoyed observing the colours changing depending on the different combinations made during the colouring step
9) Recording- participants wrote down what they observed: the colour combinations and the resulting colours

Challenges

The participants with more severe physical difficulties were helped to cut out, colour and draw the circles, while people with more severe cognitive difficulties had to be helped in understanding how to divide the circles into 8 equal parts. However, the biggest challenge was for the educators who had to differentiate the work according to the personal skills of each participant. A very important aspect was for the educators to hold back and stimulate the participants so they could use their own passion to do the tasks on their own, This enhanced their self-esteem as they succeeded in the tasks.

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Results

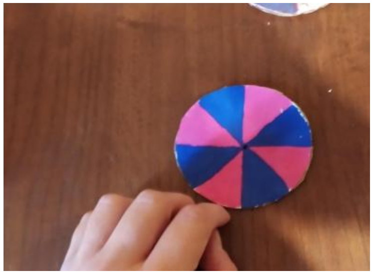
The work produced a number of results:

- The participants have acquired greater confidence in themselves and in their potential. At the beginning of the activity, they thought they would not be able to succeed in this task, but with the mediation of the educators, they were very satisfied and this increased their sense of self-esteem.
- Through observation and reflection, the participants easily discovered the mechanism that moves the turbine.
- The participants were very happy to be able to observe which secondary colours are produced by the primaries, and to discover what colours the various combinations chosen by themselves, generate.
- It was very meaningful when we talked about how colours mix when the disk spins quickly and how important speed is in this process. We also talked about the Newton Disk, which aroused a lot of interest and curiosity from the majority of the group.
- In a simple, practical and fun way, each of them felt like a scientist able to discover and deepen some topics that, before, seemed too difficult for them.

The automata made were the turbine and the spinning disk. In addition, the participants wrote down the colour combinations and the resulting colours.

Discussion

This case study shows that an **AutoSTEM** workshop was not only useful for transmitting sciences through the construction of automata. It also shows how useful they are for working on the proximal zone of development with various types of special needs people.





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12. Hearing and touch for seeing: Instructions to promote mental representation of geometric shapes in visual impaired people when constructing a moving toy

P. Vaz-Rebelo, C. Costa, G. Bidarra, A. Santos, R. Gomes, L. Barata, C. Barreira, V. Alferes, J. Josephson, O. Thiel, N. Kostova, C. Bartoletti, F. Ferrini, S. Hanssen[5]

[5] This case study is part of the article:
P. Vaz-Rebelo, C. Costa, G. Bidarra, J. Josephson, O. Thiel, A. Santos, R. Gomes, C. Barreira, V. Alferes, N. Kostova, C. Bartoletti, F. Ferrini, S. Hanssen (2020) Instructions to promote mental representation of geometric shapes in children with visual impairment when constructing a moving toy: an example from AutoSTEM project. *ICERI2020 Proceedings*, pp.9835-9839. http://dx.doi.org/10.21125/iceri.2020.2204

Introduction

This case study aims to describe the processes developed for adapting and expanding the Jellybird guide and resources designed for the **AutoSTEM** project for seeing students and teachers https://www.autostem.info/wp-content/uploads/2020/06/Jellybird-for-AutoSTEM-PT-v3-def-3.pdf to allow educational inclusion for blind or visually impaired children. The instructions and resources are intended to complement the general guidelines already developed by the **AutoSTEM** project, to promote mental representations of geometric concepts with visual imagery.

The Jellybird is a bird made from paper and cardboard, that has wings that can make bird-like movements, when constructed. Following the general aims of the project, STEM subjects can be introduced when the children are constructing an automaton, including geometric shapes, types of motion, and/or biology concepts. A pedagogical guide has been developed, with examples of how the educator or teacher can talk with the children about STEM subjects and ideas. For instance, with the Jellybird, educators can talk about the different parts, their shapes and placement, for example, 'The body is round, but not a circle. It is oblong and pointed at one end. There is a left-hand side and a right-hand side of the body' or 'The wings are rectangles. A rectangle has four sides and is oblong. There will be one wing on either side of the bird'. In the Resource section of the AutoSTEM website the guides are available in 5 EU languages.

Sight is a fundamental sense for human beings to obtain information. When people cannot access information through sight, hearing and touch become more crucial'. **Hearing (distant analyser**); for the visually impaired, is the sense for information and orientation, it enables them not only to orientate in space and the environment but also in the time and history. A visually impaired person perceives by hearing the surrounding world and people, whose voices and sounds are characterizing in the ambient space and actual social climate or story's situation. However, they do not respond to visual communication such as facial expression, gestures, gesticulation and body expression, which are important accessories to verbal communication. Markedly they feel handicapped in non-verbal communication (Kohanová, 2006).

Touch (contact analyser); compensates for sight in the area of graphical communication. Haptic sensation (touching) replaces non-verbal expression of information that is accessible by touch - models, relief and other typography pictures (Kohanová, 2006).
Although blind people use tactile information as a substitute for the eyes to explore the environment, the sense of touch has limitations in range, distance, and size so that the introduction of blind students to an object is often incomplete. This has caused the teaching of blind students to primarily be verbal. They tend to have verbal delusions about a thing, though the imagined is not experienced or seen directly. 'The imagery of something that does not exist during the process of imagining is commonly called imagery. For blind students who become suddenly blind, it is still possible them to do visual imagery because they have received visual information and stored it in their memory' (Zahra, Budayasa & Juniati, 2018, p. 2).

Researchers in mathematics education have emphasized the importance of visualization in mathematical learning and the mental imagery in the mathematical meanings construction and in the conceptual development. Visualization and visual thinking are the essence that makes geometry a special case in mathematics (Costa, 2005). The imagery is defined as a

collection of images and the power of imagery is that it can result in visualization, which helps students to make relations and meanings in learning geometry (Solano & Presmeg, 1995). Also Zahra, Budayasa and Juniati (2018,p. 2) stress the importance of visualization, stating that "In elementary school, visualization becomes one of the important abilities used to help students in understanding spatial concepts, shapes, sizes, and distances'.
Students who are blind or with impaired sight have limitations in developing their spatial conception. 'Loss of vision in the blind has an impact on the development of cognition, especially the formation of concepts through sensory experiences to perceive the environment, an essential distinction between blind and sighted students is the conceptual development of blind people in visualizing objects through tactile experience, while sighted students use their visual experiences" (Zahrai, Juniati & Budayasa, 2018, p.90). The loss of visual experience in blind students causes some difficulties in understanding of the concepts of geometry directly.

Blind students take a long time to construct a mental representation of spatial concepts making the learning of geometry difficult (Thinus-Blanc & Gaunet, 1997). In the same way, Vianna et al. (2006) also showed that students with visual impairment, such as blind students, have difficulty understanding geometrical images. The difficulty of learning and teaching geometry to sight impaired students is experienced by the students and their teachers. Although using tools like physical models, many teachers still have difficulty teaching geometry to blind students who cannot use their visual senses (Vianna et al., 2006; Pritchard & Lamb, 2012).

While seeing people have a major advantage in this area, blind people have other important abilities in their favour, capabilities that cannot be developed by people with good vision, no matter how hard they try. Based on the brain's capacity to rewire and distribute resources from affected areas, the sensors migrate from vision towards touch and hearing, balancing the scale and importance of these senses. Therefore, the brain area responsible for sight and hearing develops higher abilities (Pritchard & Lamb, 2012).

Context, approach, and implementation

This work analyses the processes and modifications introduced when adapting the pedagogical guide and construction instructions for one of the automata of the **AutoSTEM** project. The Jellybird is designed for children from 4 to 7 years old. The teacher can adapt suggestions to their own class and context, plan their own activity, and adapt the idea for other ages. The pedagogical guide and construction instructions can be found at: https://www.autostem.info/jelly-bird/ (Figures 1 & 2).

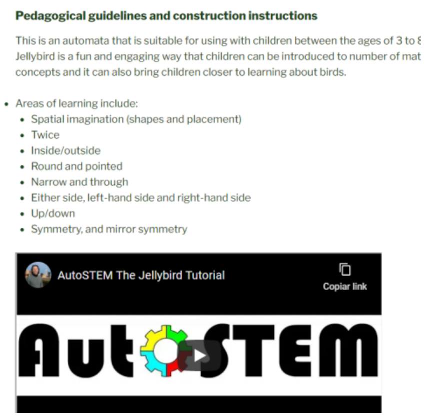


Figure 1. Overview of the webpage for the pedagogical guidelines.

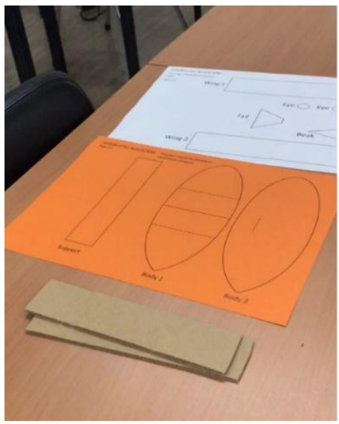


Figure 2. Parts of the Jellybird before construction.

The pedagogical guide adaptation was carried out by a multidisciplinary team, taking in to account the literature about difficulties in teaching and learning geometry experienced by blind children and teachers and embodiment in the blind students mind.

As a result, several steps were taken. Some of these steps are integrated in the general pedagogical approach of the **AutoSTEM** project, others directly address the adaptation of the guidelines itself and the analysis of the processes and changes introduced.

Overview of the process developed

The starting point is the **AutoSTEM** project that has developed pedagogical guidelines and construction instructions for a number of automata. These guidelines for teachers and educators to use in class are designed to help explore the use of automata to promote motivation in young children for STEM subjects.

Following the development of the pedagogical guidelines and construction instructions, they were used with a second grade class in Portugal. All the children constructed their own automata and the results of a short version of Intrinsic Motivation Inventory (n/d) pointed to a high level of satisfaction among the participants.

To expand the resources and activities into additional areas and promote inclusivity, the Jellybird pedagogical guidelines and instructions were adapted for children with visual impairment, by adding descriptions of the geometric shapes and the motion involved in the moving toy. This work was developed by taking into account previous evidence about the difficulties experienced by blind children in understanding the concept of geometry directly, and the difficulties faced by teachers in explaining the shapes.

Blind children cannot use visual aids to learn geometry and many teachers have difficulty giving instructions even by using physical models, because blind children take a long time to construct a mental representation of the spatial concepts. A blind child has to construct in their mind a mental image, and evaluate them, or create a new image.

The development of the adapted guide took in account the perspectives related to the body in the mind and cognition (Johnson, 1987) and the importance of socio- cultural factors for knowledge construction.

It was also produced a typographic version of the shapes that make up the Jellybird and an audio version of the pedagogical guide which was used through the Non-visual Desktop Access (NVDA) (Figures 3 & 4).

It was decided that the shapes of the Jellybird should be prepared and cut out before the session. These adapted resources were used in a session with the participation of the multidisciplinary team, involving Science Education students and teachers, as well as Maths Education teachers and technicians from the Support and Integration Unit of the University of Coimbra, one of them was a visual impaired adult (Figure 5).

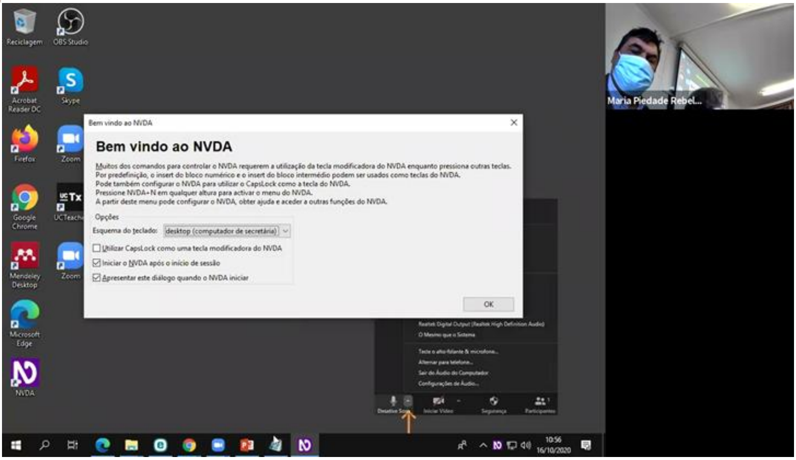


Figure 3. Presentation of the NVDA system.

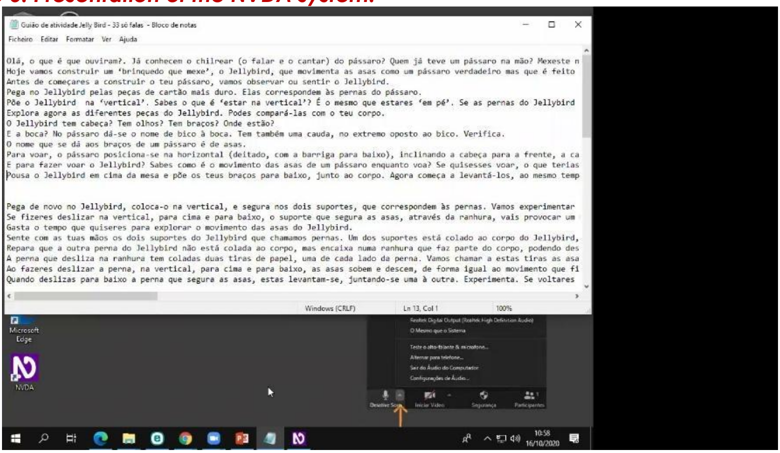


Figure 4. Reading of the audio version of the pedagogical guide.

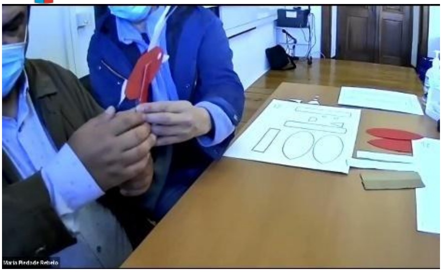
Figure 5. Listening to the audio text with instructions in NVDA format.

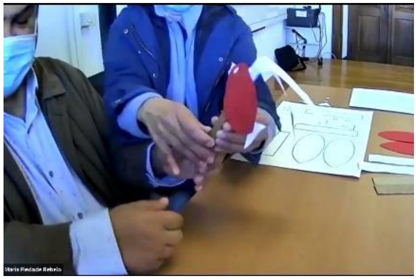
After listening to the audio version of the pedagogical guide with the instructions, the visual impaired adult was given the constructed Jellybird automata (Figure 6) and a typographical version of the shapes of the Jellybird so that they could experience the outline of the shapes (Figure 7).

Figure 6. Presentation of a Jellybird previously constructed.

Figure 7. Presentation of the typographic shapes.

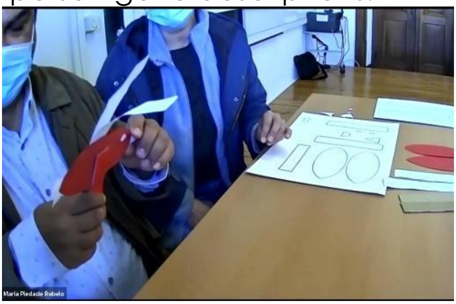
The blind person began by experiencing the Jellybird (Figures 8 & 9), with the help of a sighted person who described the parts as the blind person touched them.





Figures 8 & 9. Blind person handling the Jellybird automata.

The blind person continued experiencing and touching the outlines of the prototype (Figures 10 & 11) while the sighted person gave descriptions.



Figures 10 & 11. Blind people experiencing the outlines of the Jellybird.

Then the blind person tried to experience the movement of the toy (Figures 12, 13, 14 & 15).

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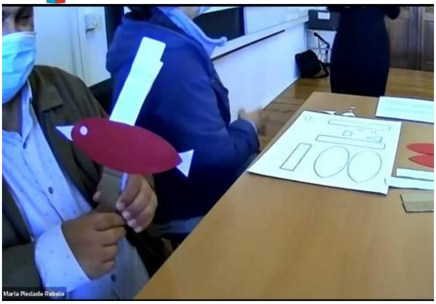
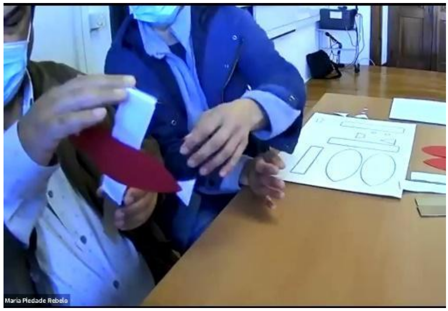



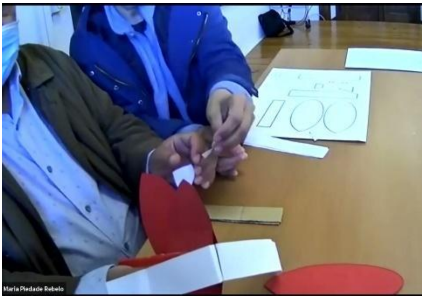
Figures 12, 13, 14 & 15. Blind person trying to experience the movement of the Jellybird.

As this was difficult the student who was helping made a suggestion for a different way to experience the bird movement, by making it go up and down in the air (Figures 16, 17 & 18)



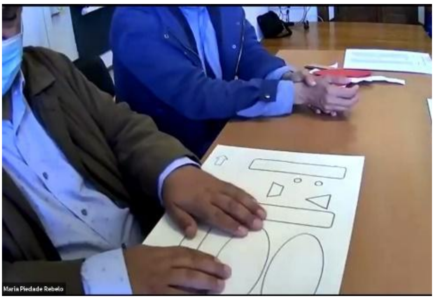
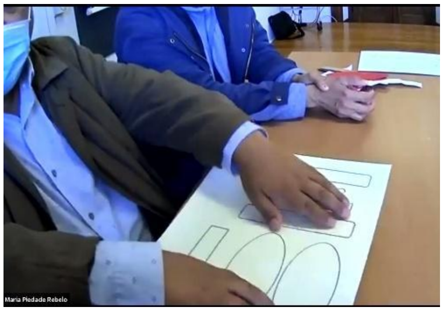
Figures 16, 17 & 18. Blind person finding a new way to produce movement of the Jellybird.

Then, blind person was given the different parts of the Jellybird to touch, while the sighted person described which geometric form each part was (Figures 19 & 20).

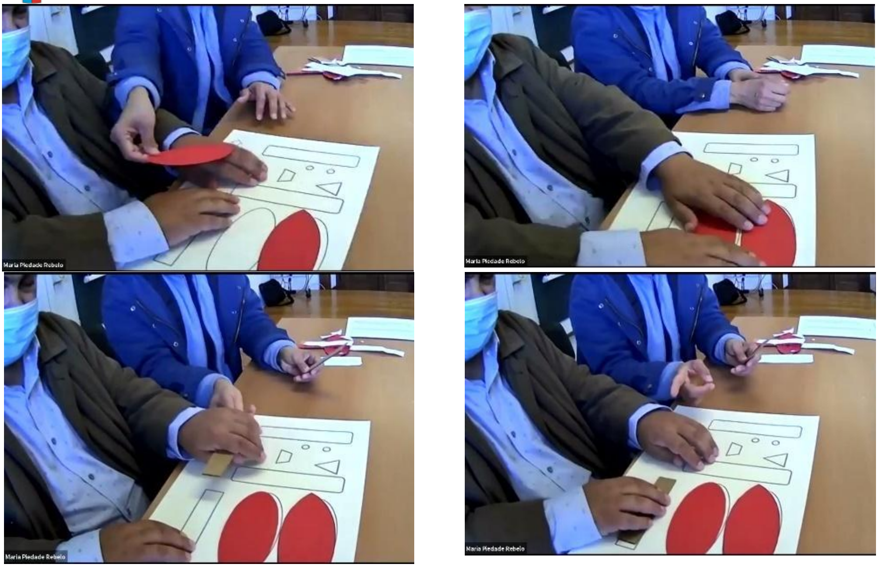



Figures 19 & 20. Blind person touching the different parts that constitute de JellyBird.

After experiencing the different geometric forms, the blind person started to touch the typographic shapes (Figures 21 & 22) and then tried to overlap the corresponding parts with their geometric embossed shapes (Figures 23, 24, 25 & 26). In Figure 27 we can see all the geometric forms positioned over the respective embossed shapes.

Figures 21 & 22. Blind person touching the embossed shapes.



Figures 23, 24, 25 & 26. Blind people overlapping the geometric forms with the respective embossed shapes.

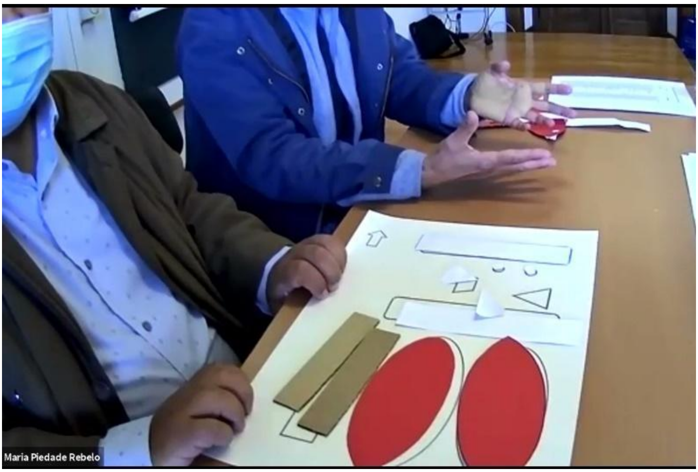


Figure 27. All the geometric forms over the respective embossed shapes.

The resources developed for this session and a further session completed 3 days later were analysed (Figure 28).

Figure 28. Register for the second session.

Both sessions were video-taped and analysed in order to identify the main challenges and ideas. This constituted a category in the results.

Documental corpus and analysis

The documental corpus includes the two guides developed: the general guide and the adapted one to be used by teachers or educators with blind or visually impaired children, plus notes taken during the sessions and their transcriptions.

The two pedagogical guides and construction instructions were analysed and compared in order to identify categories of analysis.

The categories defined to examine and compare the changes between the two pedagogical guides were; similarities, differences and changes.
The Analysis of the sessions where the updated guide was used, as well as the session of reflection allowed additional changes after the first session

Challenges

- Identify the appropriate level of detail in the oral description of the geometric figures of the automata.
- To coordinate audio information with tactile to enable a mental representation of the object/s.
- To test the material and the adaptation of the guide in classes that include blind and partially sighted children, allowing the same experience for sighted children, within the framework of the Universal Design for Learning (UDL).

Results

The analysis of the two pedagogical guides developed for the Jellybird prototype, the general one, and the one adapted for blind and visually impaired children, allowed us to identify the categories: similarities, differences and changes introduced in the adapted guide.

The **Similarities** between the two guides are:

- Framework & aims, play-based pedagogy, learning through automata, STEM.
- Number of sections; both guides include two main sections, one on how the Jellybird can be used to learn STEM subjects and the second on construction instructions.
- Both guides are aimed to teachers and/or educators.

The main **Differences** between the two guides are:

- Development and structure of the sections. The sections in the general guide are developed in a more general way, while in the adapted guide there are examples of detailed specific verbalised instructions
- Pedagogical pathways: teacher role, tasks, materials

The **Changes** introduced in the sections of the adapted guide include:

- Detailed specific verbalised instructions read to the students by the teacher or educator whose aims are, to initiate in the child mental images; and for the child to construct mental images. Both images should be related to the different geometric concepts.
- Tasks involving audio, tactile, embodiment and diary experiences.
- Tasks involving observation were eliminated.

Changes introduced in the adapted guide have a transversal concern to help the child build mental images and to promote their construction, using different tasks and materials. Changes point to additional pedagogical pathways, involving tactile, auditory, embodiment and diary experiences, with the aim that the blind child builds in their mind a mental image or creates new images.

To aid this process;

1. Sounds of birds and/or a story are used to develop mental images through hearing.
2. The bird's body is compared to the child's body, as well as diary activities, aiming to build a mental representation of how the Jellybird is made and how it functions.

With the support of the Erasmus+ Programme of the European Union. The content reflects only the author's view and the European Agency and the European Commission are not responsible for any use that may be made of the information it contains.

3. A sliding motion is presented that is associated with the automata wing motion.

Finally, in order to construct their automata, the child experiences the embossed shapes. During the construction process the child can also, whenever they want, touch and explore a JellyBird that was made previously, or hear the description of the construction process, again.

After the first session, it was possible to see some gaps in the materials and in the adapted pedagogical guide. Based on this experience some additional changes are still to be made, these are:

- Review the description of the geometric figures.
- Select the essential information and make each part shorter by adding pauses between parts when giving the instructions. Information should be presented in short sequences.
- Importantly, separate and phase the tasks and that the audio is in tandem with each phase.
- Coordinate the audio information with the timings of the tactile exploration.
- The JellyBird automata that is shown to the blind children should have parts that can detach from each other so that the students can deconstruct and reconstruct. It should be more resilient, suggestions include that Velcro and plastic material should be used (Figures 29, 30, 31 & 32).

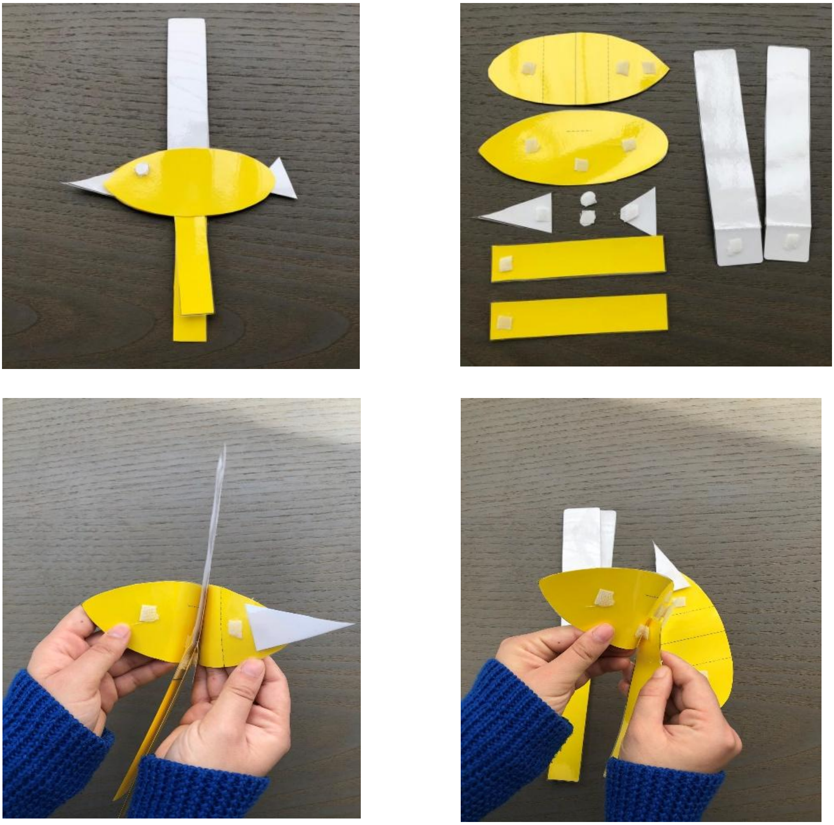


Figure 29 30 31 and 32. Example of test prototype already prepared.

In Figure 31 are some notes taken during the brainstorming done during the second session with the multidisciplinary team, in which a new timeline was proposed for the activity. In the new proposal it is proposed to start with the embossed shapes, followed by the shapes made from paper and card that are used to construct the JellyBird. Then we move on to the bird that has been built and can also be deconstructed so that the parts can be identified separately.

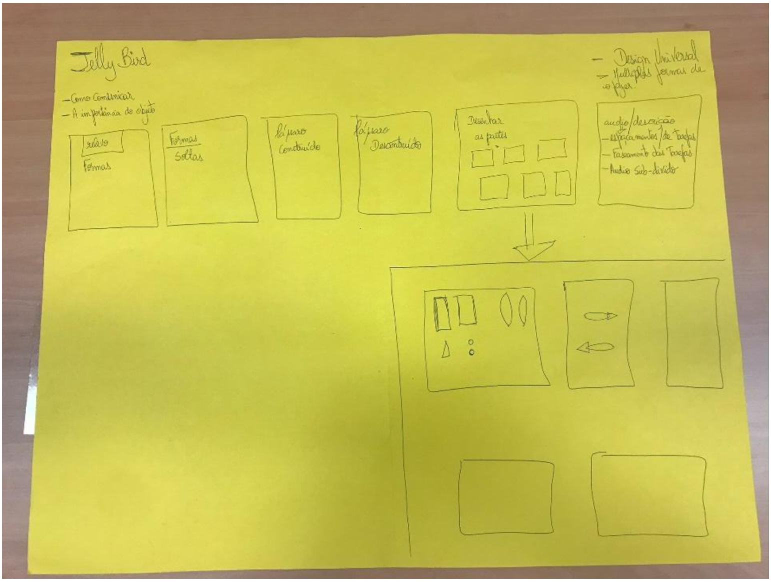


Figure 33. Notes taken during the discussion

Evaluation

The adaptation for blind and visually impaired children of the Jellybird Pedagogical Guide and construction instructions was carried out, to permit mental representation of geometric concepts.

The adaptation involved several iterations. After an initial adaptation, the comparison of the two guides, the general one and the adapted, points to three main categories of analysis: similarities, differences and changes.

The Changes introduced are evidence of a need to bring together multimodal pedagogical pathways that enable the understanding of the mental images of a child and how to build their construction that require; tactile, auditory, embodiment and diary experiences.

Several challenges emerged how to balance between auditory and tactile experiences. Including, the adaption of the teacher guide in to an oral format and the reflective analysis about the process, point to another category.

Additional changes after the first implementation, point to the need to interconnect multimodal pathways and add strategies.

The entire adaptation process was shown to be very complex and has not been completed yet, since many additional changes arose. The opinion and participation of a blind person proved to be very important since it raised points of view that the rest of a multidisciplinary team or a sighted person has no perception of as they are sighted.

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IMI Intrinsic Motivation Inventory – SDT (n/d) https://selfdeterminationtheory.org/intrinsicmotivation- inventory/