
Science Technology Engineering and Mathematics (STEM) Education: A report on how students at the primary school engage in STEM education lessons

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Abstract: STEM stands for Science Technology Engineering and Mathematics. It is a method of education where in the subjects are taught in coherence instead of in isolation. This research report investigates the strategies used in teaching STEM education lessons and the impacts it has on students. STEM education is a subject which focuses on actions that lifts foundational skills in STEM learning areas, and develops mathematical, scientific and technological literacy for students involved. It also promotes the development of the 21st century skills of problem solving, critical analysis and creative thinking. This case study is inspired by reasons that STEM is being studied as separate subjects in Papua New Guinean (PNG) schools. Also, it is yet to be formally incorporated to PNG's education system and curriculum. This case study used Arts Based Research (ABR) during data collection because ABR is a creative research approach which enables researchers to gather data through observation, interviews and/or questionnaires and analysis of first-hand information from participants. The findings indicate that students' critical thinking and problem-solving skills are enhanced through STEM education because of the hands-on approach and the practical pedagogy involved in facilitating STEM lessons using Lego sets from suppliers like the young engineers in Australia.

Key words: Science technology engineering mathematics, critical thinking, technological literacy, creative thinking, Lego, pedagogy, arts-based research, inquiry-based learning

Author's Biography: Ms. Annette Tsibois Sinnou is a Lecturer at Divine Word University (DWU) Our Lady of Sacred Heart (OLSH) Kabaleo Rabaul Campus. She is from Buka and is married to Christopher with two daughters Margaret and Lynette, a son Gerard (deceased) and a granddaughter Christal. In 2017, she was awarded an Australia Awards Scholarship and thus gained her Masters in Educational Studies at Monash University in Melbourne Australia. She is currently engaged in Primary Teacher Training and has a passion to research further on how Science Technology, Engineering and Mathematics Education (STEM Education) impacts students learning at an early stage. She first presented her research on STEM Education at the Faculty of Education Symposium in Madang (DWU) in 2023 and her paper was approved for publication at the Divine Word University Journal.

Annette is a certified Secondary School Teacher and has 13 years of teaching experience at the secondary school level. She has been lecturing under the Education Strand and also tutoring Basic Computing to year one student teachers. Her teaching experience is accompanied by vast experiences in administrative duties like being the practicum coordinator for DWU OLSH Kabaleo Rabaul Campus. Apart from work experiences under the education faculty, she has also done voluntary office work with Red Cross in Buka. She also lectured/tutored early childhood student teachers at Target Training and Consultancy Services (now known as Dianna Ope Training Institute), which is a private learning institution managed by Dr. Dianna Ope in Bougainville. Currently she is part of the lecturers send by DWU to take part in the sponsored Partnerships for Improving Education (PIE) program that upgrades Elementary Teachers in Bougainville, to gain a Diploma in Teaching Primary.

At the Pacific Islands Universities Regional Network (PIURN) conference, Annette will present on the title; Science Technology Engineering and Mathematics (STEM) Education: Her paper is a report on how students at the primary school engage in STEM education lessons. It is a research report that investigates the strategies used in teaching STEM education lessons and the impacts it has on students. In her research, Annette focuses on STEM as a subject which drives actions that lifts foundational skills in STEM learning areas, and develops mathematical,

scientific, technological literacy, critical analysis and creative thinking for students involved. email: asinnou@dwu.ac.pg.

1. BACKGROUND

In Papua New Guinea, subjects like science, engineering and mathematics, are taught as separate subjects in schools. With the introduction of Science Technology Engineering Mathematics (STEM) Education as a subject on its own in countries like Australia, its significance in children's learning has motivated educationists to explore the impacts it has on students involved.

In Australia, according to the learning areas, STEM develops mathematical, scientific and technological literacy, and promotes the development of the 21st century skills of problem solving, critical analysis and creative thinking. This development goals are challenged by Thomas and Watters' (2015, as cited in Kelley & Knowles, 2016) findings which indicate that students' interest and motivation to STEM learning have declined especially in Western countries and more prosperous Asian nations. This has raised concerns on how effective current STEM education pedagogies are in fulfilling such set goals.

Understanding the mentioned goals and the research that questions the effectiveness of STEM education pedagogies has led to this case study through arts-based research. The following questions form the core of this research report:

- In what ways does STEM education have impacts on how students acquire knowledge?
- How do students use designed STEM pedagogies to engage in critical analysis and problem solving?
- In what ways does STEM Education help motivate students to learn or get engaged in the learning process?

To investigate on the mentioned questions, Stem Primary School was chosen as the research site. The research location is important because my daughters who are also participants, have recently joined schooling in Australia without any introduction to STEM education back in Papua New Guinea (PNG). As a researcher and a mother in this case study, I have seen great learning opportunities while observing how STEM education has had an impact on their learning. Also, it has helped those students in the same class who have been exposed to inquiry-based learning which is used in STEM education lessons in Australia. The use of Lego in STEM education, has increased their interest in attending lessons.

2. RATIONALE

As an educator, this small-scale case study is valued as a starting point to major researches that can be done later. The significance of this research is based on reasons that STEM education has not been introduced as yet in PNG's Education system. Upon completion of this arts-based research at Stem Primary School; it was anticipated that there would be more understanding on how STEM education can be approached in terms of knowledge acquisition and active engagement.

As assumed, 3/4GW and 5/6Q classes that were chosen to be participants formed a very significant combination as they were a mixture of students who have had some exposure and my daughters who have never heard of STEM education. In maintaining the agreement on privacy and not exposing the identity of students, the staff and the school, all photography, interviews and voice recordings done, has not been labelled or directly named. Apart from that, direct views of students' faces have been avoided in shots.

It is such researches by Tharayil, Borrego, Prince, Nguyen, Shekhar, Finelli, and Waters (2018), claiming active learning as promoting student learning and increasing retention rates of STEM undergraduates that has given purpose to investigate further on what actually happens in STEM education at the primary level of schooling years. It has been intriguing to investigate on how STEM education has had an impact in the participants, especially when considering their differing exposure to STEM education backgrounds. This is noted as important because different setting of learning does have an impact on how one might view the success of an implemented program.

As stated by Valsiner (2006, p.601, as cited in Vasilachis de Gialdino, 2009):

“The social representation system of society at some historical period may selectively guide the researcher to seek general knowledge, or through denying the possibility of general knowledge, let the researcher be satisfied by description of local knowledge”.

The benefits anticipated from this research, though small scale, can be highly regarded and appreciated if considered from the following perspective. Firstly, it will help STEM educators at Stem primary school revisit, add or adjust on methods if need be and acknowledge the hard work that they put into each STEM lesson daily. Secondly, that participants will consider the positive outcomes of the research as a praise and the opposite as a reminder to refocus on relevant teaching strategies. Finally, that the researcher gains an insight into a highly regarded program so as to be better equipped for future work or help to my country’s possible implementation of STEM education.

The aim in this creative approach is to investigate through arts-based research by being involved in STEM education at Stem primary school. Furthermore, to investigate on how effective students acquire knowledge and how STEM education pedagogies motivate their interest to engage in learning. The research aimed at incorporating Renold’s (2018) method of giving participants a chance to express themselves. It would have been unrealistic to simply analyse information already researched by others in different countries. As Law (2009) emphasises, ‘it is the job of inquiry to discover and describe the realities as best may be’. Thus, in the course of this research, the practical inquiry that was done during STEM lessons has made it possible to unpack the concept of STEM Education.

3. METHODOLOGICAL REVIEW

While Arts-Based Education Research (ABER) seems as old as its’ first introduction in 1975 by Eisner (1998, as cited in Pentassuglia, 2017), the amended terminology of the research approach to Arts-Based Research (ABR) by McNiff (2011, as cited in Pentassuglia, 2017), has given it its’ new acronym ABR as known today. In this case study, ABR is used because of reasons connected to the definition of ABR as a creative research approach. One of the arguments in favour of ABR that is fitting to the context of this case study is given by Greenwood (2012, as cited in Pentassuglia, 2017), that ‘practices based on the ABR approach respond to the need to both bring out and share understandings and phenomena that are difficult to read properly through traditional approach’.

With reference to his argument, this case study specifically relates to the approach of using ABR as a means of better understanding how STEM education has had an impact on students as young as those in grades 3, 4, 5 and 6 who have been the focus of this study. It is significant because researching about it the traditional way as in using others’ literature to unpack the concept of STEM education would have been very different from the findings that will be discussed in the latter paragraphs. This view on ABR as a qualitative approach, is reinforced by St. Pierre (2013a, as cited in Wolfe, 2017), who makes us notice that ‘what is affectively felt in fluxing relation by the researcher (and participants and virtual audience) makes the data, rather than simply what is deciphered through a hierarchical organisation that is static qualitative coding and thematic analyses based on words as “quasi-numbers”’.

As a creative approach, ABR enables the researcher to actively participate in data collection. It also gives the power to analyse findings and make personal critical review of the findings which would have only been reviewed through the lances of others, through the traditional approach. Such research methods give researchers a voice in contributing to help shape systems where need be. Others in support of this approach have noted that the arts-based method as an indirect form of communication has proven to be effective in changing stands of power holders and experts, enabling a dialogue that creates culturally sustainable aid (Huss, Kaufman, Avgar & Shouker, 2015). This statement supports the fact that ABR can give a person that power to make a difference through finding out or showing something from primary sources collected.

4. METHODOLOGY

Arts Based Research (ABR) has been used in conducting this case study. It is a creative approach because the focus was not on gathering already researched data, but on actually getting involved in the research with

participating students in order to source valuable information to enlighten the issue. This argument is further understood when viewed from Law's (2009) perspective of methods as techniques for describing reality and treating knowledge practices as more or less performative. By getting involved with the participants of grade 3/4GW and 5/6Q, better understanding of their stories about STEM education and especially how it affects their learning has surfaced. The idea of being an active participant in the research is valued more when considering Davies' (2018) argument that 'we don't obtain knowledge by standing outside the world; we know because we are of the world and that we are part of the world in its differential becoming'.

This research used photography, interview, and observation plus active participation by the researcher, to source information from the participating students and from the classes that attended in general. The research method preference is influenced by Taylor (2017) who claims that 'the anthropocentric assumptions of qualitative inquiry posit the role of the researcher as the one whose job is to capture and understand perspectives, usually via dialogue and try to give them voice'. Using photography is a method that was aimed to capture active and fun moments of the participants as they were 'caught in the act' especially when unaware of the researcher taking a picture. This was done without exposing the identity of the participants.

With reference to photography, interview, observation and active participation, there were processes followed before attending the two classes. I had to apply for a Working with Children Check (WWCC) as a volunteer in Australia. After successfully obtaining a WWC card, I was able to be part of the class as an active participant during their scheduled STEM lessons. All these happened after a negotiation over emails to and from the school's secretary and the principal.

The other process that was also done before actually taking photos, doing interviews and recording students was the sending of a consent form with an explanatory statement from the researcher. The school principal helped in distributing the consent forms which were signed by the parents. Though there may be other detailed findings on how STEM education has an impact on students learning and engagement, this research is basically done with the understanding that research done at different settings are not always the same and thus are unique in their own rights. This is supported by Law and Mol (2001, as cited in Law, 2009) that truths are not universal.

5. PARTICIPANTS / MATERIALS / PROCEDURES

After negotiations and confirmation, participants of 3/4GW and 5/6Q classes were confirmed to undertake research on STEM education. It should be noted that the total number of 3/4GW class is 24 students and 5/6Q class is 26 students, and that despite all being part of the lessons, only 12 3/4GW students and 9 5/6Q students were actively involved in interviews, photography, questionnaire and videos recorded for analysis purposes.

A detailed overview of participants that took part in the voice recorded interviews, the questionnaire, photography, video and the recordings that were done without the students and the teacher's knowledge, has formed part of the supporting documents to this research. A transcript from an interview between the researcher and 3/4GW girls also proved to be raw evidence to results that will be discussed in this research report. Moreover, only one teacher is specialised in teaching STEM education lessons at Stem primary school.

The collection of data through interviews, recording, shots and videos was done using an iPad tablet. Despite the challenge encountered in using appropriate devices, all data collected, is of standard.

Before the lessons were attended, a scheduled time was given by the secretary to attend STEM lessons for 3/4GW and 5/6Q. Since Lego lessons were newly implemented at the school, 40 to 80 minutes was devoted to doing STEM through Lego lessons at the STEM lab. I was able to see 5/6Q class on Mondays from 9:40am to 10:20am and the 3/4GW class on Wednesdays from 11:45am to 1:05pm. From observation, the 3/4GW had more time of 1 hour 20 minutes a week, while 5/6Q only had 40 minutes of STEM lessons in a week. Because of this, data collected from 3/4GW seems more detailed than data collected from 5/6Q.

The first visit to each class was for observations to familiarise myself with the students and the teacher's teaching style. Since only three weeks was scheduled for active participation in attending classes, interviews and recordings were commenced earlier than scheduled. Timing to gather detailed data was a challenge. Despite that, interviews were conducted for 5/6Q male and female participants during their first contact of Lego lesson. The 3/4GW class however were interviewed, recorded and taken photos of during their second contact Lego lesson.

Each interview was done in another room within the STEM lab, especially away from the other students

and their teacher. The focus of the interview was on investigating whether there was active learning taking place. This methodology leans towards an epistemological assumption concerned with how knowledge can be created, acquired and communicated (Cohen et al., 2007, p.7 as cited in Scotland, 2012). Also, recordings of students conversing with their teacher was taken while they were unaware. This was purposely done to capture the innocence of the teacher to/from student interaction, without the researcher interfering.

Due to the ethics surrounding the explanatory statement in the consent form, the names of the transcripts of the recorded lessons, interview with their teacher and other students, have been purposely faked. It will however be used as an input to clarifying certain aspects in the findings and discussion sections. Furthermore, the shots were taken at an angle that would not directly expose the identity of the student. Nutbrown (2011 as cited in Allen, 2015) correctly argues that as a researcher, photography in art-based education research is used to help with interpreting what has happened during the research event, focusing on children’s learning experiences.

Procedures were followed to collect data during and after Lego lessons, and time was arranged with the teacher, for participating students to complete the questionnaire in a sitting. All anticipated activities and data collection were completed as planned by the third week of observation.

6. RESULTS AND DISCUSSION

STEM education through Lego lessons has impacted how students acquire knowledge and how it motivates them to learn. With reference to the questionnaire, the table (*Table 1*) reveals the results in percentage. The results analysed in the table indicate the following logical conclusions; that in 3/4GW class, the majority of the students indicated that they are always excited to go for all STEM lessons, in contrast to the 5/6Q students who preferred to go only sometimes.

Firstly, their reasons for attending STEM in question 6, shows that the majority of 3/4GW students attend because practical activities done, help them better understand how things work. The 5/6Q students had a balanced response of going to class for practical work, for fun with friends and for the love of learning outside of the usual classroom setting.

Table 1. Results of questionnaire responses in percentage

Questions/Purpose of Question	Class	Explanation in Percentage	Combination of two classes result
Q1. Identifying students’ motivation level during a Lego lesson	3/4GW	50% voted yes 30% sometimes 20% most times 0% not at all	34% voted yes 45% put sometimes 20% said most times 0% voted not at all
	5/6Q	10% voted yes 60% sometimes 30% most times 0% not at all	

Secondly the following photographs shown below (Photo 1, Photo 2, Photo 3, and Photo 4), portray teamwork by the students in solving problems together. It also shows students testing their completed boats, and being assisted by the teacher or other students, when they need help.



Photo 1: A team of 3/4GW girls working together to build a sailing boat. *Photo by Annette*



Photo 2: A 5/6Q Student discussing instruction paper with the other student
Photo by Annette



Photo 3: Year 3/4GW students testing their completed sailing boat. *Photo by Annette*



Photo 4: Teacher assisting a 5/6Q student with instructions. *Photo by Annette*

Moreover, the interview conducted with the 3/4GW girls, shows the team work that exists in working together to resolve problems that arise during the course of the Lego lesson. Despite the results showing students not remembering words introduced in class, it is evident through their participation and interest, that they do learn better when placed in a practical setting. Such results would not have been possible without the ABR approach which regards truth as not universal and in which methods only work to make reality in particular places (Law. 2009).

Finally, but not the least, results from the interviews done shows a trend that locals (Australians) were more interested in the practical STEM lessons while my two daughters favoured learning the traditional way. Both

can be understood from the perspective that they have not been exposed earlier in inquiry-based learning, which is mostly used and encouraged in Lego lessons.

Interview with participating students (2nd May 2018)

Anne (researcher): *Okay, Hi girls.*

All: *Hi*

Anne: *So what did you learn from today's STEM lesson?*

Hidi: *Um...*

Sow: *That I thought because my boat would sink but since we've even up the back part of the boat, it actually was even.*

Jess: *Um...I learned that um...um...if you put more weight on the back, it wouldn't nose dive. It would stay upright like, so instead of having heaps of weight at the front, and sink nose diving. It would actually keep it flat, so that's what I learned.*

Tilda: *I learned today was um...when you put um...a couple more tires on, you balance it out. At the end I was gonna put a tire at the front, another tire at the front, another tire at the back and then four then two at the back as well and then two at the front like...but I didn't get to test that out. But I learned that um... the more tires you have, the more float it is.*

Anne: *Thank you.*

Oliv: *Um...I learned that um...that if you put wheels on it, it will float more than if you don't have them.*

Anne: *Okay and...*

Hidi: *Yeh I also learned that the wheels made it float more than if you didn't have them.*

Anne: *Lyn...*

(Background noise from other students)

Lyn: *Um...I learned that.... if you...if you put um...if you put like a lot of like Lego on it won't really float. Yeh...*

Anne: *Okay, did you come across any problems while building the boat?*

All: *Yeh.*

Jess: *Ah...I didn't really...All of us...is...when we put all that SpongeBob, people and family, it would, it would like break but like if we'd made it more like steadier, it would, it would work.*

Anne: *ah...ah...*

Scow: *Um... I didn't have no problems.*

Jess: *But we had a problem with nose diving.*

Tilda: *Yeh we had problem.*

Hidi: *Cos the um...the points of the weight won't spread around evenly which means it would sink at one point.*

Anne: *How did you solve the problem when you..... you know faced a problem.*

Hidi: *We um...added..... so we had like two tires at the back and one tire at the front, we added to make two tires at the front..... spread the wait evenly.*

Anne: *Was it easy for you to follow the instructions?*

All: *Yesss/Nooo*

Hidi: *The placing of the blocks, trying to count which holes they were going in... and...that was tricky cos you can't see properly.*

Jess: *When we tryna make the bench part where the sail sticks out..Maco did that part..but like he like..it was done wrong so we had to redo it..cos um he was copying the picture and the picture wasn't really that clear..*

Hidi: *...it was really hard.. Jess: ..but um...*

Anne: *But you managed to solve the problem... Jess:...ye ye..*

Anne: *Did you all finish your boat?*

All: *Yeh...haha..that's yes yes yes yes yes yes ...haha*

Anne: *Okay, so what often inspires you or makes you feel excited about STEM lessons?*

Jess: *Umm..this is a tough one...*

Hidi: *...I know...I like modifying the things Jess: Yeh yeh.. modifying*

Hidi: *I don't know but cos we did a race car and you could race them*

Oliv: *What excites me to do is that...I get to learn all these new things that I haven't learned before.*

Jess: *I like that because..we have a big bag of Lego at home that like ...there's instructions, but we don't know where the pictures are...and like now at STEM we have Lego and then actually see the actual pieces that we...*

Hidi: *...know where they are...*

Jess: *...yeh..cos at home we just have different Lego pieces in one place*

All: *haha*

Anne: *Um you also have Maths lessons, right?*

All: *Yeh*

Anne: *In the classrooms?*

All: *Yeh*

Anne: *Um so would you say you love maths lessons more or STEM lessons?*

All: *Yeh/Ummm/Maths/Both (all shouting at the same time) Jess: Depends...times tables and divisions...haha*

Scow: *Nope ...nobody likes times tables...if it's times tables and divisions, no All: haha*

Anne: *Okay um..what would you tell your other friends about STEM lessons...if you were to say something about STEM?*

Tilda: *Um..that it's quite exciting and enjoying because you get to make stuff and you get to test them out with mottos*

Hidi: *I would probably say that um it's fun and you get to um..not many schools get experience this so um ..I mean it's a great experience.*

Jess: *Um it's a great experience because like...you might not have Lego at home so you might think... "oh Lego might be fun...I might enjoy this" because you don't have a lot of fun at home so you don't know if it's gonna be fun or not so..but yeh..I really like Lego so..*

Anne: *Okay thank you and you go back to your class*

All: *Thank you, bye...*

7. PERSONAL REFLECTION

To sum up, below are my personal views on creative/qualitative research. Identified are the phases approached in this creative research and the critical reflections on decisions in each phase of the research. ABR is a methodological approach that I saw fit in conducting this research on STEM education. Personally, I think using a creative research approach to conduct this case study was significance because it allowed for direct involvement in sourcing information and it was more creative and qualitative. As Tracy (2013) states, qualitative research is about immersing oneself in a scene and trying to make sense of it.

Apart from direct involvement, ABR has further enhanced my research and analytical skills as I used my own perspectives to create specific research questions that were aimed at trying to further understand the participants in relation to my topic. Creative researches in its true sense, has given a researcher like me, an opportunity to create something out from nothing. This is because, when drafting questions to investigate more on inspiring topics, it gave me an opportunity to grow and mature as a researcher and to understand the culture in which STEM education is taught. As Tracy (2013) claims, apart from qualitative research being an excellent approach to studying contexts that interest you, it provides insight into cultural activities that might otherwise be missed in a structured survey or experiment.

In identifying the different phases to this case study, I mostly reflected on education-based issues that are challenging to implement back in PNG. It is because of this, that I chose STEM education as my research topic.

The second phase of this case study mostly involved formalities. I had to make contacts and wait for responses before I proceeded with the actual research. This however, was not really challenging because parents, the principal, secretary and others involved were prompt in responding.

The third phase involved the actual conducting of the research. I saw this phase as very important as it helped me uncover unknown knowledge, analyse them, and thus turn it into research findings. This can be better understood when referring to Tracy's (2013) concept of 'thick description' that explains such research as a period of investigating circumstances present in that scene, and moving forward towards grander statements and theories.

I learned a lot from this phase of the research since it opened my mind to understand the difference between ‘traditional’ approaches to teaching as compared to creative approaches to teaching.

The final phase of this research, has been both intriguing and challenging. The different data collection techniques that are used, called for more analysis from a specific approach. This was a challenge because of the time frame to complete the research.

It is interesting to note that even though there is an emphasis on problem solving as a core of any STEM lesson in Stem primary school, there is still a need to research further on how students can be made to understand concepts. Especially understanding concepts that seem so difficult for them to understand at such an early age and in the context of a STEM Education methodological approach.

8. CONCLUSION / LIMITATIONS

In conclusion, everything explained, reasoned, argued and stated about creative research that was conducted, succeeded with each phase and was completed accordingly as scheduled. Despite the anticipated challenges in the course of the research, every stage of the research was finally accomplished. The principal and the secretary were very helpful and prompt in responding to emails and specially making sure those classes were held on time as scheduled.

The limitations of this research arise within the context of timing and the number of participants involved. Due to a short period of time in conducting the research and the limited number of participants, results shown may not truly portray the true essence of the impacts of STEM Education on students. Because of this, there are still greater gaps to fill, especially in understanding how STEM education can effectively help students in acquiring knowledge while at the same time being motivated in a STEM learning environment.

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REFERENCES

- Allen, L. Losing face? Photo – anonymisation and visual research integrity. *Visual Studies*, 30(3), 295-308. doi: 10.1080/1472586X.2015.1016741, (2015).
- Davies, B. Ethics and the new materialism: a brief genealogy of the ‘post’ philosophies in the social sciences. *Discourse: Studies in the cultural politics of education*, 39(1), 113-127. doi: 10.1080/0159630G.2016.1234682, (2018).
- Education Council. *National STEM School Education Strategy: A comprehensive plan for Science, Technology, Engineering and Mathematics Education in Australia*, Retrieved from www.educationcouncil.edu.au/site/Default/filesystem./documents/NationalSTEMEducationStrategy.pdf, (2015).
- Huss, E., Kaufman, R., Avgar, A., & Shouker, E. Using art-based research to help visualize community intervention

- in international aid. *International Social Work*, 58(5), #. doi: 10.1177/0020872815592686, (2015).
- Kelley, T. R., & Knowles, J. G. A Conceptual framework for Integrated STEM education, *International Journal of STEM Education*, 3(11), 1-11. doi: 10.1186/s40594-016-0046-z, (2016).
- Law, J. Seeing like a survey. *Cultural Sociology*, 3(2), 239-256, (2009).
- Pentassuglia, M. “The Art(ist) is present”: Arts-based research perspective in educational research. *Cogent Education*, #, 1-12. doi: <http://dx.doi.org/10.1080/2331186X.2017.1301011>, (2017).
- Renold, E. Feel what I feel: Making da(r)ta with teen girls for creative activism on how sexual violence matters, *Journal of Gender Studies*, 27(1), 37-55, (2018).
- Scotland, J. Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms, *English Language Teaching*, 5(9), 1-8. doi: 10.5539/elt.v5n9p9, (2012).
- Taylor, C. A. Rethinking the empirical in higher education: Post-qualitative inquiry as a less comfortable social science. *International Journal of Research & Method in Education*, 40(3), 311-324, (2017).
- Tharayil, S., Borrego, M., Prince, M., Nguyen, K.A., Shekhar, P., Finelli, C.J., and Waters, C. Strategies to mitigate student resistance to active learning, *International Journal of STEM Education*, 5(7), 1-16. doi: 10.1186/s40594-018-0102-y, (2018).
- Tracy, S. J. Qualitative research methods: Collecting evidence, crafting analysis, communicating impacts. *Qualitative Research Methods*, (1sted.). Retrieved from <https://books.google.com.au/books?hl=en&lr=&id=KAzBiMCS6uwC&oi=fnd&pg=PT14&q=Arts+based+research+advantages.scholarly+article&ots=IdDXLDPVYy&sig=xuftiqNqKk9M99u68p3CtFPy650#v=onepage&q&f=false>, (2013).
- Vasilachis de Gialdino, I. Ontological and epistemological foundations of qualitative research. *Forum: Qualitative Social Research*, 10(2), Retrieved from <http://www.qualitative-research.net/index.php/fqs/article/view/1299/3163>, (2009).
- Wolfe, M.J. Post-qualitative filmic research in education: Utilizing a “re/active documentary” methodology. *Qualitative Inquiry*, 23(6), 427-437. doi:10.1177/1077800416673660, (2017).