Cypriot Journal of Educational Sciences

Volume 14, Issue 4, (2019) 535-544

www.cjes.eu

Influence of maker-centred classroom on the students' motivation towards science learning

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Suggested Citation:

Caballero-Garcia, P. & Grau-Fernandez, T. (2019). Influence of maker-centred classroom on the students' motivation towards science learning. *Cypriot Journal of Educational Science. 14*(4), 535–544. https://doi.org/10.18844/cjes.v11i4.4098

Received August 21, 2019; revised from October 15, 2019; accepted from December 1, 2019.

Selection and peer review under responsibility of Prof. Dr. Huseyin Uzunboylu, Near East University, Cyprus.

Abstract

The aim of this study is to investigate the effect of maker-centred learning methodology on the motivation of secondary school students towards science learning using a quasi-experimental design pretest–posttest. For this purpose, a sample of 200 students in eighth grade (110 boys and 90 girls) was selected from two different schools in Madrid during 2017–2018 academic year. The experimental group selected covered the learning standards by doing a project in the makerspace, and the control group covered the same standards by traditional learning in the classroom. Data were collected through a Students' Motivation Towards Science Learning questionnaire developed by Tuan, Chin and Shieh (2015). The results of the data analysis revealed a significative difference between groups in the post-test, finding a higher level of motivation towards science in the experimental group (maker-centred learning based), in comparison with the control group (traditional learning based). Findings in this study confirm the benefits of makerspaces in schools as learning environments that motivate students to learn science, so we strongly recommend the use of these spaces to teach science, allowing the students to find their passion and fostering a love of learning.

Keywords: Makerspaces, motivation, science learning, secondary school, Quasi-experimental design.

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1. Introduction

We live in a rapidly changing world, one that is increasingly interconnected. Our 21st-century learners are growing up not only in an exciting but also challenging world that is fast-paced and technology-driven. Motivating this new generation of learners requires us to understand more deeply what it means to successfully communicate and collaborate across borders and cultures in this ever-changing world (Shin, 2018).

Smith System, a company that has provided classroom furniture for more than a century in the United States, affirms that today's education is much more interactive and hands-on learning. For that reason, designers and educators are reimagining learning and environments to transform traditional classrooms into innovative spaces for students to get creative and use their imagination in hands-on learning projects. As a result, an increasing number of educators are launching School Makerspaces around the globe.

Makerspaces have gathered widespread interest and support in both policy and education circles because of the ways they have been shown to link science learning to creativity and investigation (Caballero-Garcia & Grau Fernandez, 2018). Makerspaces, also known as hackerspaces and fablabs, are collaborative learning environments where students can gather together in order to share knowledge and resources, collaborate and build projects (Aoki, 2018). According to Smith System, these spaces vary widely in terms of furniture, equipment and level of technological sophistication and can consist of everything from a simple cart filled with arts and crafts materials and Legos to a high-tech lab with 3D printers, laser cutters and hand tools.

Unlike traditional classrooms, makerspaces are places of self-directed, participatory learning where students are encouraged to follow the direction of their interests and strengths. Studies have shown that participatory learning leads to higher student motivation, greater self-confidence and increased cognitive ability. Academic performance in science is equated to students' motivation and interests in the academic pursuits that they do, e.g., scientific cognition that they are exposed within school science (Libao et al., 2016).

1.1. Motivation towards science learning

Much effort has been made to review the contemporary issues and challenges faced in motivating students to like science and to outline relevant factors contributing to the cognitive, psychomotor and affective domains of science learning (Lay & Chandrasegaran, 2016). Students' motivation plays a crucial role in conceptual change process, critical thinking process and scientific process skills (Cavas, 2011).

Many definitions can be found in the literature to define students' motivation towards science learning (SMTSL). According to Lee and Brophy (1996), students' motivation in learning science is defined as students' active engagement in science-related tasks for achieving a better understanding of science. Bolat (2007) defines it as a desire for science learning. Other authors define motivation towards learning science as an internal condition that stimulates, directs and maintains an attitude of learning science (Glynn, Brickman, Armstrong & Taasoobshirazi, 2011). All these definitions state the important role of motivation in learning science, promoting students' construction of their conceptual understanding (Cavas, 2011) and influencing the decisions that students will make during their school life, ranging from the courses that they will attend to the profession that they will choose (Koul, Lerdpornkulrat & Chantara, 2011).

Sanfeliz and Stalzer (2003) think that helping students to foster their motivation to learn science is one of the most important roles for them in the education process since they will enjoy learning science, believe in their ability to learn and take responsibility for their learning if they are motivated (Salih, Mai & Al Shibli, 2016). Motivation in science learning is believed to bea vital part of developing and supporting a lifelong interest in science and develop students' scientific literacy level.

Unfortunately, many studies revealed that students' attitudes, interest and motivation towards science learning decline throughout their years at school, especially during secondary school years (Chan & Norlizah, 2017).

Several researchers have used specialised assessment tools to investigate student motivation, targeting either the broader domain of science or specific science domains, such as biology, chemistry and physics in primary, secondary and university students (Dermitzaki, Stavroussi, Vavougios & Kotsis, 2013). Among the instruments that have been constructed to measure students' motivation towards science are the science motivation questionnaire proposed by Glynn, Taasoobshirazi and Brickman (2009) to assess undergraduate non-science students' motivation, the students' adaptive learning engagement in science by Velayutham, Aldridge and Fraser (2011) to assess motivation and self-regulation in science learning with a focus on the lower secondary level students and the SMTSL by Tuan et al. (2005) to assess junior high school students' motivation (Andressa, Mavrikaki & Dermitzaki, 2015).

Many studies put focus on how students' motivation is affected by variables such as gender, academic achievement, parents' educational level and whether students attend special private courses and laboratory activities (Andressa et al., 2015). But there is not enough research about students' motivation towards science in a school's setting different from the traditional classroom or the laboratory. Srisawasdi and Panjaburee (2013) reported an effect in students' motivation towards learning science when implementing a series of open-inquiry science learning activities in a computer-based laboratory classroom. Su and Cheng (2015) demonstrated that incorporating mobile and gamification technologies into a botanical learning process could achieve a better learning performance and a higher degree of motivation than either non-gamified mobile learning or traditional instruction. A study in educational robotics conducted by Park (2015) revealed a significant improvement ($p < 0.05$) in both motivation and academic achievement.

The aim of the present study is to determine the effect in SMTSL throughout a period of six weeks when learning the same unit of study in two different learning environments: a makerspace and the traditional classroom.

1.2. Design-based makerspaces

In recent years, the focus of the educational community has shifted towards helping students gain 21st century skills that lead to success in higher education and the workplace (Vongkulluksn, Matewos, Sinatra & Marsh, 2018). Research about student-centred instruction in Science, Technology, Engineering, Arts & Math content (STEAM) with students taking an active role in the learning process rather than being passive recipients of information from the teacher demonstrates outcomes consistent with developing 21st-century skills and STEAM mastery. A variety of instructional models in STEAM classes define themselves as student-centred (Keiler, 2018). Design-based instruction and makerspace programs have been shown to be effective in increasing student motivation for STEAM learning.

Design-based instruction aims to increase students' reasoning skill and transfer of content knowledge by engaging students in designing artefacts that solve real-world problems. Although design-based instruction is known by various names, including design-based learning (DBL), learning by design, problem-based learning or design-thinking instruction, the steps remain relatively consistent (Vongkulluksn et al., 2018), getting an understanding of the context of use when examining open-ended design problems. Working on and completing design-based activities can make students feel proud of their achievements, as well as building up their confidence as thinkers, designers and doers that will benefit them through their education and life (Barron, Kim, Lim & Stevens, 1998).

Makerspaces are collaborative work spaces inside a school, library or separate public/private facility for making, learning, exploring and sharing that uses high tech to no tech tools. These spaces are open to kids, adults and entrepreneurs and have a variety of maker equipment including 3D printers, laser cutters, numerical control machines, soldering irons and even sewing machines. A makerspace, however, doesn't need to include all of these machines or even any of them to be considered a makerspace. It's more of the maker mindset of creating something out of nothing and exploring your own interests that's at the core of a makerspace (Caballero-Garcia & Grau Fernandez, 2018).

'Design-based makerspaces' is a term proposed by Vongkulluksn et al. (2018) and her associates to refer to makerspaces structured with design stages similar to other DBL programs. This term combines the clear design goals associated with DBL and the STEAM-focused creative production emphasised in makerspaces, giving a more well-defined making and designing process needed for makerspaces, due to its increasing popularity in education.

A design-based makerspace is the perfect scenario for maker-centred learning. Maker-centred learning is oriented around the learner's context and knowledge is built by creating and interacting with physical objects, following the principles of Jean Piaget and Seymour Papert of 'Learning by doing' (Gonzalez & Arias, 2018). With design-based makerspaces, learning outcomes and effective instruments for measuring those outcomes are clearly identified, transforming the informal and playful makerspaces into formal learning environments, where the required curriculum can be covered for any subject area.

Despite an upsurge in research on making in education and the manifest popularity of the movement (Halverson & Sheridan, 2014), demonstration of its efficacy towards meeting any of its intended learning goals is limited. In particular, there has been little research on effective maker teacher education to date and few studies have directly examined how DBL is related to motivational outcomes. Much of the peer-reviewed research has taken place in informal spaces, rather than in formal classrooms, or as one-time interventions (Marshall & Harron, 2018).

2. The method

The purpose of the present study is to explore the effect of maker-centred learning in a design-based makerspace science course compared to traditional learning science method by examining the results obtained from SMTSL questionnaire applied to eighth grade students using a quasi-experimental design pretest–posttest (Cook & Campbell, 1979).

2.1. Participants

Participants were 200 students in eighth grade, selected on a non-random and intentional way, aged between 13 and 15 years old, from two private schools in Madrid, Spain. Respecting the system of intact classrooms, 100 students (experimental group) attended a design-based makerspaces science classroom as part of their regular school experience and the other 100 students (control group) attended to a traditional science classroom, during a period of eight weeks. The experimental group was comprised 48 girls and 52 boys, and the control group was comprised 42 girls and 58 boys (Table 1).

The private schools in which the research took place belong to SEK institution. SEK international schools are nationally recognised for being a pioneer in implementing the latest educational technologies in its classrooms, including digital whiteboards, interactive books, videoconferences, iPads in its classrooms, the use of artificial intelligence and makerspaces. SEK institution was the first to launch the makerspace initiatives at their schools in Spain, aware of the important role of non-formal spaces, enabling students to boost their skills to go beyond curriculum requirements of the educational system.

Table 1. Distributions belonging to students' gender for experimental and control group

Gender	N	Experimental group	Control group
Female	90	48	42
Male	110	52	58
Total	200		

2.2. Measures

In this research, the five-point Likert-type 'SMTSL' scale developed by Tuan et al. (2005) was used to collect data. The original language of the scale is English and consists of 35 items allocated into six scales: self-efficacy (SE) (items 1–7), active learning strategies (ALS) (items 8–15), science learning value (SLV) (items 16–20), performance goals (PGs) (items 21–24), achievement goals (AGs) (items 25–29) and learning environment stimulation (LES) (items 30–35). Items 2, 4, 5, 6, 7, 21, 22, 23 & 24 are negatively stated and reversely coded as suggested by Tuan et al. (2005).

For the purpose of this study, the SMTSL questionnaire was translated from English to Spanish. In order to confirm the original factor structure of the instrument, a principal component analysis with Equamax rotation was performed. The results of the factor analysis indicated that the factorial structure of SMTSL was the same as that observed by Tuan et al. (2005). Item 30 was deleted from the Spanish instrument because factor loading was lower than 0.3, so the final Spanish version consisted of 34 items, 6 scales. Two equivalent tests were used as pre-test and post-test.

Regarding the scales' internal consistency, Cronbach's alpha coefficient revealed acceptable consistency for all the scales in the pre-test (from 0.71 to 0.85, see Table 2) and post-test (from 0.68 to 0.92, see Table 3). An increased alpha in post-test appeared in SE (from 0.85 to 0.92), ALS (from 0.83 to 0.90), SLV (from 0.79 to 0.86) and LES (from 0.71 to 0.86) scales. However, pre-test analysis showed a greater alpha value than post-test in PG (0.71 vs. 0.68) and AG (0.83 vs. 0.81). The Cronbach alpha reliability coefficient for the whole instrument was 0.89 for pre-test and 0.93 for post-test.

Table 2. Cronbach alpha coefficients of the SMTSL Pre-test and scales

Variable	Number of items	Cronbach alpha
SE	7	0.85
ALS	8	0.83
SLV	5	0.79
PG	4	0.71
AG	5	0.83
LES	5	0.71
SMTSL	34	0.89

Table 3. Cronbach alpha coefficients of the SMTSL post-test and scales

Variable	Number of items	Cronbach alpha
SE	7	0.92
ALS	8	0.90
SLV	5	0.86
PG	4	0.68
AG	5	0.81
LES	5	0.86
SMTSL	34	0.93

2.3. Data collection

Students were informed the purpose of the research. When they agreed to voluntarily participate in the experiment with centre and family permission, the SMTSL questionnaire was administered to students (pre-test) during science class at school in one session of 40 minutes of duration approximately. In order to adapt the SMTSL questionnaire so that it would assess Spanish SMTSL, we translated the original questionnaire into the Spanish language. Then, the experimental group attended a design-based makerspace science course as part of their regular school schedule for 8 weeks, and the control group worked their science lessons with a traditional methodology. At the end of the makerspace sessions, the questionnaire was administered again (post-test) to provide evidence of a significant difference between the experimental and control groups with the statistical data analysis.

2.4. Data analysis

Data were analysed by using SPSS for Windows (version 24) to test inferential statistical analysis. *T*-test and analysis of variance were executed to test the following hypothesis: there are significant differences in SMTSL between the experimental group attending a design-based makerspace science course and the control group attending to a traditional science classroom. Alpha value was set at 0.05 level of significance. Answer options of the scale items in the SMTSL questionnaire are 'strongly agree, agree, no opinion, disagree and strongly disagree'. In the analysis, five-point was given for 'Strongly agree' option while one-point was given for 'Strongly disagree' option for positive items. On the other hand, one-point was given for 'Strongly agree' option while five-point was given for 'Strongly disagree' option for negative items.

3. Results

In order to find out whether there was a significant difference between experimental and control group mean scores of every subscale, independent t-tests were carried out. The results are shown in Table 4.

Table 4. Descriptive statistics of each subscale from SMTSL questionnaire

			Experimental group							Control group	
Subscale	**N**	**Mean Pre-Test**	**Standard deviation (SD)**	**Mean post-test**	**SD**	***p***	**Mean pre-test**	**SD**	**Mean post-test**	**SD**	***p***
SE	100	3.77	0.68	3.79	0.61	0.827	3.77	0.83	2.92	1.03	0.000(*)
ALS	100	3.93	0.49	3.97	0.57	0.595	3.81	0.77	3.54	0.65	0.008(*)
SLV	100	4.04	0.63	4.24	0.69	0.034(*)	4.00	0.71	4.04	0.55	0.657
PG	100	3.37	0.81	3.36	0.78	0.929	3.49	0.88	3.22	0.84	0.028(*)
AG	100	3.89	0.85	3.95	0.75	0.597	4.00	0.78	3.93	0.59	0.475
LES	100	3.18	0.68	3.43	0.82	0.020(*)	3.09	0.78	2.96	0.75	0.231

(*) Meaningful difference at 95% level of significance

Also, significant differences for each subscale among groups in Pre-test and Post-test were studied. Results are shown in Table 5 (for Pre-test) and Table 6 (for Post-test).

Table 5. *t*-student analysis among groups in Pre-test from each subscale with α = 0.05

Subscale	Group	N	Mean	SD	F	Sig.	*t*	*p*
SE	Experimental group	100	3.77	0.68	1.490	0.0237	0.000	1.000
	Control group	100	3.77	0.83				
ALS	Experimental group	100	3.93	0.49	2.469	0.0000	1.315	0.190
	Control group	100	3.81	0.77				
SLV	Experimental group	100	4.04	0.63	1.270	0.1168	0.421	0.674
	Control group	100	4.00	0.71				
PG	Experimental group	100	3.37	0.81	1.180	0.2043	-1.003	0.317
	Control group	100	3.49	0.88				
AG	Experimental group	100	3.89	0.85	1.188	0.1958	-0.953	0.342
	Control group	100	4.00	0.78				
Learning environment stimulation	Experimental group	100	3.18	0.68	1.316	0.0859	0.870	0.385
	Control group	100	3.09	0.78				

Table 6. *t*-student analysis among groups in post-test from each subscale with α = 0.01

Subscale	Group	N	Mean	SD	F	Sig.	*t*	*p*
SE	Experimental group	100	3.79	0.61	2.851	0.0000	7.268	0.000(*)
	Control group	100	2.92	1.03				
ALS	Experimental group	100	3.97	0.57	1.300	0.0954	4.974	0.000(*)
	Control group	100	3.54	0.65				
SLV	Experimental group	100	4.24	0.69	1.574	0.0121	2.267	0.024(*)
	Control group	100	4.04	0.55				
PG	Experimental group	100	3.36	0.78	1.160	0.2300	1.221	0.223
	Control group	100	3.22	0.84				
AG	Experimental group	100	3.95	0.75	1.616	0.0086	0.210	0.834
	Control group	100	3.93	0.59				
LES	Experimental group	100	3.43	0.82	1.195	0.1869	4.229	0.000(*)
	Control group	100	2.96	0.75				

4. Discussion

Table 4 indicates the descriptive statistics of each subscale from the SMTSL questionnaire for experimental and control groups. In the experimental group, all the subscales except 'PG', students had higher mean scores in the post-test. In SLV ($p = 0.034$) and LES ($p = 0.020$), these differences were significant. In the control group, all the subscales except 'SLV', students had lower mean scores in the post-test. These differences were found significant in SE ($p = 0.000$), ALS ($p = 0.008$) and PG ($p = 0.028$) subscales.

It is observed that students, who take part in design-based makerspace activities, have higher motivation levels towards science learning in terms of 'LES' and 'SLV'. Makerspaces are environments, where students are more autonomous, forming their own learning paths with a feeling of belonging of their learning process. These findings are supported by the work of researchers who have found that by increasing proficiency in STEAM, positive STEAM identity can be increased as well (Vongkulluksn et al., 2018). Design-based makerspaces have the possibility for developing proficiency in STEAM by providing authentic science inquiry engaging students through exploratory investigation, collaboration and technology use (Martin-Hansen, 2018).

Another observation is that students, who don't take part in design-based makerspace activities, have lower motivation levels towards science learning in all the subscales except in the SLV. Traditional learning methods in science led to students' lack of interest as well as their declining ability to do science (Salih et al., 2016). The fact that 'SLV' is almost the same indicates that the instructor's teaching materials are adequate but students struggle with tasks and concepts causing the decline in the other subscales of the motivation questionnaire.

Results in Table 5 indicate that there were no significant differences in every subscale value between experimental and control groups before the introduction of the design-based makerspace activity in the experimental group. However, results in Table 6 revealed that the mean scores of SE, ALS, SLV and Learning Environment for the experimental group were significantly different from the control group. In PG and AG scales, no statistically significant differences were found between groups.

As researchers have determined that the environment plays a large role in the development of science identity (Martin-Hansen, 2018), results in Table 6 confirm that makerspace activities foster the development of positive science identity in students and have an impact in SMTSL.

5. Conclusion

Results from this study point to the potential for design-based makerspaces to support middle school students' motivation towards learning Science. The data analysis of the SMTSL questionnaire reported a significant difference in SLV (p = 0.034) and LES (p = 0.020) of the experimental group when introducing design-based makerspace activity. Regarding significant differences between experimental and control groups, these were found in SE (p = 0.000), ALS (p = 0.000), SLV (p = 0.024) and Learning Environment (p = 0.000) scales. The results of this study confirm the motivational implications when the learning environment is different to the traditional classroom, as Srisawasdi and Panjaburee (2013) reported in their study of the effect of integrated computer-based laboratory environment on eleventh grade students, obtaining results that showed a promotion of the students' motivation towards learning science.

The intention of our research was to understand students' motivational characteristics in a naturalistic makerspace setting. Results confirmed the potential for design-based makerspace activities to support middle school students' learning in science. This potential of design-based makerspace programs has been studied by Vongkulluksn et al. (2018) with results showing the potential of these spaces to be an effective instructional medium for developing STEAM-related knowledge and interest development in elementary students.

6. Recommendations

Design-based makerspace activities are possible instructional strategies to change the passive role the students play in a traditional class, where they learn by memorising scientific facts, and what science is, and how to do science. According to Srisawasdi and Panjaburee (2013), the traditional way of learning science does not work for motivating students into meaningful learning in science and understanding science in the way it is, so science teaching must be shifted from traditional schooling to more constructivist-oriented instruction.

Design-based makerspace programs aim to increase students' reasoning skills to solve real-world problems and constitute a positive and motivating learning environment for students. That's why we believe it would be very positive to introduce makerspace programs in schools as a way to combine the school's focus on student-led inquiry with technology-rich instruction needed in education nowadays.

In order to understand students' motivation in science learning in different grade levels using design-based makerspace programs, further research should be conducted for assessing this learning environment to different courses to find significant differences in the subscales of the SMTSL questionnaire.

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