Teachers' self-perception in maker education: three approaches for STEM professional development

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***Abstract*— Maker education plays an important role in joining the STEM education fields for preparing students for the new demands in society. It is essential to prepare teachers to implement the maker education in their lessons, not only focusing on the technical skills they need to acquire, but also on their attitudes and self-perception regarding the maker education. This paper analyzes the effect that three different approaches for teacher professional development on the maker education have on teachers' self-perceived ability for implementing the maker education in their practice. The results indicate that there is a significant improvement regarding the feeling of being able to design maker-based educational lessons after participating in any of the professional development courses. This effect is more significant in those approaches where participants are self-motivated to participate and that foster individual learning. Participating in an online training that doesn't teach on the specific technological tools nor requires to design nor implement a maker-based project, decreases the perception of having training opportunities to learn how technological tools work. More practical activities requiring the development of a maker project should be offered to teachers to improve their self-perception regarding the maker and STEM education in primary education levels.**

Keywords*— *Primary education, Teachers professional development, maker education, STEM Education

I. Introduction

According to the European Commission H2020 Science with and for Society Education programme, innovative formal and informal science learning is important in order to raise both youth awareness of the different aspects encompassing science and technology in today's society and to address the challenges faced by young people when pursuing careers in Science, Technology, Engineering and Mathematics (STEM) [1]. Through formal STEM education, it is intended to decrease the gap and faced challenges such as the disparity between skills that the jobs of the future will demand, women interest in scientific and technological studies or innovation activities.

It is important to ensure new approaches to develop STEM skills from a young age are being implemented. The way that students are educated should be aligned to the new technologies, working environments, organizational structures and different forms of internal and external cooperation that are being established in the new society [2]. Schools are at the front line of this change and need to think about how they can prepare young people for the future workplace [3]. In this scenario, it is equally important to equip teachers with effective knowledge, competences and appropriate teaching methods [4].

Educators are being challenged to design curricula and pedagogies to develop 21st century skills [5]. There are many actions oriented to introduce the development of the 21st digital skills in schools by different organizations at the European level [6, 7]. These actions are not only oriented to students but also to promote the competence development of teachers in the context of 21st century skills [8]. In the context of the present study, Spain, there is a reference framework at the national level that puts special emphasis on digital competencies that Spanish teachers need to have for successfully conducting their teaching practice [9].

A. *The maker education to foster STEM*

This study focuses its attention on an innovative method that is showing positive impact to develop 21st century digital skills and STEM in education: the maker education, sometimes also known as 'Tinkering' or 'Bricolage' [10, 11, 12]. The 'maker' concept comes from the maker movement, which refers to people who enjoy producing creative artefacts in their daily lives [13]. Maker activities can support learning processes that involve the 21st century skills acquisition and not focus only on a specific subject [14, 11]. Through maker education, it is possible to combine two important elements that are key for a successful 21st century education: creativity and technology [15].

Since maker activities involve the use of some type of digital material, users have to be familiarized with technology and broaden the interest in computer science in general [11]. It is considered that education should provide all children with the opportunity to design and develop digital technologies and not only use them [16]. It has also been advocated that technology in school is an emancipatory tool that puts the most powerful construction materials in the hands of children, it doesn't have the purpose to optimize traditional education [17]. It is expected that maker sessions can engage students in the design and fabrication process, in thinking and problem solving, as well as in programming [11].

Most of the research has proved the efficacy of introducing maker activities in curricular areas related to STEM, which challenges us as researchers, teachers and/or educators to see in which other subject areas it could benefit [11]. When introducing a maker space, an area where students go to explore, build, create and tinker, students get engaged in intellectual activities and practices that would not be possible anywhere else, letting them experience new ways of working and increasing the levels of team collaboration [17]. Using robots to teach problem-solving, critical thinking and basic programming concepts has shown to improve students' knowledge about robotics and programming, increasing students' interest in STEM [18]. It has been also shown that doing maker activities increases the self-efficacy of the participants, making them gain confidence, enjoyment and interest in programming and technology [11]. Introducing making in the classroom can influence students' self-perceptions by creating a maker mindset determined by three factors [14]: Motivation; Interest; and Self-efficacy. Moreover, it has been demonstrated that it can be effectively and economically implemented in the elementary school curriculum [19].

B. The maker education in the teaching practice

In the teachers' community, it is known that the maker movement is leading the path of education, but some educators struggle to implement it in their practice for different reasons such as problems with access, time, beliefs, professional development and institutional vision [20, 21, 22], as Schad and Jones describe, it is still necessary to identify best practices [23]. Most teachers are not well prepared for STEM education and they have problems with making connections across the STEM disciplines [24, 25].

In order to prepare teachers to face this change in education, several initiatives are being developed for encouraging and helping them to develop and extend their competences. When focusing on teacher competencies, four themes have been considered fundamental: the ability of thinking, knowing, feeling and acting as teachers [26]. The present work focuses on the "feeling like a teacher" theme, which refers to the formation of a personal identity involving self-knowledge, self-efficacy and self-awareness, as well as fundamental attitudes, towards the teaching practice.

C. Research questions

This paper analyzes teachers' self-perceptions regarding how to teach maker education in primary schools, the RQs addressed are:

RQ1. How do teachers perceive their ability to develop maker activities?

RQ2. How does professional development improve teachers' perception of their ability to develop maker activities?

RQ3. How do different professional development approaches improve teachers' perception of their ability to develop maker activities?

The current paper addresses these questions presenting, first of all, the research methodology that has been followed; the three professional approaches applied, as well as the instruments used, and the experimental design followed. Section 4 presents the results, offering a detailed description of the sample and an understanding of the ability perception of teachers. Finally, section 5 discusses the results, including the limitations and the proposed future work.

II. Research Methodology

A. Professional development approaches

Under the initiative of a project named "Makers a les Aules" (translated "Makers in the Classroom"), three different approaches were implemented to foster professional development among teachers regarding the introduction of the maker education in primary schools. Concretely, teachers were aimed to understand the objectives of the maker education where teachers act as coaches (similar to [27]), promoting the development of Design Thinking and Computational Thinking, as well as to learn how to implement it in different contexts as interdisciplinary projects, where technological tools such, as the programming language Scratch, Makey Makey and/or Tinkercad, are integrated. As a brief description Scratch is a programming language that was created by MIT that allows programming through the combination of visual programming blocks to create an animation or a game [28]. Makey Makey is an electronic tool that allows users to connect everyday objects to computers to develop specific programs using Scratch [29]. Finally, Tinkercad is a software application developed by Autodesk that allows users to create 3D designs and print them with a 3D printer [30].

In all cases, teachers were provided with an open online maker community for primary education teachers aimed to support the learning design of maker activities and be used as a repository of activities made by the members of the community. This online maker community had been developed by the same research group leading these professional development approaches, called "ILDE+ Makers a les Aules" (ILDE standing for Integrated Learning Design Environment) [31], which can be accessed through this link: https://ildeplus.upf.edu/makersalesaules.

This paper does not aim to investigate in detail each approach but to compare how the three types of training approaches contribute to changing teachers' perceptions regarding the maker education (see RQs). The differences between the three approaches are presented in Table I.

TABLE I. Professional Development Approaches Characteristics

	Approach A	**Approach B**	**Approach C**
Format	On-site	On-site	Online
Training style	Individual	In group (1 instructor - 10 teachers)	Individual
Duration	10-hours/ 20-hours*	10-hours	3-hours
Organization	2 co-design sessions 4/5 implementation sessions*	5 sessions	1 session
Instructor role	Instructor as a support	Instructor as a trainer	Without instructor
Project design	Required	Required	Not required
Project implementation	Required	Not required	Not required
Enrollment procedure	Self-enrollment	Enrollment by the school organization	Self-enrollment

*1st (2018-19) and 2nd edition (2019-20) respectively

B. Instruments and experimental design

To analyze teachers' perceived ability to introduce maker activities in their lessons and evaluate if the different professional development approaches contributed to its improvement, questionnaires were distributed through Google Forms before and after the different interventions (done as approaches A, B and C). These questionnaires included different types of questions for collecting demographic data, teachers' prior experience and perceived ability. Concerning the perceived ability, different statements were created based on those aspects that have been seen as important in previous studies, such as access, time, beliefs, professional development and institutional vision [20].

- Q1. Do you use or have you ever used the maker education in your teaching practice? *(Forced choice)*
- Q2. What tools do you use or have you used*? (Multiple-choice: Scratch, Makey Makey, WeDo, Beebot, Other)*
- Q3. With what frequency do you use/have you used them? *(Likert scale 0-4: Once a day, Once a week, Once a month, Once every three months, Once a scholar year)*
- Q4. In the context of what subject do you use/have you used them? *(Multiple-choice: National languages, Foreign language, Maths, Natural sciences, Social sciences, Arts, Physical education, Projects, Computer science)*
- Q5. How do you assess your experience using these tools? *(Likert scale 0-3: Bad, Improvable, Good, Very good)*
- S1. I am able to design an educational lesson using maker tools and activities.
- S2. I have sufficient time to design an educational lesson using maker tools and activities.
- S3. I am able to conduct an educational lesson using maker tools and activities.
- S4. I have sufficient time to conduct an educational lesson using maker tools and activities.
- S5. I am able to introduce the maker education in my teaching practice throughout the academic year using it in different lessons.
- S6. I am able to introduce the maker education in my teaching practice throughout the academic year using it in different subjects.
- S7. I have available the needed material to conduct maker activities (computers, tablets, electronics and robotics components, etc.).
- S8. I receive support from the school organization to conduct maker activities.
- S9. I know enough about how technological tools work to be able to apply them in the classroom.
- S10. I have training opportunities to learn more about how technological tools work to be able to apply them in the classroom.
- S11. I know enough about how to apply technological tools in the classroom.
- S12. I have training opportunities to learn more about how to apply technological tools in the classroom.
- S13. I have spaces where I can share experiences based on maker education with other professionals.
  (Likert scale 0-4: Absolutely disagree, Disagree, Neither agree nor disagree, Agree, Absolutely agree)

Questions Q1 to Q5 were asked before the intervention. Statements S1 to S13 were asked before and after the intervention.

III. Results

A. Sample description

The final sample consisted of 109 participants (gender: 85 females, 22 males, 2 preferring not to specify it; age: M = 39.04, SD = 10.292). When looking at the specific groups, in Approach A there were 26 participants (gender: 20 females, 5 males, 1 preferring not to specify it; age: M = 39.35, SD = 8.523), in Approach B there were 57 participants (gender: 47 females, 9 males, 1 preferring not to specify it; age: M = 41.47, SD = 9.918) and in Approach C there were 26 participants again (gender: 18 females, 8 male; age: M = 33.38, SD = 10.852).

Less than a quarter of the participants had prior experience with the maker education (N = 25, 22.93%). From this subgroup, the tools that they had used or were using were the programming language Scratch (83.33%), the Beebot robot (66.67%), the WeDo robot kit (62.50%) and the Makey Makey electronic board (45.83%). 21.74% of the participants used the tools once a day, 34.78% used them once a week and another 34.78% used them once every 3 months; only one participant used the tools once a month and another one once throughout the course. The maker education was mostly applied in the context of Computer Science related subjects (39.13%), followed by Maths (30.43%) and Natural Sciences (26.09%). About their experience's assessment using these tools, most of them indicated that it had gone "Very good" (56.52%) and "Good" (26.09%), and the rest mentioned that it could be improved (17.39%).

Regarding the three different groups (teachers from approach A, B or C), there weren't any significant differences in the frequency of using the different tools in the classroom ($F(2, 20) = .277$, $p = .761$) or on their experiences' assessment ($F(2, 20) = .479$, $p = .626$) after applying an Analysis of Variance. Likewise, any significant differences were found between the tools they had used. Nevertheless, when looking at the subjects where they had used the different tools, it can be seen that the category "Maths" presents significant differences among groups ($F(2,20) = 4.183$, $p = .03$). While in the Approach A group 3 teachers had used this methodology in the Maths subject, and 4 teachers had used it in the Approach B group, any teacher had used it in Approach C group. However, since only this category among all the others was different, we considered the groups as homogeneous regarding their prior knowledge and continue with further analysis.

B. Answering the research questions

To answer the RQ1 "How do teachers perceive their ability to develop maker activities?", the statements related to teachers' perception about their ability to develop maker activities were analyzed at the beginning of each formative approach. Regarding RQ2 "How does professional development improve teachers' perception of their ability to develop maker activities?", the same statements were analyzed at the end of each formative approach. Table II shows the data obtained from these two measurements and offers relevant data for the comparisons between them. The statements S1-S13 can be seen in section "B. Instruments and experimental design" in the section "II. Research methodology".

Concerning RQ2, several changes can be seen before and after the intervention. Two statements show a statistically significant increase after implementing the Wilcoxon Signed-Ranks test. These are S1 "I am able to design an educational lesson using maker tools and activities" with a large effect ($Z = -3.683$, $p = 0.001$, $r = -0.506$) and S3 "I am able to conduct an educational lesson using maker tools and activities" ($Z = -2.348$, $p = 0.019$, $r = -0.323$) with a medium effect.

TABLE II. STATEMENTS BEFORE AND AFTER THE PROFESSIONAL DEVELOPMENT TRAINING

	Before		After			
Statement	***M***	***SD***	***M***	***SD***	***Z***	***p-value***
S1	1.82	1.195	2.54	.926	-3.683	.001***
S2	2.15	.980	1.80	.998	-1.237	.216
S3	2.07	1.176	2.65	.894	-2.348	.019*
S4	2.24	.961	2.17	1.060	-.266	.790
S5	2.40	1.019	2.76	.950	-1.426	.154
S6	2.21	1.028	2.65	.955	-1.946	.052
S7	2.36	1.110	2.15	1.053	-.312	.755
S8	2.76	.980	2.63	1.069	-1.100	.271
S9	1.81	1.049	1.94	1.123	-1.198	.231
S10	2.71	.761	2.39	.998	-1.537	.124
S11	1.93	1.025	2.04	.990	-.542	.588
S12	2.61	.838	2.61	.920	-.426	.670
S13	1.91	1.059	2.19	.973	-1.709	.087

* p<0.05; **p<0.01; ***p<0.001

To answer RQ3 "How do different professional development approaches improve teachers' perception of their ability to develop maker activities?" analyses were done for each of the different approaches (the results for each of the approaches can be seen in Tables III, IV and V at [32]).

Regarding Approach A, there is only one statement that presents a significant improvement, S1 "I am able to design an educational lesson using maker tools and activities" with a large effect (Z = -2.524, p = 0.012, r = -0.579). A similar thing happens for Approach C, where S1 also presents a significant improvement with a large effect (Z = -2.739, p = 0.006, r = -0.685), while S10 "I have training opportunities to learn more about how technological tools work to be able to apply them in the classroom" presents a significant worsening also with a large effect (Z = -2.209, p = 0.027, r = -0.552). In Approach B, there weren't any statistically significant differences before and after the intervention.

IV. DISCUSSION

A. Conclusions

The results of this work contribute to a better understanding of how teachers feel concerning to the maker education and the introduction of the STEM fields in Primary education settings, extending the "feeling like a teacher" theme, using Feiman-Nemster terms [26]. Furthermore, it contributes to giving support to the idea that participating in teacher development courses can improve teachers' self-perception regarding their ability to develop maker-based and STEM educational practices.

Teachers didn't feel they were yet able to design a full maker-based educational lesson, neither they felt they had sufficient knowledge about the tools to be used, nor a professional community with whom to share maker-based experiences. These three aspects could be considered as potential limitations for the integration of the maker and STEM education in their teaching practices. Nevertheless, it has been seen that after participating in the professional development practices, teachers' self-perception of being able to design a full maker-based educational lesson improved. Furthermore, teachers also felt that they were more able to conduct educational lessons following the maker education after participating in the training.

When looking at the different professional development approaches, only teachers in approaches A (Codesign course) and C (Online course) show significant improvement in their perceived ability to design an educational lesson using maker tools and activities. Previous studies had also found that teachers felt more confident to create maker activities for their lessons after having received training about it [27, 33]. Approach B does not show these differences, something that could be associated with the differences between groups. One common factor in approaches A and C is that training was done individually and not in groups as in group B. This could mean that individual training tends to generate further improvement regarding their perceived ability, contrary to what has been found in previous research [34, 35]. Another common factor that could explain this contradiction regarding previous research, is that teachers in approaches A and C chose to participate in the courses by themselves instead of having this chosen by the school organization; this could mean that they had a higher motivation and a better attitude, which could contribute to this higher improvement as seen in previous studies [36]. Furthermore, teachers in approach C (Online course) worsened their perception of having training opportunities to learn more about how technological tools work. This perception could have been generated because teachers in this approach, unlike approaches A and B, weren't required to work with the technological tools (Scratch, Tinkercad or Makey Makey) nor to create a project and implement it. This can suggest that practical activities are needed in the context of maker activities to generate better perceptions among teachers. Nevertheless, more investigation should be done to conclude these aspects.

B. Limitations and future work

While this study has been conducted with a sample comprising a relatively high number of primary education teachers, it still has some limitations. First of all, all participants are from the same geographical area. Therefore, further studies should be done to better understand how teachers feel about maker education in different places.

Regarding the different professional development approaches, while they were very similar in terms of content, they were different regarding their duration and format. Furthermore, the maker projects that teachers were developing were different in every case. Therefore, while analyzing the different groups all together gives interesting information about the effect of all types of training, the comparisons between groups should be cautiously interpreted because of possible confounding variables explaining the differences found.

Regarding the research tools used, it is also important to consider that the questionnaire used in this study does not derive from any standardized tool. This has allowed the collection of interesting descriptive data, but any specific standardized levels of self-perception can be concluded from it.

Based on the conclusions from this study, it is also suggested that further efforts should be put to promote courses for teachers' development of digital competencies related to digital content creation [9]. More practical activities should be offered in professional development approaches, as well as free open sessions for experimentation [27]. Moreover, teachers' community platforms related to STEM and maker education could be promoted to generate the engagement needed for increasing the probability of implementing these practices.

This study supports the idea that teacher professional development initiatives can improve teachers' perceived ability to apply the maker education and the STEM fields in primary education settings, and more work should be done to further develop our understanding about the introduction of these fields in primary education.

ACKNOWLEDGEMENT

We would like to thank all the schools, teachers and students who participated in this project. We would also like to extend our gratitude to the Barcelona City Council for trusting us on this initiative. This work has been partially funded by the EU Regional Development Fund and the National Research Agency of the Spanish Ministry of Science, under project grants TIN2017-85179-C3-3-R, MDM-2015-0502. Dr. Hernández-Leo acknowledges the support by ICREA under the ICREA Academia programme.

REFERENCES

[1] European Commission. (n.d.) *Horizon 2020. Science with and for Society.* Retrieved October 6, 2020, from https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society

[2] Tschimmel, K., Santos, J., Carenzo, M. & Manzini, S. (2017) D-Think Toolkit. Design Thinking Applied to Education and Training.

[3] Green, H. & Hannon, C. (2007). Their Space. Education for a digital generation. DEMOS.

[4] European Commission (2013). Supporting teacher competence development for better learning outcomes.

[5] Taylor, P.C. (2016) Why is a STEAM Curriculum Perspective Crucial to the 21st Century? In: *14th Annual conference of the Australian Council for Educational Research,* 7 - 9 August 2016, Brisbane

[6] Larson, L. C., & Miller, T. N. (2011). 21st century skills: Prepare students for the future. *Kappa Delta Pi Record,* 47(3), 121-123.

[7] National Research Council. (2010). Exploring the intersection of science education and 21st century skills: A workshop summary. *National Academies Press.*

[8] Caena, F., & Redecker, C. (2019). Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (Digcompedu). *European Journal of Education,* 54(3), 356-369.

[9] INTEF. (2017). *Marco Común de Competencia Digital Docente.* Available at: https://aprende.intef.es/sites/default/files/2018-05/2017_1020_Marco-Com%C3%BAn-de-Competencia-Digital-Docente.pdf. (Accessed: August 2020)

[10] Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 5(1), 4.

[11] Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2017). Empirical studies on the Maker Movement, a promising approach to learning: A literature review. *Entertainment Computing*, 18, 57-78.

[12] Sharples, M., Adams, A., Ferguson, R., Mark, G., McAndrew, P., Rienties, B., ... & Whitelock, D. (2014). *Innovating pedagogy 2014: exploring new forms of teaching, learning and assessment, to guide educators and policy makers.* The Open University.

[13] Halverson, E. R. & Sheridan, K. (2014). The Maker Movement in Education. *The Harvard Educational Review.* 84, 495–504.

[14] Chu, S. L., Quek, F., Bhangaonkar, S., Ging, A. B. & Sridharamurthy, K. (2015). Making the Maker: A Means-to-an-Ends approach to nurturing the Maker mindset in elementary-aged children. *International Journal of Child-Computer Interaction.* doi:10.1016/j.ijcci.2015.08.002

[15] Henriksen, D., Mishra, P., & Fisser, P. (2016). Infusing creativity and technology in 21st century education: A systemic view for change. *Educational Technology & Society,* 19(3), 27-37.

[16] Eriksson, E., Heath, C., Ljungstrand, P. & Parnes, P. (2018). Makerspace in school— Considerations from a large-scale national testbed. *International Journal of Child-Computer Interaction* 16, 9–15.

[17] Blikstein, P. (2013). Digital Fabrication and 'Making' in Education: The Democratization of Invention. *FabLabs: Of Machines, Makers and Inventors,* 21.

[18] Newley, A., Deniz, H., Kaya, E., & Yesilyurt, E. (2016). Engaging elementary and middle school students in robotics through hummingbird kit with Snap! visual programming language. *Journal of Learning and Teaching in Digital Age,* 1(2), 20-26.

[19] Heiner, C. (2018). A Robotics Experience for All the Students in an Elementary School. *SIGCSE'18*, 729–734. doi:10.1145/3159450.3159567

[20] Kopcha, T. J. (2012) Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development. *Computers & Education*, 59.

[21] O'Brien, S., Hansen, A. K., & Harlow, D. B. (2016, October). Educating teachers for the maker movement: Pre-service teachers' experiences facilitating maker activities. *In Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education* (pp. 99-102).

[22] O'Neal, L. J., Gibson, P., & Cotten, S. R. (2017). Elementary school teachers' beliefs about the role of technology in 21st-century teaching and learning. *Computers in the Schools,* 34(3), 192-206.

[23] Schad, M., & Jones, W. M. (2020). The Maker Movement and Education: A Systematic Review of the Literature. *Journal of Research on Technology in Education,* 52(1), 65-78.

[24] Geng, J., Jong, M. S. Y., & Chai, C. S. (2019). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher,* 28(1), 35-45.

[25] Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3(1), 11.

[26] Feiman-Nemser, S. (2008). *Teacher learning. How do teachers learn to teach?* Teoksessa M. Cochran-Smith, S. Feiman-Nemser, DJ McIntyre, & KE Demers (toim.) Handbook of research on teacher education: Enduring questions in changing contexts.

[27] Alimisi, R., Loukatos, D., Zoulias, E., & Alimisis, D. (2018, October). Introducing the making culture in teacher education: the eCraft2Learn project. *In International Conference EduRobotics 2016* (pp. 27-41). Springer, Cham.

[28] Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., ... & Kafai, Y. (2009). Scratch: programming for all. *Communications of the ACM,* 52(11), 60-67.

[29] Silver J, et al. (2012). Makey Makey improvising tangible and nature-based user interfaces. *In Proceedings of the ACM tangible embedded and embodied interaction*, Kingston, Ontario, Canada, pp 367–370.

[30] Kelly, J. F. (2014). 3D Modeling and Printing with Tinkercad: Create and Print Your Own 3D Models. Que Publishing.

[31] Hernández-Leo, D., Asensio-Pérez, J. I., Derntl, M., Pozzi, F., Chacón-Pérez, J., Prieto, L. P., & Persico, D. (2018). An Integrated Environment for Learning Design. *Frontiers in ICT,* 5, 9. doi: 10.3389/fict.2018.00009

[32] Martínez-Moreno, J., Santos, P. & Hernández-Leo, D. (2021). Teachers' self-perception in maker education: three approaches for professional development. Zenodo. http://doi.org/10.5281/zenodo.4542765

[33] Rinke, C. R., Gladstone-Brown, W., Kinlaw, C. R., & Cappiello, J. (2016). Characterizing STEM teacher education: Affordances and constraints of explicit STEM preparation for elementary teachers. *School Science and Mathematics,* 116(6), 300-309.

[34] Hung, H., Yeh, H. (2013) Forming a change environment to encourage professional development through a teacher study group. *Teaching and Teacher Education,* 36, 153- 165.

[35] Stewart, C. (2014). Transforming Professional Development to Professional Learning, Journal of Adult Education, 2014. *Journal of Adult Education,* 43(1), 28–33. Retrieved from https://eric.ed.gov/?id=EJ1047338

[36] Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological bulletin,* 130(2), 261.