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Planning a Science, Technology, Engineering, and Mathematics (STEM) Curriculum for Young Children: A Collaborative Project for Pre-service Teacher Education Students

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Abstract

Science, Technology, Engineering, and Mathematics or STEM is one of the important innovations currently implemented in Philippine education. This is in recognition of the importance of STEM education for the development of learner. This study focuses on how to plan a STEM curriculum for young children. It aims to present the result of a study conducted in one-semester undergraduate class on STEM for Young Children that was offered for second year and third year pre-service teacher education students. The classes were used to train pre-service teacher education students to plan curriculum and instruction for STEM for young children. The results of the study includes (1) things to consider in developing STEM curriculum, (2) criteria for selecting STEM activities, (3) content standards for STEM curriculum, (4) important skills to be developed, and (5) criteria for selecting instructional materials. Planning a STEM curriculum for young children can be an alternative program to develop gifted potentials of young Filipino learners.

Keywords: STEM, teacher education, curriculum

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1. Introduction

Science is for everyone. Prior and after the scientific revolution, various people and societies have tried their best to explore the natural world and gain deeper understanding of nature and everything in the universe. Science has always been interwoven in the activities and rituals of people in different communities. It has started as a product of what is called as *thought experiment* and curiosity to provide an explanation to basic questions about the natural world, and evolved to give birth to what is now known as *scientific method*. Early civilizations have integrated science in arts, music, tools, food production, medicine, and folk engineering works. Then and now, Science has always been an individual, social, as well as cultural activity.

The story of science cannot be completed without understanding Mathematics as a field of study. These two fields are important treasures or cultural heritage to humanity. In real-life, they are always integrated disciplines; science provides the contexts while mathematics provides the tools and skills to understand science. Like science, mathematics is an integral part of human and social activities. It is integrated in arts, music, philosophy, logic, and science. Through Mathematics, people solved problems and sought accurate explanations to almost every question and problem they found.

Science and Mathematics are also influential in the development of ideas and innovations in the field of Technology and Engineering. These two fields require Science and Mathematics to develop something, to invent, to build, to design, and to create almost everything to the level of perfection. Creativity and innovation is at the core of Technology and Engineering. People have invented these two fields to make life better and comfortable for them. From the early technology and engineering works of the ancient civilizations up to the current generation, one can always marvel on how Science and Mathematics have been used in the development of technology and engineering.

Science, Mathematics, Technology, and Engineering are always integrated in real-life context. They provide knowledge, skills, and tools to improve the quality of human life. These three fields are always present in every aspect of social and cultural activities. Thus, it is necessary to teach STEM to all students. STEM knowledge and skills could help people in improving the quality of life in every community.

This study will focus on the development of a STEM (science, technology, engineering, and mathematics) program for young children. Specifically, this study will focus on a STEM program for young children ages 5-7 (K-2). The sophomore and junior pre-service teacher education students

initiated this project as part of their training to teach STEM to young children, which is a new initiative since STEM is introduced as an area in the Senior High School program in the Philippines. The study is part of an advocacy to capture and nurture students' gifted potentials and interest in learning STEM starting at the preschool level.

STEM for Young Children

Children are naturally curious and very enthusiastic to explore their environment and discover new things. These basic dispositions demand that our pedagogical methods provide a wide range of contexts for young children to use them (Katz, 2010). A statement from the National Association for Educators of Young Children (NAEYC) underscores research that shows that the earlier we guide and support children's wonder about the world--and thereby identify opportunities for children to acquire foundational STEM skills--the more successful they are in all areas of learning later on (NAEYC).

There are various ways to increase young children's interest and motivation in science, mathematics, and engineering. It is imperative that they should see the application of science in daily life situations, perform hands-on activities that involve STEM concepts and skills, engage in making decisions and problem solving, and create innovative ideas and tools that are useful in everyday life. Young children should be exposed to the scientific process of doing things. They must experience acting and thinking like scientists, engineers, and mathematicians.

Conezio and French (2002) explained that for young children science is finding out about the everyday world that surrounds them, which is exactly what they are interested in doing every day. Children's everyday experience is the foundation for science and science in kindergarten includes a process of scientific inquiry – theorizing, hands-on, and open-ended activities and simple experiments that involve children in a wide range of developmental levels and respond to their individual strengths and needs. In science, young children learn important concepts and facts that are related to their daily life experience (Carale & Campo, 2003; Conezio & French, 2002; Meador, 2005; Tolman, 1995; Worth & Grollman 2003); that is why an interest in science can be nurtured early and easily.

Children's inquiry into appropriate experiences is not only the place to build foundational experiences for later science learning; it is also a rich environment for the development of many cognitive skills. Children learn important skills such as process skills, critical thinking skills, and life skills that are needed in coping with daily life activities (Chaille & Britain, 2002; Tolman, 1995). Science is also a context in which children can develop and practice many basic skills of literacy and

mathematics. Finally, science is a collaborative venture in which working together and discussing ideas are significant to the practice (Worth, 2010).

Real science begins with childhood curiosity – a desire to learn or to know that leads to the discovery and exploration of the environment with the teacher's help and encouragement (de Boo, 2000; Evans, 2005; Harlan & Revkin, 2004; Tolman, 1995). Therefore, responding to children's curiosity is very important in the construction and production of knowledge (Freire 1998; Shor, 1992). This sets the stage for all future learning especially in the process of scientific inquiry (Evans, 2005; Harlan & Rivkin, 2004; Lupdag, 1999). Science in kindergarten develops young children with scientific discipline and attitude – the love for knowledge, passion for innovative things, curiosity to study about nature, and creativity (Lind, 1997).

Technology is an essential contribution of Science, Mathematics, and Engineering. It has been considered as the application of Science and Mathematics and a product of Engineering Science. Technology is also regarded as an essential tool for everyday life. It could be an idea, a process, or a tool used everyday to make life better. With the demands and the nature of life in this century, technology is fast becoming more sophisticated and advanced. The invention of computer and the creation of Internet brought significant technological developments literally in all fields and areas of life.

Technology education for young children is about developing ideas, designing, inventing, and creating something, which is related to engineering science. Exposing young children in technology will allow them to examine how objects are developed, how things work, what objects or tools can be developed to address a need or solve a problem, and develop curiosity and creativity in making innovations on existing technology. Technology education for young children allows them to experience hands-on and minds-on activities that involve ideation and invention.

Engineering education is also essential for young children. Exposing them to engineering experiences long before they study in college increases the likelihood they will understand and appreciate various engineering works. Increasing their engineering knowledge is also likely to improve their interest in pursuing a degree or career in engineering. Saloma (2014) pointed out that the Philippines needs to have more engineers and scientists in order to improve its capacity in science and technology. Engineering education could yield more immediate academic benefits to students by

helping develop important skills students need to become successful. These skills include communication of ideas, critical thinking, creativity, and ability to collaborate with others.

Engineering education allows them to utilize mathematical skills and scientific knowledge to develop something, model, and analyze, and develop solutions to problems. Also, the engineering design process that includes identifying problems, evaluating options, and optimizing solutions, is important to many kinds of problem solving. Young children are also young engineers in the sense that they modify the world to satisfy their own needs and wants. Teachers of young children can take advantage of activities that regularly take place in most early childhood classrooms (such as building with unit blocks) to nurture young children's developing abilities in engineering and design. Young children can create, solve problems, experiment, test, adapt, collaborate, explain, and they can participate in the design process as young engineers (Van Meeteren & Zan, 2010).

Mathematics is also an essential subject in the curriculum. The most popular argument for Mathematics is the fact that people perform basic mathematical calculations everyday (Passe, 1999). People always use the mathematical skills of counting, estimating, calculating, comparing, sorting, classifying, problem solving, and interpreting data in everyday life. Mathematics also teaches people how to think logically by enabling people to use logical thinking in solving and understanding different issues, concerns, and problems in life (Pawilen & Manzano, 2007).

It is important, therefore, that young children should learn how to use mathematical skills and concepts in daily life. It is also imperative that the curriculum should provide experiences to young children where they can see connections and appreciate the usefulness of Mathematics with other subjects like Science, Technology, and Engineering. This will enable learners to see and appreciate the use of Mathematics as a tool or skill in learning and in doing life tasks. The National Council of Teachers of Mathematics (NCTM, 1989) advocates the idea of *mathematical connections* – that is, appreciating the integrated whole of Mathematics as well as its connections with other areas of human thought and activity, as one of the cornerstones of Mathematics curriculum standards.

2. Method

This study aims to describe and document how student teachers plan for a STEM Curriculum for young children. Curriculum planning involves situational analysis to gather data for the curriculum to be developed. Specifically, this study aims to answer the following questions:

1. What are the things to consider in planning the STEM Curriculum?
2. What are the essential curriculum standards and skills in the proposed STEM Curriculum?
3. What curriculum design will be used to organize the contents of the curriculum?

2,1, Data Gathering Procedure

The research is descriptive and it utilizes qualitative data from the result of planning sessions and discussions from two undergraduate classes. There are six phases done in conducting the study:

Phase 1: Review of relevant theories and practices. The undergraduate students discussed the theories and practices of STEM Education, after which, they collaboratively planned for a STEM Curriculum for young Filipino children.

Phase 2: Designing the curriculum framework. From the result of phase 1, the students identified the things to consider in planning a STEM curriculum for young children. This will serve as the important principles in developing any STEM curriculum.

Phase 3: Identification of essential curriculum standards and skills. From the result of phase 2, the students identified important content standards and skills that should be developed in the STEM curriculum, proposed a curriculum design, and developed sample lessons.

Phase 4: Identification of curriculum design. The student teachers discussed the essential curriculum standards and skills needed for the proposed STEM curriculum and developed an appropriate curriculum design.

Phase 5. Identification of STEM lessons and sample activities. The result of Phase 4 was used to identify STEM lessons and activities. Since classes in basic education are on vacation, the try-out was done in class. The students were divided into several groups and were asked to present their STEM lessons through demonstration teaching. Suggestions and comments were given after each presentation to improve the lessons.

Phase 6: Finalization of output. From the result of phase 5, the students revised the lessons for actual implementation.

2.2 Data Analysis

The data from the study were analyzed qualitatively. The results of discussions with the students were discussed and summarized into themes that are relevant to answer the research questions

of the study. A graphical presentation was used to illustrate the three levels of outcomes for the STEM curriculum and proposed framework for the activity-based STEM curriculum for young children.

The research participants include two sections of a course on STEM for Young Children with total 60 female students enrolled. These students are enrolled in the Bachelor of Science in Child Development Studies program of in a private college. Most of them planned to teach early childhood education and special education after they graduate.

3. Results and Discussion

The results of the study are presented and discussed based on the three research questions. Relevant ideas and important principles were summarized into key ideas that are relevant for planning a STEM curriculum for young children.

3.1. What are the things to consider in planning the STEM Curriculum?

The pre-service teacher education students spent one semester planning for the STEM contents and activities that they wish to include in the curriculum. Based on their discussion, research, and experiences, there are important things that need to be considered in designing STEM learning.

Table 1 *Things to Consider in Developing a STEM Curriculum*

• Interests of the students on the topics and activities
• Availability of materials to be used
• Appropriateness of the topics and activities to the learners
• Relevance to learners' daily lives
• Connection of the contents and activities to the K-12 Curriculum
• Integration of science, technology, engineering, and mathematics

The criteria listed in Table 1 are the summary of what student teachers think as necessary to consider when developing a STEM curriculum for young children. The criteria will ensure that the STEM curriculum will be learner-centered and mentally engaging, and will capture the interests of the students in STEM topics. The integration of science, technology, engineering, and mathematics will

ensure that the curriculum is interdisciplinary and will allow the students to develop interdisciplinary knowledge about STEM and its role and importance in everyday life. Based on the listed criteria, teachers will be able to develop curriculum standards and competencies for STEM that is relevant and responsive to the needs of the learners.

3.2. What are the essential content standards and skills in the proposed STEM Curriculum?

STEM as an interdisciplinary curriculum provides a myriad of opportunities to develop important content standards and skills useful in everyday life. It also allows the learners to explore the connection among science and other subjects, making it more relevant and interesting to learn.

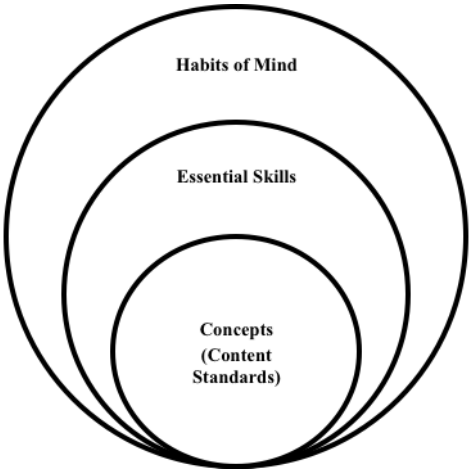

*Figure 1***.** Three Levels of Learning Outcomes for the STEM Curriculum

This study defines curriculum as a set of learning outcomes identified by the student teachers as essential for students to learn. As shown in Figure 1, there are three levels of learning outcomes that are essential for the planned STEM curriculum. This means that STEM educators should develop and design the instructional objectives and lessons based on these three levels. It should be noted, however, that these three levels are not fragmented; they are interrelated in every lesson, projects, and activities related to STEM. The goal of STEM for the learners to develop their understanding and appreciation of the different concepts of Science, Technology, Engineering, and Mathematics that is necessary in everyday life. It is also imperative that learners develop essential skills such as thinking skills, leadership skills, life skills, and creativity, among others. STEM should also develop essential habits of

mind to ensure that each learner internalizes the vales, attitudes, principles, and mental disciplines that characterize a successful person in the field of STEM.

Table 2. *Important Core Content Standards to Learn in a STEM Curriculum*

• Science Concepts: life sciences, physical sciences, chemical sciences • Technology Concepts: technology as tools, technology as ideas, technology as product of science • Engineering Design Concepts: models, designs, problem-solving, communicating ideas, planning, implementing • Mathematical Concepts: numbers, problem solving, geometry, measurement, representation of math ideas using objects, symbols, and words:

Table 2 shows the important content standards to learn in a STEM curriculum identified by the student teachers. Since STEM is an integration of four disciplines (science, technology, engineering, mathematics), the student teachers believe that it is important to select concepts that will integrate these disciplines. The primary emphasis of the STEM curriculum is on learning *concepts* rather than topics. Learning concepts will allow the children to explore more areas and topics of their interests. It provides them an opportunity to experience inquiry learning and discovery learning.

The STEM curriculum will allow the learners to experience science as a way of thinking that involves various process skills like problem-solving, predicting and inferring, observing and experimenting, sharing discoveries, asking questions, and wondering how things work. It will also allow the learners to see technology as tools, as ideas, and as product of innovativeness and creativity. Through technology, the learners will use and invent tools, and understand how things work.

In engineering, the learners will experience planning, making projects, solving problems, communicating ideas, constructing models, and designing and creating. Through STEM, the learners will be able to recognize that mathematics is not just a study of numbers and formulas. They will see Math as a tool for science and engineering, as a language, and as an important skill in everyday life.

Table 3 *Essential Skills to be Developed in the STEM Curriculum*

• Leadership Skills
• Initiative and Independent Learning
• Collaborative Skills
• Planning and Implementation
• Creating Designs and Models
• Developing Practical and Creative Ideas
• Creativity and Innovation Skills
• Scientific Reasoning and Critical Thinking
• Utilization of Technology
• Mathematical Reasoning
• Communication Skills

As shown in Table 3, the student teachers also identified important skills they think should be developed in the STEM curriculum designed for young children. Many of these skills are related to the 21st Century Skills that are considered essential for every individual to live a productive life in this century that is highly influenced by advanced technology and increasing cultural diversity.

Engaging the learners in STEM activities enables them to develop higher order thinking skills as they reason using mathematical tools and processes, and science process skills and ideas. It will provide young children with an opportunity to develop their leadership skills as they plan, collaborate and implement, take initiative and become independent. It also allows them to develop their creativity as they design models, create ideas and solutions, and innovative.

Table 4. *STEM Habits of Mind to be Developed in the Curriculum*

• Optimism in Solving STEM Problems
• Metacognition
• Creativity and Innovation
• Interdisciplinary Thinking
• Scientific Reasoning and Critical Thinking
• Curiosity to Explore New Ideas
• Interest is Understanding the Natural and Physical World
• Communicating STEM Ideas with Clarity
• Willingness to Work with Others
• Applying and Connecting Knowledge and Skills Learned to Everyday Life
• Ethical Mind and Behavior
• Persistence in Pursuing STEM Activities and Projects

These STEM habits of mind are akin to the 16 habits of mind identified by Costa and Kallick (2009) to be essential for all citizens living in the 21st century. These 12 STEM habits of mind will ensure that every learner is able to experience learning the proper attitude and mental discipline of an ideal scientist, technocrat, engineer, and mathematician. It is necessary that the STEM activities should ignite the learners' interest in learning, infuse them with new ideas and knowledge, skills, and values, and inspire them to become more interested in STEM. The student teachers agreed that a good STEM program for young children should enable them to experience being a scientist, mathematician, and engineers.

3.3. What curriculum design could be used for the proposed STEM Curriculum?

Curriculum planning activities include making decision about the curriculum design that should be used in organizing the curriculum content. During the discussion, the student teachers decided to use the *Activity-based Curriculum* as the curriculum design for the proposed STEM curriculum. The activity-based curriculum design is composed of a series of organized activities that are selected to implement a curriculum (Tanner & Tanner, 2007). These activities should allow the students to learn STEM concepts and apply various STEM skills.

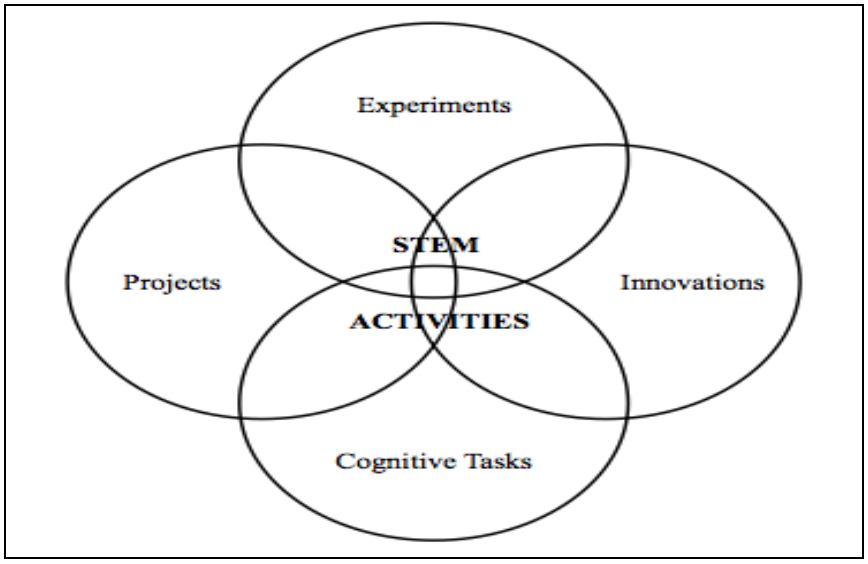

*Figure 2***.** Framework for an Activity-Based STEM Curriculum

Figure 2 shows an ideal framework for an Activity-based STEM Curriculum. The curriculum is a combination of carefully selected and planned experiments, projects, innovations, and cognitive tasks that will provide the learners with an opportunity to construct models, plan, manipulate objects, design, experiment, and solve problems. The activities also serve as a venue for collaboration and critical discussion of various STEM concepts and issues.

Table 5. *Criteria for Selecting STEM Activities*

- Encourage collaboration among students
- Provide opportunities for students to plan, design, and experiment
- Encourage all students to think creatively and critically
- Play-based
- Encourage academic discussion
- Fun, exciting, and age appropriate
- Provide opportunities for children to solve simple problems

Table 5 shows the criteria for selecting activities for the STEM curriculum. Based on the experiences of the student teachers, there are important things to consider in selecting STEM activities. Principally, the criteria are based on the theory of learner-centered education and constructivism. These theories support the development of learners' knowledge, values, and skills through lessons that will engage the learners in meaningful and enjoyable learning. The student teachers believe that the learners should experience "learning by doing." Accordingly, this will allow the learners to have a hands-on experience in the development and validation of ideas, which is essential in STEM Education.

Table 6. *Sample Lesson Activities for the STEM Curriculum*

- Constructing a model of different types of bridges using popsicle sticks
- Designing a model of an earthquake-safe building using jelly and sticks
- Designing an airplane that is balanced by coins
- Designing and building catapults
- Inflating balloons with vinegar and baking powder
- Making play dough
- Designing containers that will keep eggs whole even when thrown from a high altitude
- Modeling energy and batteries using toy cars

Table 6 shows the sample lesson activities done by the students. Designing and selecting activities are crucial to ensure that the students will enjoy, learn, and experience inquiry learning, problem-based learning, engineering science, design thinking, and mathematical reasoning. The activities are crucial in developing critical thinking, creativity, and innovative behaviors among the students. It is through these learning activities where the students will master the concepts and skills learned in STEM. It is also through the learning activities that they experience constructing new knowledge and understand various concepts and processes.

Table 7 *Criteria for Selecting Materials and Resources in a STEM Curriculum*

- Availability
- Utility
- Appropriateness to the lesson and to the level of students
- Model STEM concepts (educational value)
- Safety

Table 7 shows the criteria that could be used for selecting materials and resources for implementing a STEM curriculum. The student teachers believe that a good STEM curriculum for young children should utilize materials and other resources that are available in the community and in their homes. This will allow the learner to see the development and application of STEM concepts in real-life context. It is important that STEM should use indigenous and recycled materials to provide an opportunity for the learners to use their creativity and inventiveness.

Table 8 *Example of Local Materials and Resources for the STEM Curriculum*

- Paper box
- Old Newspapers and Magazines
- Used Bottles and Containers
- Used Plastic Straws
- Used Cans
- Wooden Sticks
- Used Plastic Cups and Glasses
- Rubber Bands
- Balloons
- Old toys
- Cloth
- Masking tape/Scotch tape
- Candies and Mallows
- Index Cards
- Crayons
- Paper Plates
- Baking Powder
- Vinegar
- Gelatin
- Scissors

• Water and soda	• Pens and pencils
• Coins	• Used bags
• Pasta and Flour	• Mallows

Table 8 shows some of the materials that they used for STEM activities. They used these materials to illustrate the concepts of balance, weight, movement of the earth, natural disasters, acceleration, and speed among others. The students believed that it is important to use materials that are available for the learners. Using indigenous materials from the community is even more desirable to be used for STEM lessons.

Insights and Lessons Learned from Planning a STEM Curriculum

Aside from the important principles and criteria that they learned and identified, during the last day of the class, the student teachers shared their reflection about the things they learned from the course. These are the results of their sharing and reflection:

1. Developing a STEM curriculum for young children can be a good innovation for children who are interested in and have gifted potentials in STEM.
2. Teachers should plan their lesson activities effectively based on research-based pedagogical principles.
3. STEM could be an enrichment program for schools with special science sections from kindergarten to Junior High School.
4. STEM lessons should be made available for all teachers and they should be trained on how to implement them in their schools.
5. Young children should experience the joy of learning how to learn by collaboratively doing STEM lessons and activities.
6. STEM is a good way for the learners to develop critical thinking and creativity.
7. Using design thinking model can be explored in designing STEM lessons and activities
8. STEM activities allowed young children to analyze and explore how things work and how tools and objects are developed.
9. Collaborative planning is important in any curricular and instructional innovation.
10. STEM curriculum could also be an appropriate curricular program for kindergarten.

4. Conclusion

Young children are always fascinated in doing science activities. They also enjoy manipulating tools and are curios to know how technology works. They are interested in the activities of engineers, and they are naturally applying Mathematics in every day. This makes STEM interesting and relevant to young children. The STEM curriculum could be an alternative program for kindergarten and for developing the gifted potentials and interests of young children in the fields of Science, Technology, Engineering, and Mathematics.

Planning a STEM curriculum is an important training for student teachers. It developed their creativity and critical thinking. It certainly enabled student teachers to develop deeper awareness and appreciation of STEM as a field of study, as an approach in organizing activities, and as a curricular program. They had a fist-hand experience of how STEM curriculum is planned and implemented through lessons and activities that reflect the interdisciplinary nature of STEM.

Finally, using the class as a venue for developing innovative ideas is important in teacher education. The student teachers experienced curriculum planning as a collaborative endeavor in an enjoyable way. They experienced how to plan, develop prototype, implement, and revise the lesson activities that they prepared. The student teachers also experience developing educational innovations that they could use in their future work as teachers of young children.

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