Reflections on the TALKING CELLS PROJECT: A STEAM Approach to Learning

Meltem OKSUZ KARAGOZ[1]

Hazan BUYUKAKMANLAR[1]

[1] Erkan Ulu Schools

Abstract

This small-scale action research reports on a design and implementation of a 'Talking Cells' project which aims to teach students the subject of "Cell" through an integrated STEAM approach. For this project, the school's ICT teacher, science teacher and educational technology specialist worked collaboratively to design a series of activities that provided a context for children to solve real-life problems. In total 3 teachers from different subject fields worked as a team on this project with 51 sixth grade students. The students experimented with the ideas by designing solutions for real-life problems that were given to them. The students transformed organelles from cells into objects by using different materials and programming these using digital tools and electronics. The study which took place during lessons totaling 400 minutes, allowed students to experiment with STEAM concepts and skills. The study found that learning through solving real-life problems using programming and STEAM skills had a significant effect on students' performance.

Key words: STEM, STEAM, 21st Century skills, Technology, Cell, Organelle, Programming, Makey Makey

1. Introduction

For some students learning mathematics has been a challenging experience mainly because of their mathematics anxiety (MA). Ma and XU (2004) defines mathematics anxiety as a state of discomfort caused by performing any form of mathematical tasks. Ashcraft & Ridley (2005) describes MA as the negative emotional response to situations involving math which can cause stress and avoidance behaviour (Ashcraft & Ridley, 2005). This state of discomfort or negative emotional response can be observed in many different ways such as feeling worried, being frustrated, having a fear, disliking (Ashcraft & Ridley, 2005; Wigfield & Meece, 1998). A number of studies have shown that there is a strong relationship between MA and children's performance in mathematics (Ashcraft & Kirk, 2001; Hembree, 1990; Ma, 1999). Similar issues were also reported by some children, during science lessons, where students develop a fear towards learning science concepts and any situations that involving science (Mallow, 2006). Likewise, the link between science anxiety and performance was reported by number of studies (Udo, Ramsey, Reynolds-Alpert, & Mallow, 2001). The difficulty in helping students who might develop mathematics or science anxiety is the reasons and causes can be very diverse, making it very hard to identify. We propose teaching mathematics and science concepts through a STEM approach where the focus will move on to developing concepts through a project-based approach rather than learning of domain specific knowledge under each subject. This integrated teaching of different curriculum subjects was also supported by Huber and colleagues (2005) who argued that making connections between disciplines can support learners to develop a deeper understanding of concepts. Moore and colleagues (2014) focusing on integrated STEM education, defines STEM as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38).

Some studies suggested that integrating art into STEM based learning would engage learners and has potential to improve cognition (Henriksen, 2011; McGrath & Brown, 2005). These views encouraged educators to include Art in STEM education and focus on STEAM rather than STEM. Wang and colleagues (2011) studied the way subjects were taught in schools. Focusing on three different class teachers, they reported on their observations at the end of each day. When they observed the mathematics teacher, they suggested that the teaching was teacher-led, and the lessons did not encourage students to question or investigate the concepts. The second teacher taught the same grade and subject for seven days using real-life problem-solving approach. The teaching was defined still as teacher-led and students couldn't relate to the issue or formulate questions. The final teacher used interdisciplinary methods and provided the children with a problem that was all about building an adult-sized cardboard chair that could hold someone that weighs 150-200 pounds. The teacher let the students figure out their own solutions, through the planning and design process, allowing them to use their own creativity. As a result, the students were supported to develop their problem solving, design & engineering skills. They were therefore able to analyse the problem and manage their own learning process. They were able to design their own research and questioning methods.

The studies we discussed above influenced the way that we developed and taught the Talking Cells project. This will be explained in Section 3.

2. Methodology

An action research approach was used for investigating our own teaching approaches to children's learning of concepts from different domains in an integrated manner. We followed the stages of action research process suggested by Altrichter and colleagues (2007). Data was collected through unstructured observations and questionnaires. The students and their interactions were observed by the branch teachers whilst working on their project. Any behaviour, words or description that would provide us with an insight into their learning and engagement was written down. The students' prior knowledge on the subject, knowledge during the course and the output knowledge after the course were measured using questionnaires.

Data was analysed by looking at the data collected from the observations, followed by analysis of the questionnaires. A traditional approach based on Strauss's (1987) "coding from the data" method was adopted where we analysed the data as we collected it during the project. We explored what was more significant based upon our knowledge and understanding of the topic as we found that having three experts from different backgrounds was very useful for this process. Quotes from the interviews with the students were used to give an insight into the student's experiences. The data collected was analysed using the constant comparative method to conceptualize the overall data and establish the links to the research question (Glaser and Strauss, 1967).

The children and parents were informed about this project and that the outcome of the investigation would be published both on the Internet and also presented in conferences. A generic permission letter that had been prepared by the school, regarding studying the children's work to improve standards in school was signed by all of the parents. The children were also reminded that they may withdraw from the activity at any time they liked.

3. Implementation of Talking Cells project

As our discussion in the previous section demonstrated; teaching science, technology, engineering and mathematics concepts through art-based learning can improve students understanding and problem-solving abilities. At this point we need to remind ourselves what the core elements of the STEM approach are. Jolly (2014) has listed the characteristics of STEM as:

- *lessons focus on real-world issues and problems.*
- *lessons are guided by the engineering design process*
- *lessons immerse students in hands-on inquiry and open-ended exploration.*
- *lessons involve students in productive teamwork.*
- *lessons apply rigorous maths and science content for students to learn.*
- *lessons allow for multiple right answers and reframe failure as a necessary part of learning.*

We developed our Talking Cells project with these core elements of STEAM learning in mind. The students were given a real-life problem and asked to formulate solutions through planning, design, testing and evaluation. The students were taken on an open-ended exploration where they worked as part of a team. The project focused on developing concepts in different subject domains.

The project was based on a story which had a main character called ATP. The story tells how ATP decided to go to his dad's science lab without his permission and used his new invention, which shrinks the size of the objects.

ATP shrinks himself by accident to the size of an atom, then falls onto the floor inside a petri dish and sinks into an animal cell. This is the beginning of his adventure with organelles. ATP has to follow the nucleus commands in order to get out of the cell safely. During this project, the students were asked to act as ATP and visit organelles in order to prepare themselves for following the commands of the nucleus.

The implementation of the project involved several steps:

Real Life Problem and Restrictions (1 hour)

The story describing ATP's cell adventure (Appendix 1) and project notebooks (Appendix 2) were distributed to students. At the beginning, the story was read by the teacher, using an Interactive White Board to display the visuals related to the story. At the end of the story, the teacher asked the students the following questions;

- What do you think that the interesting machine in the science lab did to ATP?

- Where did ATP find himself after the effects of the machine?

- What do you think the round shapes were that ATP saw when he fell into the water drop?

- What should ATP look for when navigating inside the cell?

- If you were ATP what would you do to get out of the cell?

Acquiring Information (2 hours)

- The students filled in the first part of the" Recruitment Form" in the project books.

- The teacher asked the students to use the subject materials (iPad, science textbook, etc.) in science to study the topic, "Cell" which is included in the unit "Systems in Our Body"

- The teacher distributed capsules in which the names of the organelles are written to the students. Individually, the students conducted research about Molecular Biology and Genetic Engineering in the computer laboratory about the organelles that were written in the capsules.

- The students filled in the second part of the" Recruitment Form" in the project books.

- Based on the results of their research, they described the organelles using their characteristics. One example of this can be illustrated through Child A's description.

Vacuoles is my name. I have five siblings. The nucleus is my boss, but he's always late with my salary. I'm found in all eukaryotic cells, but I still may not be present in some cells. Mostly big in plants, but less, in animals I'm small, but I'm too many.

Child B described Lysosome:

Hello my name is Obur(Greedy) Necmettin. I'm a lysosome. I'm in the plant cell. I am very oburu. That's why I can digest within the cell. Bring everything to me, but don't bring it cooked food. I'd like to introduce you to five fingers. When you're talking, give me the amoeba between bread!

Idea Development (2 hours)

- Students decided on the voice that they wished to use for their presentation.

- After giving the presentation of the study to the science teachers in the classroom, they filled in the second part of the adventure of ATP with their friends. They received feedback on their ideas.

- Students filled in the "First Days" section of the project books.

Product Development: (Total 3 hours)

- The science teacher prepared A3 sized models and shared the models covered with PVC with the students (Appendix 4, Animal Cell Model)

- Students filled in the "Product Analysis" section of the project books.

Visual Arts Course (1 hour)

- The students start to make 3D models.

- They improved their design by looking at real 3D organelle images that are shown on the IWB board.

- At the end of the course, the science teacher checked the designs that the students had made and directed the students to the information technology class.

Information Technologies and Software (2 course hours)

- Throughout the study, the students took on their professional roles by selecting one of the professions in the project books.

- 3D Modeling Professionals paste 50x70 dried models onto canvas (Figure 1).

Figure 1: Models of organelles

- Computer Engineers encoded the audio files that they collected in accordance with the use of the Makey Makey and Scratch program. (Note for the teacher: Each organelle will be associated with a letter from Makey Makey.)

- Electrical Electronics Engineers, in cooperation with the Modeling Professionals, installed Makey Makey by creating their system with electronic cables.

- Public Relations Specialists prepared presentations for the marketing of the product.

Testing

The three different branch teachers created and completed the rubric jointly based on their observations whilst the children were creating their models and when they presented their product to whole class. The students had opportunities to evaluate their own project throughout the sessions.

Sharing and Mirroring (Total of 2 courses)

- The students presented their project to the teachers of the three courses and their peers. (1 lesson hour)

- The students took an exam in science. (1 lesson hour)

- Self-evaluation forms were distributed to the students to be completed.

The detailed list of skill and knowledge set that this project aims to cover can be found in Appendix 1 and all the necessary materials for delivering the sessions can be found in Appendices 2-5.

4. Discussion of findings and conclusion

The data from the observations showed that when evaluating their own learning, the students gave full marks to themselves in working as part of a team, research, application, presentation and comprehension skills. This shows, that not only were they able to assess their own learning, but also had high self-esteem.

The students were able to recall the concepts that they had learned and to use the skills that they had developed after the project in other sessions. This shows that they were able to retain the information and skills. We could link this to both Piaget (1970) who highlighted the importance of learning through doing and also Vygotsky who emphasised the role of social interactions in children's learning (1978).

Both the observations and student's exam results showed that there was a significant increase in children's understanding of concepts and processes in many subject domains. For example, in science, the results showed that the children were able to use scientific inquiry and technology to implement their solutions. This also involved coding skills as they used the Scratch application to program their organelles. They were able to create a 3D representation of cells where they learned to work using a wide range of materials.

In terms of mathematics when drawing cells, they learned to calculate the diameter-radius of the model and draw the circle using compasses. They also used the measurement techniques to create 3D models of organelles on the canvas. This also requires the skill of imagination, creativity, visualization, which can highlight the role of art in design and making processes. From an engineering perspective, the students documented the stages of their production using an engineering notebook and systematically identified issues and modified their design accordingly.

One other interesting finding of this classroom investigation was how children that normally showed anxiety when learning mathematics or science, did not display any negative emotions during this project. One reason for this might be that they perceived this project as a problem-solving activity rather than learning in any specific subject.

In conclusion we can suggest that designing learning opportunities for children using a STEAM approach can support their learning of concepts in different disciplines in a meaningful way as long as real-life problems are used for the project. It is also important to have experts from different disciplines involved in the design, teaching and evaluation of the project as this would bring in the expertise of professionals from different fields, increasing the validity and reliability of the project.

References

Altrichter, H., Posch, P. and Somekh, B. (2007, 2nd edition) Teachers Investigate Their Work: An introduction to action research across the professions (Routledge: London).

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. Journal of experimental psychology: General, 130(2), 224.

Ashcraft, M. H., & Ridley, K. S. (2005). Math anxiety and its cogni- tive consequences: A tutorial review. In J. I. D. Campbell (Ed.), Handbook of mathematical cognition (pp. 315–327). New York, NY: Psychology Press.

Glaser, BG. & Strauss, AL. (1967). The Discovery of Grounded Theory: Strategies for Qualitative Research. New York: Aldine De Gruyter.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. Journal for Research in Mathematics Education, 21(1), 33-46. doi:10.2307/749455

Huber, M.T., Hutchings, P, and Gale, R. (Summer/Fall 2005). Integrative learning for liberal education. *Peer Review.* Association of American Colleges and Schools: Washington, DC. [Online], Available: http://www.aacu.org/peerreview/pr- sufa05/pr_sufa05_analysis.pdf [February 2019]

Jolly, A. (2014). *Six Characteristics of the Great STEM Lesson*. [online], Available:

https://www.edweek.org/tm/articles/2014/06/17/ctq_jolly_stem.html

Ma, X. (1999). A meta-analysis of the relatioship between anxiety toward mathematics and achievement in mathematics. Journal for Research in Mathematics Education, 30(5), 520-540. doi:10.2307/749772

Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. Journal of Adolescence, 27, 165–79.

Mallow, J. V. (2006). Science anxiety: research and action. *Handbook of college science teaching*, 3-14.

Mcgrath MB, Brown JR (2005) Visual Learning for Science and Engineering. IEEE Comput Graph Appl 25:56–63

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In *Engineering in pre-college settings: Synthesizing research, policy, and practices*. Purdue University Press.

Piaget, J. (1970) *Logic and psychology*. NY: Basic Books.

Strauss, A. (1987). Qualitative analysis for social scientists. New York: Cambridge University Press.

Udo, M. K., Ramsey, G. P., Reynolds-Alpert, S., & Mallow, J. V. (2001). Does physics teaching affect gender-based science anxiety? *Journal of Science Education and Technology*, *10*(3), 237-247.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wang, H.; Moore T. J.; Roehrig, G. H. & Park, M.S. (2011). *STEM Integration: Teacher Perceptions and Practice*. [online], Available:

https://docs.lib.purdue.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1036&context=jpeer

Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. Journal of Educational Psychology, 80, 210–216. doi:10.1037/0022- 0663.80.2.210

Appendices

Appendix 1: The knowledge and skill set covered

Cognitive Process Attainments

1.1. Attainment related to the main discipline:

Science

6.1.1.1. Compares animal and plant cells with their basic structure and their objectives.

a. As for the basic structure of cells, cell membrane, cytoplasm and nucleus are given.

b. Only the surface information about organelles such as names and objectives are mentioned.

1.2. Attainments related to other disciplines of STEAM:

IT and Software programming

6.1.3.5. Develops a strategy for storing files and accessing files. Customizing the working environment for storing files is highlighted.

6.4.2.2. Uses software that can edit audio and video files. Open source or free access audio and video editing programs are preferred.

6.5.1.5. Develops an algorithm to solve the problem.

6.5.2.15. Creates an original project with all programming structures

Mathematics

6.3.3.1. Recognizes the center, radius and diameter by drawing a circle.

Visual Arts and Design

6.1.2. Uses different materials and techniques to create visual art work.

6.1.4. Reflects his / her ideas on visual art work according to the selected theme and subject.

Liberal arts

6.5.6. Investigate the personality traits, skills and training process required by the profession.

Turkish

6.2.1. Makes a prepared speech.

6.3.4. Uses reading strategies.

1.3. Social Product Achievements:

He communicates effectively with his group mates and shares his ideas and actively participates in group work. The student presents the designed product clearly. Develops skills in front of the public, having empathy, and being open minded about the opinions of their friends.

Appendix 2: Adventures of ATP / Story Book

 https://drive.google.com/open?id=1WU8kEdsxmQTTZe-W9RZMWHWHc_Sk-A5N

Appendix 3: Project Notebook

https://drive.google.com/open?id=1uMw_i43_0Qgc1BGAm5H2UOd-GI5121hC

Appendix 4: Voice Record

https://drive.google.com/open?id=10Fcjlt2Vu52EsKfv7FZlgEewxblWxHcH

Appendix 5: Cell picture

https://drive.google.com/open?id=1wQ1BXcP3FJgy8W4nw-netS0NR6MuuYhX