Training the 21\textsuperscript{st} Century Workforce of Early Childhood Teachers in STEM Education through an eLearning Environment

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Abstract—It is a compelling need for early childhood teachers to be trained to implement more challenging and technology-oriented methods at teaching including interdisciplinary learning approaches. Towards this end, an eLearning training program is proposed to be implemented for supporting teachers in exploring new ideas and enhancing skills related to Science, Technology, Engineering, and Mathematics (STEM Education). Based on the fact that children's interests, desires and abilities are formulated during the early years, STEM education aims to enrich their education. For this reason, STEM education should begin in the early years.

The aim of the research is the implementation of the STEM methodology (Science, Technology, Engineering and Mathematics) supported by the model of Cognitive Apprenticeship in an eLearning Environment providing a means to enhance collaboration among early childhood teachers. An autonomous electronic environment named 'apSTEM,' was designed following the principles of Cognitive Apprenticeship as a constructivist learning model, combined with the Jigsaw collaborative strategy. The proposed environment is more than a continuing training program; it is also aimed at supporting teachers to integrate technology and engineering with science and mathematics in everyday practice. This also improves the quality of work offered to students and enhances their thinking processes through providing crucial brain-building interactions early in life.

An experimental research was conducted in order to examine collaborative skills and how teachers improved their teaching skills, developing new approaches of learning (STEM Methodology). Data was collected through a rubric on the collaboration skills, such as participation in discussion through a communication tool, identification of team roles, respect, behavior and obedience to rules, leadership, consequence, participation in scenario and a questionnaire on the methodology STEM and the electronic environment. The findings revealed that teachers were able to succeed in collaboration, in supporting students to construct knowledge of the world through exploration and experimentation and in taking advantage of children's natural curiosity.

Index Terms— early childhood education, STEM, Cognitive Apprenticeship, collaborative learning

I. INTRODUCTION

The education and training of teachers and specifically early childhood teachers is an important element so as to be up to date with the skills required in a knowledge-based society. Early childhood teachers strive to equip learners with a wide range of 21\textsuperscript{st} century skills; this highlights the need for the development of more competence-centered approaches to teaching, together with greater emphasis on learning outcomes. It is argued that early childhood teachers must be trained to implement more challenging and technology-oriented methods in teaching including interdisciplinary approaches in learning. This means that teachers should have access to effective Continuing Professional Development (CPD) training programs. CPD is a lifelong process or activity based on approaches, strategies and techniques that will contribute to an increase in skills and knowledge related to learning and teaching. CPD training programs should emphasize on teaching transversal competences, teaching heterogeneous classes, and collaborating with colleagues and parents [1]. To this end, an eLearning training program is proposed to be implemented for supporting early childhood teachers in exploring new ideas and enhancing skills related to Science, Technology, Engineering, and Mathematics (STEM). This CPD STEM training provides a structured pathway to develop, keep up to date, or even specialize in knowledge and skills relevant to their occupation, so that they may continue providing high quality programs and services to children. STEM Education aims at reforming the educational process and encouraging learners to solve current problems and future unforeseeable ones [2]. It is suggested that STEM education should begin at an early age when children's interests, desires and abilities are taking shape and while being natural explorers. A critical issue is the way STEM links to the world outside and to the work that scientists do in their everyday lives. Moreover, it has been observed that a lot of researches have been done on STEM fields, were supported by the model of Cognitive Apprenticeship to enhance the collaboration [3] showing the use of this model in a learning environment [4]. The best way for a preschool teacher to teach interdisciplinarity in preschool is by using the cognitive apprenticeship [5], as an instructional design model, suitable to provide early intervention with the use of STEM fields [6]. The aim of this research is the implementation of the STEM methodology (Science, Technology, Engineering and Mathematics) supported by the model of Cognitive Apprenticeship in an eLearning environment providing a means to enhance collaboration among early childhood teachers. An autonomous electronic environment named ‘apSTEM,’ was designed following the principles of Cognitive
Apprenticeship as a constructivist learning model, combined with the Jigsaw collaborative strategy.

The proposed environment is more than a CPD STEM training program, aimed at supporting teachers to integrate technology and engineering with science and mathematics in every day practice. It also improves the quality of work offered to children and enables the students’ thinking by providing crucial brain-building interactions in early life.

The paper is organized in five sections. The literature review is detailed in Section 2 along with an introduction to Continuing Professional Development, STEM in Early Childhood and Collaborative Learning. In Section 3, the electronic environment and its design are presented. In Section 4, the experimental procedure (method and results) is detailed. Finally, Section 5 encompasses conclusions, limitations and future plans.

II. LITERATURE REVIEW

A. Continuing Professional Development (CPD) for Early Childhood Teachers

CPD training programs should encourage and support teachers throughout their careers to review their learning needs and to acquire new knowledge, skills and competence through formal, informal and non-formal learning [7]. In early childhood education, in particular, when the learners’ brain is flexible, or “plastic,” the accommodation of a wide array of environments and interactions is imperative. This implies that CPD training programs should not only emphasize the specific knowledge of a given subject but should also place emphasis on creativity, collaboration, problem solving, the ability to innovate, entrepreneurship and flexibility.

The training is now, or should be, an integral and organic part of the professional activity of teachers and ought to be aimed at both the personal, professional development and scientific support of their teaching practice. To achieve these objectives, training is necessary to establish a grid of various activities and programs of an educational and professional nature [8]. However, sometimes training programs do not meet training needs of teachers and lack clear references to specific cognitive areas. Thus, it is necessary to match training programs, in terms of interdisciplinary content, to their career [8].

B. Early Childhood Teachers and STEM

As for early childhood teachers training in new technologies and methodologies, especially in science concepts such as STEM, education will improve and will offer benefits that will enhance the training standards and expand their career opportunities [3].

STEM early childhood teachers combine problem solving and problem posing with the work plan across disciplines. Students and teachers can work together in classroom activities that develop students’ critical thinking, communication, evaluation and research skills. Teachers can only teach one subject: math, science, engineering and technology - or may combine two fields to bring in learning opportunities. STEM focuses on four levels of education: K-12, undergraduate, graduate and post-doctoral and early career stages [9].

STEM education refers to teaching and learning in the disciplines of Science of Technology of Mechanics and Mathematics. If one breaks this term down, they can witness that much of this is already happening in early childhood programs [10]. The link between early childhood and STEM is indisputable. Early exposure to STEM supports children’s overall academic growth, develops early critical thinking and reasoning skills, and enhances later interest in STEM study and careers [11].

California Stem Learning Network (CSLNet) claims that STEM education is more than just science, technology, engineering or mathematics; it is an interdisciplinary and applied approach that is coupled with real-world, problem-based learning. This bridging among the four discrete disciplines is now known as STEM [12]. A STEM-literate student is able to make great connections between school, community, work and global issues and in future they can enroll at a college in order to study and get a degree in science, technology, engineering, and math without the need for remediation. There is solid evidence that in future years, high-wage jobs will be coming from STEM fields and all employees will need to utilize these STEM skills in order to solve several problems.

Science, technology, engineering and mathematics is already happening in preschool activities. Science may be planting seeds, mixing materials together to make an experiment, or touching objects with a magnet to control the attraction. Technology and computers would be tools. In Mathematics students can measure and install the correct shapes. In Engineering children can daily plan and design structures with little teacher direction. Through asking children open-ended questions and encouraging the latter to write down their thoughts, the teacher can add an experience through the recording process [10]. Therefore, it is a compelling need to get more early preschool teachers educated in STEM.

The presented CPD training program was held through an autonomous electronic environment named “apSTEM,” that had been followed the principles of Cognitive Apprenticeship as a constructivist learning model, combined with the Jigsaw collaborative strategy. It was consisted of four courses which were divided into three phases.

The research was focused on collaboration and particularly in the collaboration skills, such as participation in discussion through a modern communication tool, identification of team roles, respect, behavior and obedience to rules, leadership, consequence and participation in scenario.

C. Collaborative Learning

Collaborative learning is defined as ‘a situation in which two or more people learn or attempt to learn something together’ [13]. It is argued that successful collaborative learning relies on effective interaction of learners. More recent studies have explored group collaboration and
support as agents in raising teacher performance [14]. It is obvious that the importance of supporting learners working on collaborative activities will encourage young students to use scientific inquiry processes in the future. Thus, a learner should become engaged in some structured forms of social interaction with the purpose of learning and knowledge processing. This means that early childhood teachers should be able to apply collaborative learning strategies and inquiry-based approaches (such as STEM methodology) in order to produce effective collaborative interactions among the learners [15]. 

Jigsaw is a collaborative strategy [16] that provides students with an opportunity to actively help each other build comprehension. In this strategy, students can be assigned to learning groups composed of varying skill levels. Each group member is responsible for becoming an "expert" at one section of the assigned material and then "teaching" it to the other members of the team. Several pedagogical advantages have been attributed to jigsaw, such as the encouragement of attention and participation of each team member in a substantial portion of an educational activity. Team members must work together as a team to achieve a common goal. Each student is dependent on others and no learner can succeed if collaboration does not occur [17].

III. METHOD

A. Research Method

This study is an action research. Generally, action research can be carried out by an individual teacher, a group of teachers working within the school, or by a number of teachers who consistently work with researchers. In this case, the action research used for the development of in-service early childhood teachers improves teaching, develops new learning methods (STEM Methodology) and enhances collaborative learning.

B. Research Question

The research question is: “Can the implementation of the STEM methodology (Science, Technology, Engineering and Mathematics) be supported by the model of Cognitive Apprenticeship in an eLearning Environment providing a means to enhance collaboration among early childhood teachers?”

C. Participants

The sample of the study consisted of 16 early childhood teachers (14 females and 2 males) who participated voluntarily. Participants assigned to the Experimental Group (N=16) followed the process of implementing the eLearning Environment named ‘apT²STEM,’ in order to acquire new knowledge (STEM Methodology) and enhance collaborative learning.

D. The eLearning Environment ‘apT²STEM’

The eLearning environment named ‘apT²STEM’ is built up in Google Sites web application and is based on the STEM methodology (Science, Technology, Engineering and Mathematics) supported by the model of ‘Cognitive Apprenticeship’ and the ‘Jigsaw’ collaborative strategy.

Google Sites offered by Google as part of the Google Apps productivity suite and is a simple and intuitive tool for creating collaboratively personal and business web sites. The ‘apT²STEM’ provides users (early childhood teachers) with a vehicle for collaborating and supporting their everyday teaching practice through an interdisciplinary educational methodology (STEM).

E. Experimental Procedure

The experimental procedure follows the model of ‘Cognitive Apprenticeship’ and the ‘Jigsaw’ collaborative strategy. Each phase consists of activities based on the STEM methodology in order to provide teachers with different collaborative application in Science, Technology, Engineering and Mathematics. It was consisted of four courses, which were divided into three phases. The phases of the design have been enriched with knowledge domain-oriented activities from STEM Methodology, on the grounds that the rationale behind its creation has been teachers’ improvement in new learning approaches. A brief description of ‘apT²STEM’ activities is illustrated in Figure 1:

Phases of the design has been enriched with knowledge domain-oriented activities from STEM Methodology.
brought about. Therefore, metacognitive development is promoted and the ground for autonomy and self-regulation is set.

Activity 3.1: Implementation of STEM methodology.
Activity 3.2: Discussion between teams and educator.

F. Instruments

The research variables for the eLearning environment ‘aptSTEM’ that have been studied were collaboration skills. Collaboration skills are measured by the assessment rubric ‘R2-COLL’. Data was gathered on-line by Google Docs rubric of collaborations skills, created by the researcher. This rubric contains (7) modules with (7) questions, which are:

M1: Participation through a communication tool with discussion and chat features
M2: Identification of team roles
M3: Respect
M4: Behavior and obedience to rules
M5: Leadership
M6: Consequence
M7: Participation in scenario

G. Results

For the statistical analysis of the results the statistical package SPSS (Statistical Package for the Social Sciences) [18] was used. Analyses of the resulting data were performed using both descriptive and inferential statistics. To assess the internal consistency of the rubric the coefficient Cronbach alpha [19], where the index value is 0.843, confirming the reliability and internal consistency of this tool (rubric R2-COLL), was employed. All statistical tests were performed on a 5% statistical significance level [20]. In order to test the relations between the ordinal variables, we used Fishers exact test, since our data was not adequate to use Pearson’s X²-test of independence (the presumptions performing Pearson’s X²-test were not met: 1. no expected cell frequencies <1 and 2. no more than 20% of the expected cell frequencies < 5) [21]. To answer the research question concerning the collaboration skills, an analysis through combinations of variables has been conducted (Table 1).

Table 1: Results from combination variables

<table>
<thead>
<tr>
<th>Fisher’s Exact Test</th>
<th>M3</th>
<th>M4</th>
<th>M6</th>
<th>M7</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2</td>
<td>5.855* (16), p= 0.058</td>
<td>4.376* (16), p= 0.165</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M5</td>
<td>8.059* (16), p= 0.007</td>
<td>0.750* (16), p= 0.007</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M6</td>
<td>4.333* (16), p= 0.096</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: *Fisher’s Exact Test.
\* Kendall’s tau-b.
\** important test in a>=0.05

An analysis deriving from the combinations of variables between Rubric ‘R2-COLL’ and specific questionnaire questions has also been conducted (Table 2).

Table 2: Variables from R2-COLL and specific questions from questionnaire

<table>
<thead>
<tr>
<th></th>
<th>Participation in Skype</th>
<th>Participation in scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to the socialization of collaboration activities</td>
<td>3.237* (16), p= 0.694</td>
<td>5.629* (16), p= 0.351</td>
</tr>
<tr>
<td>Reinforcement of Collaboration</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Participation in scenario</td>
<td>5.435* (16), p= 0.279</td>
<td>5.629* (16), p= 0.351</td>
</tr>
</tbody>
</table>

Note: *Fisher’s Exact Test.

Table 2 analyses the variables “participation in Skype” and “participation in scenario” of the Rubric R2-COLL with specific questionnaire questions “Contribution to the socialization of collaboration” and “Reinforcement of Collaboration” in order to be defined if there is a strong relation between them.

IV. CONCLUSIONS

According to the independence test between the modules (M1: Participation through a modern communication tool with discussion and chat features, M2: Identification of team roles, M3: Respect, M4: Behavior and obedience to rules, M5: Leadership, M6: Consequence and M7: Participation in scenario), it is observed that the variables found to be independent include:

- Identification of team roles does not affect respect.
- Identification of team roles does not affect good behavior and obedience.
- Consequence does not affect participation in scenario.

The correlation between the variables Leadership and Consequence has been performed. It was concluded that there was a positive correlation between the variables. The more the participants were involved and helping others, the more they were fulfilling their obligations. Although implementation of team roles did not impact respect, their behavior as well as obedience to rules and participation in the implementation of the scenario, it should be noted that the leadership factor has displayed a great relation to their consistency to their obligations.

Furthermore, four independent variables were identified from combinations of variables between the ‘R2-COLL’ rubric and specific questions that had been gathered from the questionnaire (Table 2):

- Socialization in the collaboration activities does not affect participation in Skype.
- Socialization in the collaboration activities does not affect the participation in the scenario.
- The reinforcement of collaboration does not affect the participation in Skype.
- The reinforcement of collaboration does not affect participation in the scenario.
Teachers’ participation in the program through an online environment enhanced their, collaboration and led to greater respect. Additionally, there wasn’t a single moment when a preschool teacher would feel vulnerable or anxious had he experienced difficulties in the program or in its electronic use. Being provided with the potential to create groups and communicate through electronic tools, preschool teachers provided help to each other at any time. As it happens with all data collection methods, the Internet surveys are also met with challenges. One of these is not enjoying a personal contact with the administration of the survey and not providing incentives to participate. This limitation potentially resulted in a lower response rate than would occur with other survey types. To reach a conclusion, the findings revealed that teachers were able to succeed in collaboration, in supporting students to construct world knowledge through exploration, experimentation and in taking advantage of children’s natural curiosity. Further research should examine the efficacy of ‘apT?STEM’ through implementation and evaluation procedures.

REFERENCES


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