

The Flipped Chemistry Classroom: A Case Study with Year 9 Students

Graziella Schembri

graziella.schembri.09@um.edu.mt

Abstract

This case study was conducted amongst fifteen Year 9 Chemistry students attending a co-ed state senior school in Malta. It set out to explore how the chemistry topic 'Nature of Matter, Atomic Structure and Chemical Bonding', which tends to be challenging for students due to the abstract concepts involved, can be taught using the flipped learning technique. Students' views regarding this approach were also sought. Special attention was given to their engagement, motivation and learning.

Data were collected through various sources including teacher observations, students' reflective diaries and a focus group. Findings indicate that although the students were mostly teacher dependent, they liked the new technique. This was mostly due to the fact that this approach helped them feel more prepared when attending a lesson, they were able to learn at their own pace and the technological aspect of it made it more enjoyable. The flipped learning technique was found to be advantageous since it frees up classroom time from the passing on of factual information such that more student-centred activities and student-teacher interaction could take place.

Keywords: flipped learning; active learning; self-directed learning, class time

Introduction

"Rapid changes in the world – including technological advancement, scientific innovation, increased globalisation, shifting workforce demands, and pressures of economic competitiveness – are redefining the broad skill sets that students need to be adequately prepared to participate in and contribute to today's society" (National Science Teacher Association, 2011, p.1). These skills,

also known as 21st century skills, comprise four main areas, that is, “digital age literacy, inventive thinking, effective communication and high productivity” (Turiman, Omar, Daud & Osman, 2012, p.110). Scientific literacy, one of the aims of science education, contributes to the development of 21st century skills as it includes basic skills such as making predictions, observing, taking measurements, interpreting results as well as presenting and communicating data, amongst others. With so many contemporary local and international issues that are related to science, being able to understand and make use of scientific concepts is surely crucial.

In order to equip students with higher order thinking skills, teachers need to dedicate a lot of classroom time in direct contact with their students. However, many teachers feel that they do not have such a privilege and thus end up solely focusing on the content, making sure that they cover everything by the end of the scholastic year (Bonello, 2016). In 2012, two American chemistry teachers, Jon Bergmann and Aaron Sams, developed a new pedagogy called the Flipped Learning technique. The technique helped them make better use of classroom time, enabling them to not just teach the concepts found in their curriculum but to also allocate time to help students develop their critical-thinking skills.

What is Flipped learning?

Many think that flipped learning is simply a method where the tasks that are usually done at home are interchanged with those that are typically done at school. However, this learning technique requires much more than that in order to be implemented successfully.

Flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter (Flipped Learning Network, 2014, p. 1).

In fact, simply assigning videos or tasks to the students to do at home does not lead to an effective flipped learning environment. For students to truly engage in flipped learning, teachers must create learning spaces based on the four F-L-I-P pillars established by Hamdan, McKnight, McKnight and Arfstrom (2013).

1) F - Flexible Environments.

Firstly, students within a flipped classroom must be given the opportunity to learn new material where and when they like, as long as they are well-prepared for the next lesson. In order to do this, teachers are required to prepare a video showcasing an explanation of a particular concept. Teachers may either videotape themselves giving a lecture, use ready-made videos such as those found on YouTube, or else make their own videos by using screen-capture software and including voice-over instructions (Roehl, Reddy & Shannon, 2013).

2) L - Learning Culture

Some critics “believe that flipping is simply a high-tech version of an antiquated instructional method: the lecture” (Ash, 2012, p. 6) and they therefore do not think of it as a student-centred pedagogy. However, flipped learning is not simply a way to teach students a particular concept. On the contrary, it is about how class-time can be used more efficiently. Instead of spending most of the time listening to a teacher’s explanations, students will have more class-time interaction, engaging in a variety of activities that will help them develop higher-order thinking skills (Sams & Bergmann, 2013). This means that, in contrast to a traditional classroom, students within a flipped classroom are assigned tasks which will help them reach the less- demanding objectives such as remembering, understanding and applying, whilst they are on their own at home. Teachers would then be able to use the freed-up class time to organise tasks and hands-on activities which would help their students reach the more challenging objectives, such as analysing, evaluating and creating, under their support and guidance (Lopes & Soares, 2018).

3) I - Intentional Content

With more class time available for direct contact with their students, teachers would then be able to move away from a ‘one-size fits all’ approach and instead make use of differentiated teaching. Since different students have different needs and learn in different ways, making use of a variety of pedagogies such as inquiry-based learning, experimental tasks and group work ensures that all the students are given the opportunity to understand, learn and finally reach their potential (Sams & Bergmann, 2013).

4) P - Professional Educator

In a flipped classroom the roles of the teacher and the students are switched. In contrast to practices obtaining in traditional classrooms, the teacher in the flipped classroom takes the role of a cognitive coach, deducing what the students need in order to do well, choosing the appropriate pedagogies that will help the students reach the set goal and preparing tasks and activities that will help scaffold the students' learning. In addition, they offer their support and guidance to students whenever they meet an obstacle, prepare formative assessment tasks and give students constructive feedback (Berrett, 2012).

It would be extremely useful if chemistry teachers had to take up this role as it would allow them to combat the challenges that they are faced with. However, due to the lack of time there is hardly ever the opportunity. Can the flipped learning approach help in this aspect?

Research Questions

During this study, the flipped learning technique was used with fifteen Year 9 chemistry students whilst dealing with the topic called 'Nature of Matter, Atomic Structure and Chemical Bonding'. This topic contains many factual concepts which are very crucial for students to grasp since they are the stepping stones of other theories (Taber & Coll, 2003). Unfortunately, numerous studies have reported that students find the topic challenging (Talanquer, 2011). In addition, being so factual, teachers tend to spend a lot of classroom time explaining the concepts involved (Borg, 2013) with little room available for the teacher to help students overcome challenges involved when learning the topic. These challenges arise due to the nature of the subject operating simultaneously at the macro, sub-micro and representational levels (Johnstone, 2000), the language involved (Boddey & De-Berg, 2015) and possible misconceptions (Salierno, Edelson & Sherin, 2005).

Hence, the research questions in this study were:

- i) How can the flipped learning technique be used in order to teach the topic 'Nature of Matter, Atomic Structure and Chemical Bonding'?
- ii) What are the students' views on the flipped learning approach with regard to their engagement, motivation and learning?

Methodology

This case study was carried out with 15, Year 9 students who attended a co-ed secondary senior state school in Malta. The students within this group had different levels of achievement and motivation. A qualitative approach was taken, since the focus of this study was on the narration and hence explanation of how the flipped learning technique was being experienced by a particular group of students rather than on the gathering of statistical data coming from a bigger population (Erickson, 2012). Being a case study, it allowed me

to view the world with the eyes of the examinees, to describe and take into account the context, to emphasize the process and not only the final results, to be flexible and develop the concepts and theories as outcomes of the research process (Devetak, Glažar & Vogrinc, 2010, p. 78).

During this study, various teaching and learning tools and research methods and tools were used. These include:

- i) *Lesson plans and resources* – Firstly, the learning outcomes of the topic ‘Nature of Matter, Atomic Structure and Chemical Bonding’ were identified. They included outcomes related to themes such as diffusion, Brownian motion, atomic structure, isotopes, ionic and covalent bonding as well as writing chemical formulae. A homework pack was then created, which consisted of activities through which students could gain factual information and hence prepare for the following classroom lesson. Whilst in class, students carried out other tasks which helped them reach the remaining learning outcomes that required more guidance and support. These tasks were spread over twelve double lessons, each of which was one hour twenty minutes long.
- ii) *Observations* – During this study I was a participant observer. This is because whilst in class I was both the researcher and the teacher and the students participating in this study knew that I was observing them for research purposes. All the observations made were jotted down in a journal, after each lesson.

- iii) *Students' Reflective Journals* – During the last ten minutes of every lesson, students were allowed to reflect on the lesson and write their thoughts in a journal.
- iv) *Focus Group* – When all the lessons regarding the topic 'Nature of Matter, Atomic Structure and Chemical Bonding' came to an end, an audio recorded focus group was carried out with the participating students.

Being a case study, the results obtained cannot be generalised. However, the study is highly relatable. Moreover, triangulation of data served to improve the study's validity and reliability, by using "more than one approach to the investigation of a research question in order to enhance confidence in the ensuing findings" (Bryman, 2004, p. 1). This is because, "exclusive reliance on one method... may bias or distort the researcher's picture of the particular slice of reality she is investigating. She needs to be confident that the data generated are not simply artefacts of one specific method of collection" (Cohen, Manion and Morrison, 2000, p. 112).

During this study, I had a dual role, that of a teacher and at the same time that of a researcher. This placed me in a difficult position due to the "tension between trying to be systematic and thorough [as a researcher] and [at the same time] trying to be responsive and compassionate [as a teacher]" (Hoong, Chick and Mass, 2007, p. 5). In order to address this conflict, and to pursue ethical correctness, I focused mainly on my teaching role whilst I was in the classroom, guiding students so that they would be able to reach the intended learning outcomes. Then, once outside the classroom, I reflected on and evaluated my pedagogies as well as the students' attitudes keeping the study's aims in mind. Furthermore, although the flipped learning technique was used with all students in my class, the students were free not to participate in the study or to opt out whenever they liked. Ethical issues involved were carefully considered before the implementation of this study. The procedures followed included obtaining ethical clearance, permissions from gatekeepers and informed consent from parents/guardians and assent from students.

Once all the data were gathered, they were then analysed using the inductive/grounded theory approach. This "involves analysing data with little or no predetermined theory, or structure or framework and uses the actual data itself to derive the structure of analysis" (Burnard, Gill, Stewart, Treasure & Chadwick, 2008, p. 429).

Data Analysis and Discussion of Findings

A. Pre-Class Preparation

The tasks students were assigned to do at home, in preparation for the following lesson, were found to have an impact on the cognitive load for students and their level of motivation.

The cognitive load

All the participating students stated that they liked being given a task to do at home prior to the lesson carried out at school. One of the main reasons was that “It will give me a heads up and I’ll get the feel about what the subject is” (Student L, Focus group). In fact, all of the participating students showed interest in their studies and wanted to feel mentally prepared for the classroom lesson believing that doing so will increase their level of understanding.

The topic ‘Nature of Matter, Atomic Structure and Chemical Bonding’ is quite a factual topic and it contains numerous abstract concepts and scientific terminology. Students often feel overwhelmed by all the new material covered in just one lesson. Such a lesson would for example be the one regarding the structure of the atom. However, when the same exact lesson was carried out using the flipped learning technique, students were observed to be more confident in explaining the concepts involved.

This finding is in line with the information processing theory which warns of possible cognitive overload when learners are bombarded with large amounts of information at once. Since the concerned topic addresses all the three levels of chemistry, that is the macro, sub-micro and representational levels (Johnstone, 2000) it has a high intrinsic cognitive load. Sweller, Van Merriënboer and Paas (1998) suggest that in order to combat this, one has to “reduce total cognitive load to manageable proportions” (p. 265). This was achieved through the use of the flipped learning technique as follows:

- i) Students’ worksheets included lesson objectives that helped them focus on what they were expected to learn. In addition, the text was kept at a minimum, key words were written in bold, and complementary pictures were included.

- ii) The videos assigned for the students to watch at home contained cues such as key-words, images or animations that helped to make important ideas memorable. In fact, one student wrote “We didn’t have a lot and the videos requested for us to watch are fun and informative” (Student L, Reflective journal).
- iii) Students were allowed to learn at their own pace. Ten of the participating students stated that they used to pause the video every so often whilst eight students said that they used to watch the video multiple times “so that I will know what he’s saying exactly” (Student E, Focus group).

Motivation

Motivation is “the process of instigating and sustaining goal-directed behaviour” (Schunk, 2012, p. 346). Feather’s (1992) expectancy-value model is going to be used in order to discuss students’ motivation to complete the assigned tasks at home. As the name itself implies, according to this theory, whether a student carries out the designated work or not depends on two factors. These are:

- i) **Value** – that is, the amount of importance students give to the assigned piece of work; and
- ii) **Expectancy** – that is, the abilities and skills students believe they possess in order to perform the assigned task.

According to this theory, a student will only accomplish a given task if s/he values the task itself or its outcomes and expects him/herself to be successful when completing it. If one of these factors is missing, students will refuse to carry out the given task (Goodyear, Jones, Asensio, Hodgson & Steepies, 2004).

i) Value – Why did the students get involved?

The two main factors that stimulated the students’ motivation and helped them value the flipped learning technique were:

- Novelty – Students looked at the flipped learning technique as an innovative type of homework stating that “I enjoyed them because they are different from the rest of the hw” (Student O, Reflective journal). Novel tasks tend to attract students’ attention, help them remain

engaged for a longer period of time, boost their memories and sustain their creativity (Lisman & Grace, 2005).

- Technology – Comments such as “I don’t like hw much but the power points and videos are entertaining and fun” (Student L, Reflective journal) clearly show that technology plays an important part in stimulating the students’ motivation. Educational videos tend to be captivating since they grasp students’ attention, generate sensory curiosity and arouse cognitive inquisitiveness (Ciampa, 2014). They also help make abstract concepts more visual, reducing the chances of having misconceptions that are usually derived from images within books.

ii) Expectancy – What were the Students’ Beliefs Regarding their Success?

A factor which determined whether students completed a given task whilst they were at home was their belief about how well they were going to do in the assigned piece of work. In turn, this was affected by the students’ beliefs regarding their abilities as well as their perceptions regarding the level of difficulty of the task at hand.

During this study, students were observed to have different levels of self-efficacy. Students with a high self-efficacy were very persistent and did not give up immediately whenever they encountered a difficulty. One such student claimed that “the homework was a bit challenging but I managed to do them” (Student M, Reflective journal). This contrasts with the comment made by Student L who stated that

I used to try to do the tasks and watch the video but then if I don’t understand something I didn’t use to search a lot on my own because I could have got confused... for example mixing the valency number with the number of atoms used... I would have got confused (Student L, Focus group).

Moreover, there seemed to be a link between the students’ level of self-efficacy, the level of difficulty of the given task as well as the rate of completion of the assigned piece of work. This is because when the students felt the given task was at the same level of their abilities, they stated that it was easy and hence completed it. However, when they felt that the task was too challenging they did not even attempt it. For example, one of the students wrote “No [I didn’t

do them] but I think they were difficult” (Student D, Reflective journal). This clearly shows that her perception of task difficulty combined with her low self-efficacy impacted her decision of not completing the assigned task.

These findings are in line with Bandura’s hypothesis which states that “expectations of personal efficacy determine whether coping behaviour will be initiated, how much effort will be expended, and how long it will be sustained in the face of obstacles and aversive experiences” (Bandura, 1977, p. 191). One’s self-efficacy is built along the years and depends on various factors such as the amount of praise received after completing a task, the amount of successes or failures one experiences and comments received (Schunk 1991).

B. Class Time

Identifying Students’ Prior Knowledge and Misconceptions

For most of the lessons, I used to start off by asking the students several questions in order to prompt them to explain what they had learned at home. Most of the students liked the way the lessons were introduced stating that “in the beginning of the lesson you used to ask us questions about what we did and learned. I find that very useful because I tend to remember things more that way” (Student F, Focus group). Through this exercise, I was able to determine the students’ prior knowledge, gauge their level of understanding, and identify any difficulties or misconceptions that they might have.

While the topic ‘Nature of Matter, Atomic Structure and Chemical Bonding’ involves many new concepts, the students possessed schemata that helped them handle the new information through a procedure referred to by Piaget (1954) as assimilation. For example, since students already knew that matter is made of particles, when they watched a video regarding the structure of a particle they could simply add the newly acquired information to what they already knew. However, there were times when students possessed incorrect schemata which interfered with the assimilation process and hence led to the rise of misconceptions. One such instance was when a student who regarded osmosis as being the movement of particles in water, concluded that when a drop of food colouring is placed in water, osmosis occurs.

It is very crucial that teachers tap into the students’ prior knowledge before introducing new concepts. This is because “the acquisition of new content can be thwarted if it conflicts with students’ pre-existing misinformation”

(Campbell & Campbell, 2008, p. 7). In addition, students may resort to rote-learning and cease to apply what they learned when they are faced with a different situation.

Building a Culture of Inquiry

The participating students have passed through an educational system where they have been “schooled to become masters at answering questions and to remain novices at asking them” (Dillon, 1988, p. 115). Fortunately, the flipped learning technique allowed me to free up some class time and probe at their inner sense of inquiry.

First of all, I wanted to show students that inquiry lies at the heart of all scientific discoveries and it is thanks to the inquisitive nature of our ancestors that many scientific theories are nowadays well formulated. Therefore, I introduced the topic by giving the students an insight into the history of the atomic theory. In addition, certain classroom tasks were designed in a way that allow students to raise questions. For example, when presented with the experiment regarding the diffusion of ammonia and hydrogen chloride, where students had to predict where the two gases would meet inside a glass tube, they were able to formulate an answer after identifying a gap in their knowledge (that is the density of the gases involved) and hence asking about it. In other instances, students were instigated to ask questions. For example, when asked to look at the periodic table and state the mass number of chlorine, one of the students quickly asked whether it was possible that an element has half a neutron.

So why do students find it so difficult to ask questions? Suzić (2017), suggests that this can be due to several factors including the fact that subjects have an overloaded curriculum which needs to be tackled in a short period of time, and the fact that good grades are usually given to students who are able to memorize facts rather than to those that question them. However, due to the rapid advancements in technology, today’s successful individuals are those who possess skills such as critical thinking, flexibility, problem solving and innovation (Saavedra & Opfer, 2012). During this study, thanks to the flipped learning technique, I was able to free some classroom time in order to help students develop some of these skills.

Encouraging Peer Tutoring

During this study, the freed up class time gained through the use of the flipped learning technique was used to organise student-centred activities such as collaborative learning. In fact, pair work and group work was highly encouraged during the lesson since research shows that this “results in higher achievement, greater retention, more positive feelings by the students about each other and the subject matter, and stronger academic self-esteem” (Johnson & Johnson, 2008, p. 29). Since most of the given tasks involved answering questions with a definite answer (due to the nature of the topic being tackled), students interacted more in the context of peer-tutoring than in solving inquiry-based problems.

Twelve students stated that they enjoyed the group work tasks due to the fact that “sometimes there are things that you know well for example, but the others do not and they may know things that you don’t” (Student E, Focus group). Peer-tutoring is advantageous for all parties involved. Peer tutors benefit since “the best way to really develop one’s understanding of an area is to teach it to some-one else” (Beasley, 1997, p. 21) whilst tutees are able to gain a simplified version of the explanation given by the teacher. Moreover, peer tutoring helped to “transform students from being passive, ‘teacher’ dependent, uncritical recipients and reproducers of information into engaged, questioning, reflective and autonomous learners” (Gardiner, 1996 as cited in Beasley, 1997, p. 21).

However, not all students enjoyed peer tutoring and in fact one particular student stated “I prefer to work out ionic bonding, covalent bonding and similar things on my own.... It’s because they involve a lot of writing and practice and you have to be careful that you don’t forget anything such as a dot or a cross. So I prefer to work alone. I tend to concentrate more and be able to check whether I completed everything” (Student L, Focus group). There is a possible explanation for this comment. This student was a high-achieving student who may have been paired with a less-achieving student. Being high-achieving, she may have taken the role of a tutor and hence she felt that she was not gaining anything out of peer-tutoring. She may have felt that her classmate was more of a burden, keeping her back from completing her work in a shorter amount of time (Robinson, 1990). Getting to know one’s students is of the essence. So is differentiation based on what works best for each student.

Supporting Students

While peer-tutoring was encouraged throughout all the lessons, sometimes students still sought my support. Therefore, I dedicated some of the freed-up class time gained through the use of the flipped learning technique to guide the students as necessary. Students needed:

- i) help in organising their lines of thought, stating “at first I was a bit confused but then my teacher came and explained them to me” (Student N, Reflective journal);
- ii) to be reminded of the concepts they learnt since they kept “forgetting the rules” (Student G, Reflective journal);
- iii) someone to pinpoint certain mistakes that they were unknowingly making;
- iv) to be prompted to reach the set objective; and
- v) reassurance that they were on the right track.

In contrast to what usually happens in a traditional classroom, instead of spending most of the classroom time explaining concepts, I was able to go around the class, observe students as they worked, determining what kind of support they needed and helping them reach their goals. I spent my time with the students who needed me the most, thereby promoting educational equity.

Assessing Students and giving them Feedback

The flipped learning technique allowed me to allocate some of my class time to assess students on a more regular basis as well as provide them with better feedback. In order to do this, I prepared a number of tasks including written exercises which consisted of graded questions, verbal questions, power point games, quizzes and group work activities. A variety of assessment tasks were chosen so that I would be able to evaluate a number of skills. During these tasks, feedback was most often given orally and I used to congratulate the students on those areas in which they were doing well as well as pinpoint those areas where students needed to exert more effort, practice and study. Students liked the fact that they were given these formative assessment tasks since “if we had any mistakes or difficulties you could have told us at school and then we’ll be careful and get used to them at home” (Student L, Focus group). In addition, since “we had to revise our work” (Student A, Reflective journal), students were able to reflect on their performance. This helped some students

realise that “I should study more so I could understand more” (Student N, Reflective journal).

The formative assessments used were a means to “shape and improve the student’s competence” (Sadler, 1989, p. 120). In fact, whenever the students were working on one of these tasks, I always used to go round, observe them work and hence identify “the gap” (Ramaprasad, 1983, p. 4) between the students’ present performance and the desired one. This always led to a dialogue between the students and myself where goals were clarified and ways of how their work can be improved were discussed.

Are students ready to take responsibility for their own work?

Taking responsibility for one’s own work means being self-driven, being able to determine what one’s own strengths and weaknesses are, being able to identify the best strategy that will lead one to make progress, being able to keep track of one’s advancements and being able to learn how to learn. According to Grow (1991), students can be in one of four stages in their journey towards self-directed learning:

- i) Dependent - Students depend on their teacher to be given information, drilling exercises and immediate feedback in order to learn.
- ii) Interested - Students view the teacher as a guide who sets the goals and hence chooses the pedagogies that are the most adequate for them to use.
- iii) Involved - Students view the teacher as the person who facilitates learning by organising activities in which they can actively participate and hence learn.
- iv) Self-directed - Students take ownership of their own learning and hence they are able to set their own targets and choose their own learning strategies. They view the teacher as the person whom they can consult in case they encounter any difficulties.

From the observations carried out during this study, it can be said that the participating students are in Stage two of Grow’s model. This is because although they are motivated to learn, they do not have the internal drive and willingness to learn on their own. They are still teacher-dependent. For example, they rely on the teacher to give them the “ideal” answers, they do not inquire what was done during the lesson when they were absent, they copy directly from the videos’ subtitles in order to answer questions instead of

giving an explanation using their own words and they only study and complete their work if they are constantly prompted to do so.

Conclusion

This study revealed that if the acquisition of factual knowledge is shifted such that students gain it whilst they are at home, class-time is freed so that there is more time for student-teacher interaction for activities which can help develop higher-order thinking skills and for formative assessment and feedback, thereby making students feel more at ease whilst studying chemistry.

For the flipped learning technique to be implemented successfully, a shift in the responsibility of learning, from the teacher to the students, is required. Although challenging, it is “when learning is in the hands of the students and not in the hands of the teacher, [that] real learning occurs” (Bergmann & Sams, 2012, p. 111). For such a major leap to happen, teachers need to help students “understand that what they need to learn and what they do to learn are different” (Ford, Knight & McDonald-Littleton, 2001, p. 61).

Students need to start reflecting on themselves as learners so that they will be able to identify their strengths and weaknesses, determine which strategies are the most effective to reach the required goal and establish ways of monitoring their progress. Such a mind-set can only be adopted by students if teachers employ, on a day-to-day basis, certain strategies that will encourage the students to take ownership of their own learning. These include giving students a choice of how to present their work, asking open-ended questions and organising tasks that require students to plan, debate, discuss, share their thoughts and collaborate together.

References

- Ash, K. (2012). Educators evaluate ‘Flipped Classrooms’: Benefits and drawbacks seen in replacing lectures with on-demand video. *Education Week*, 32(2), 6-8.
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological review*, 84(2), 191-215.
- Beasley, C. (1997). Students as teachers: The benefits of peer tutoring. *Learning through Teaching*, 21-30.
- Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. Washington, DC: International Society for Technology in Education.
- Berrett, D. (2012). How ‘flipping’ the classroom can improve the traditional lecture. *The Chronical of Higher Education*, 12(19), 1-3.

- Boddey, K., & de Berg, K. (2015). The impact of nursing students' prior chemistry experience on academic performance and perception of relevance in a health science course. *Chemistry Education Research and Practice* 16(2), 212- 227.
- Bonello, K. (2016). The context-based approach in the chemistry classroom: Teachers' views and attitudes. A Dissertation presented to the Faculty of Education in Part Fulfilment of the Requirements for the Degree of Master in Science Education at the University of Malta. Retrieved July 9, 2021, from <https://www.um.edu.mt/library/oar/bitstream/123456789/15567/1/16MED0058.pdf>
- Borg, A. (2013). Physics students' perceptions on teacher pedagogies. A Dissertation Presented to the Faculty of Education in Part Fulfilment of the Requirements for the Degree of Bachelor in Education (Honours) at the University of Malta. Retrieved August 10, 2021, from <https://www.um.edu.mt/library/oar/bitstream/123456789/8688/1/13BED031.pdf>
- Bryman, A. (2004). Triangulation. In M. Lewis-Beck, A. Bryman, and T.F. Liao (Eds.), *Encyclopedia of social science research methods*. California USA: Sage Publications.
- Burnard, P., Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Analysing and presenting qualitative data. *British Dental Journal*, 204(8), 429-432.
- Campbell, L., & Campbell, B. (2008). *Mindful learning: 101 proven strategies for student and teachers success*. California, USA: Corwin Press.
- Ciampa, K. (2014). Learning in a mobile age: An investigation of student motivation. *Journal of Computer Assisted Learning*, 30(1), 82-96.
- Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education*. New York, NY: Routledge.
- Devetak, I., Glažar, S. A., & Vogrinc, J. (2010). The role of qualitative research in science education. *Eurasia Journal of Mathematics, Science & Technology Education*, 6(1), 77-84.
- Dillon, J. T. (1988). Questioning in education. In M. Meyer (E.d.), *Questions and questioning* (pp. 98-118). Berlin, Germany: Walter de Gruyter.
- Erickson, F. (2012). Qualitative research methods for science education. In B. J. Fraser, K. Tobin & C. J. McRobbie (EDs.), *Second international handbook of science education* (pp. 1451-1469). Springer, Dordrecht.
- Feather, N. T. (1992). Valus, valences, expectations, and actions. *Journal of Social Issues*, 48(2), 109-124.
- Flipped Learning Network. (2014). What is flipped learning? Retrieved June 2, 2021, from https://flippedlearning.org/wp-content/uploads/2016/07/FLIP_handout_FNL_Web.pdf
- Ford, J., Knight, J., & McDonald-Littleton, E. (2001). *Learning skills: A Comprehensive Orientation and Study Skills Course Designed for Tennessee Families First Adult Education Classes*. Tennessee: Centre for literacy Studies.
- Grow, G. O. (1991). Teaching learners to be self-directed. *Adult Education Quarterly*, 41(3), 125-149.

- Goodyear, P., Jones, C., Asensio, M., Hodgson, V., & Steeples, C. (2004). Undergraduate students' experiences of networked learning in UK higher education: A survey-based study. In P. Goodyear, S. Banks, V. Hodgson & D. McConnell (EDs.), *Advances in research on networked learning* (pp. 91-121). Springer, Dordrecht.
- Hamdan, N., McKnight, P., McKnight, K., & Arfstrom, K.M. (2013). *The flipped learning model: A white paper based on the literature review titled a review of flipped learning*. Retrieved June, 2, 2021, from https://flippedlearning.org/wp-content/uploads/2016/07/WhitePaper_FlippedLearning.pdf
- Hoong, L. Y., Chick, H. L., & Moss, J. (2007). Classroom research as teacher-researcher. *Mathematics educator*, 10(2), 1-26.
- Johnson, R. T., & Johnson, D. W. (2008). Active learning: Cooperation in the classroom. *The Annual Report of Educational Psychology in Japan*, 47, 29-30.
- Johnstone, A. H. (2000). Teaching of chemistry-logical or psychological? *Chemistry Education Research and Practice*, 1(1), 9-15.
- Lisman, J. E., & Grace, A. A. (2005). The hippocampal-VTA loop: Controlling the entry of information into long-term memory. *Neuron*. 46(5), 703-713.
- Lopes, A. P., & Soares, F. (2018). Flipping a mathematics course, a blended learning approach. In INTED2018 Proceedings, 12th International Technology, Education and Development Conference, Valencia, Spain. Retrieved June 9, 2021, from https://recipp.ipp.pt/bitstream/10400.22/12042/1/03_Flipping%20a%20Mathematics%20Course%2C%20a%20blended%20learning%20approach.pdf
- National Science Teacher Association. (2011). Quality science education and 21st-century skills. Retrieved March 7, 2022, from https://static.nsta.org/pdfs/PositionStatement_21stCentury.pdf
- Piaget, J. (1954). *The Construction of Reality in the Child*. New York: Basic Books.
- Ramaprasad, A. (1983). On the definition of feedback. *Behavioral Science*, 28(1), 4-13.
- Robinson, A. (1990). Cooperation or exploitation? The argument against cooperative learning for talented students. *Journal for the Education of the Gifted*, 14(1), 9-27.
- Roehl, A., Reddy, S.L., & Shannon, G.J. (2013). The flipped classroom: An opportunity to engage millennial students through active learning strategies. *Journal of Family & Consumer Sciences*, 105(2), 44-49.
- Saavedra, D. R., & Opfer, V. D. (2012). Learning 21st-century skills requires 21st-century teaching. *Phi Delta Kappan*, 94(2), 8-13.
- Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18(2), 119-144.
- Salierno, C. Edelson, D., & Sherin, B. (2005). The development of student conceptions of the earth-sun relationship in an inquiry-based curriculum. *Journal of Geoscience Education*, 53(4), 442-431.
- Sams, A., & Bergmann, J. (2013). Flip your students' learning. *Educational Leadership*, 70(6), 16-20.

- Schunk, D. H. (2012). *Learning theories: An educational perspective*. (6th ed.). Boston, MA: Pearson.
- Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist*, 26(3-4), 207-231.
- Suzić, N. (2017, May). Traditional schools in the modern age. Paper presented in Proceedings of the Conference on Innovation, ICT and Education for the Next Generation, Serbia. Retrieved August 16, 2021, from https://www.researchgate.net/profile/Milan-Vemic/publication/326547571_Enhancing_Effectiveness_in_Business_Management_Curricula_and_Teaching_The_Serbian_Perspective/links/5b72ae35a6fdcc87df798560/Enhancing-Effectiveness-in-Business-Management-Curricula-and-Teaching-The-Serbian-Perspective.pdf
- Sweller, J., Van Merriënboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10(3), 251-296.
- Taber, K. S. & Coll, R. K. (2003). Bonding. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust & J. H. Van Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 213-234). Dordrecht, Netherlands: Kluwer Academic Publishers.
- Talanquer, V. (2011). Macro, submicro, and symbolic: The many faces of the chemistry “triplet”. *International Journal of Science Education*, 33(2), 179-195.
- Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering the 21st century skills through scientific literacy and science process skills. *Procedia-Social and Behavioral Sciences*, 59, 110-116.

Acknowledgements

I would like to express my deepest gratitude to Dr. Josette Farrugia whose guidance and encouragement made this study possible. In addition, an appreciation goes to my school's senior management team and students without whom this study would not have been possible.