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RESEARCH ARTICLE

Research on STEM education with flipped classroom model in the microcontroller development course

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ABSTRACT

The study investigates the implementation of STEM education with a flipped classroom model in the microcontroller development course. The study aims to identify the needs of students and teachers of the microcontroller course within the framework of STEM education with the flipped classroom teaching model, to develop and implement STEM education with the flipped classroom model in the microcontroller course, to assess and compare students' microcontroller application ability and innovative thinking between experimental and control group. The study adopted both quantitative and qualitative approaches and was carried out in three phases; in phase 1, a needs assessment was done from 100 responded students through a questionnaire which was analyzed through means and standard deviation, while teacher needs were explored by interviewing five teachers and content analysis. In phase 2, flipped classroom model was developed with the help of a focus group interview with 6 experts. While in phase 3, the evaluation of the flipped classroom teaching model's effectiveness was studied through experimental design, and results were drawn by applying MANOVA. The data revealed seven key problems, lack of understanding of students' learning situations, ineffective teaching strategies, encumbered teaching content, teacher-centered classrooms, theoretical teaching, inadequate evaluation, and limited access to hardware. The Flipped Classroom Model can be optimized to improve STEM education and better prepare students for future challenges by providing teacher professional development, adopting diverse and student-centered teaching learning strategies, integrating real-world applications, balancing theory and practice, implementing multi-dimensional evaluation, ensuring access to necessary hardware, and introducing international perspectives.

INTRODUCTION

The construction of smart homes, transportation, and cities has improved people's lives while also making them increasingly dependent on electronic products (Perwej et al., 2019). Microcontrollers, as the core control components of electronic products, play an indispensable role in people's lives. Therefore, promoting the innovative development

of the microcontroller industry is crucial for a country's industrial transformation and technological revolution. The microcontroller industry is the "industrial blood" of a nation, and its development is very important in the global high-tech field. It can enhance the development advantages of national industries and boost international competitiveness (Khan et al., 2020).

To enhance the core competitiveness of national industry, continuous strengthening of technological innovation and talent cultivation in the microcontroller industry is essential. Firstly, basic research and applied technology innovation must be reinforced to improve innovative thinking ability. Secondly, talent cultivation and team building should be promoted to improve microcontroller application capabilities. Finally, research and development investment must be strengthened to promote independent brand building (Wan and Wan, 2013).

Kelley and Knowles (2016) highlighted that STEM education has emerged as a pivotal domain in contemporary education, given its impact on economic growth and technological advancement. However, traditional teaching methods often struggle to meet the demands of diverse learners and integrate real-world applications effectively. The Flipped Classroom Model involves flipping the conventional learning process, where students study instructional materials independently before class and engage in collaborative activities during class time. This approach aims to create a more interactive and student-centered learning environment. (Altemueller and Lindquist, 2017).

STEM (Science, Technology, Engineering, and Mathematics) education plays a vital role in preparing students for the rapidly evolving technological landscape. To enhance STEM education, innovative teaching models like the Flipped Classroom have gained attention (Kinshuk et al. 2016). The potential of the Flipped Classroom Model to address the challenges faced in STEM education calls for empirical exploration, particularly in the context of the Microcontroller Development Course. The research seeks to identify student and teacher needs, develop a suitable flipped classroom model, and evaluate its impact on students' microcontroller application ability and innovative thinking in comparison to traditional teaching methods.

Objectives of the research study

The study is directed by the following research objectives:

- To identify the student and teacher needs related to the microcontroller course within the framework of STEM education with the flipped classroom teaching model.
- To develop and implement STEM education with the flipped classroom model in the microcontroller course.
- To assess and compare students' microcontroller application ability and innovative thinking between those who learn with STEM education and flipped classroom model and those who learn using the traditional teaching method.

Research questions

- What are the student and teacher need about the microcontroller course based on STEM education with flipped classroom teaching model?
- How to develop STEM education with flipped teaching model of the classroom within the microcontroller course?
- What is the effectiveness of STEM education with flipped teaching model of the classroom to improve students' microcontroller application ability and innovative thinking ability?

LITERATURE REVIEW

Javidi and Sheybani (2010) stated that STEM education refers to a combination of science, technology, engineering, and mathematics education. Sırakaya and Alsancak Sırakaya, (2022) highlighted that through comprehensive learning of knowledge and skills in science, technology, engineering, and mathematics, scientific literacy, information literacy, and teamwork spirit enable them to have the ability and competitiveness to adapt to future career needs. The Flipped Classroom Model, presented by Bergmann and Sams (2012), is an innovative method that shifts the paradigm of traditional teaching. In this model, students learn the introductory content outside the classroom independently, while in-class time is devoted to collaborative activities, discussions, and application of knowledge, etc. The Flipped Classroom Model has been studied in various

educational contexts and resulted in improving student commitment and academic performance (Strayer, 2012; Roehl et al., 2013).

According to Murphree and Mercer (2018), the flipped classroom model is the model which "flips" the outmoded classroom model of students listening to classes and teachers explaining knowledge. That is, guiding students to explore knowledge points through discussion, cooperation, and other methods in the classroom, while autonomous learning of basic course content is conducted outside the classroom through the internet and other methods.

Tu and Liu (2016) asserted that students can learn outside the classroom based on their own learning progress and needs in order to better participate in discussions, solve problems, and apply knowledge in the classroom. Betty Love (2014) proposed to integrate STEM education into a flipped classroom teaching model, allowing students to learn basic knowledge outside the classroom, leaving more time for problem research and practical activities in class, and improving students' learning interest and learning effectiveness.

Milheim (2012) pointed out that the degree to which students meet curriculum needs directly affects their learning effectiveness and growth. Teachers need to fully understand students' needs for the curriculum and make corresponding adjustments and improvements based on students' needs to improve teaching effectiveness and students' learning experience.

Feuerborn and Chinn (2012) mentioned that teacher needs to refer to the needs of teachers for curriculum teaching, that is, the needs of various resources, skills, knowledge, and abilities needed by teachers in conducting teaching activities.

Hong (2003) stated that with the rapid development of mobile devices and cloud computing technology, more and more computing tasks and applications could be implemented through non-traditional devices such as smartphones, tablets, and smart watches. Garnham (2000) predicted that microcontroller technology would develop rapidly in the next four to five years and become the most influential great invention after personal computers and the internet.

Yang (2002) added that innovation aids in adding creativity. Zhang (2008) highlighted that thinking is a variety of cognitive activities directed towards rationality, with various forms of thinking. Similarly, Boonsong and Meesup (2020) verified the impact of flipped classrooms and project-based teaching on students' innovative thinking.

In a nutshell, the above discussion highlights the potential significance of incorporating STEM education with the Flipped Classroom Model in the Microcontroller Development Course. By addressing student and teacher needs, carefully developing and implementing the flipped classroom model, and assessing student outcomes, this research can contribute valuable insights into the effectiveness of this innovative approach in enhancing microcontroller learning and fostering innovative thinking among students.

Conceptual framework of the study

Following is the Conceptual Framework of the study.

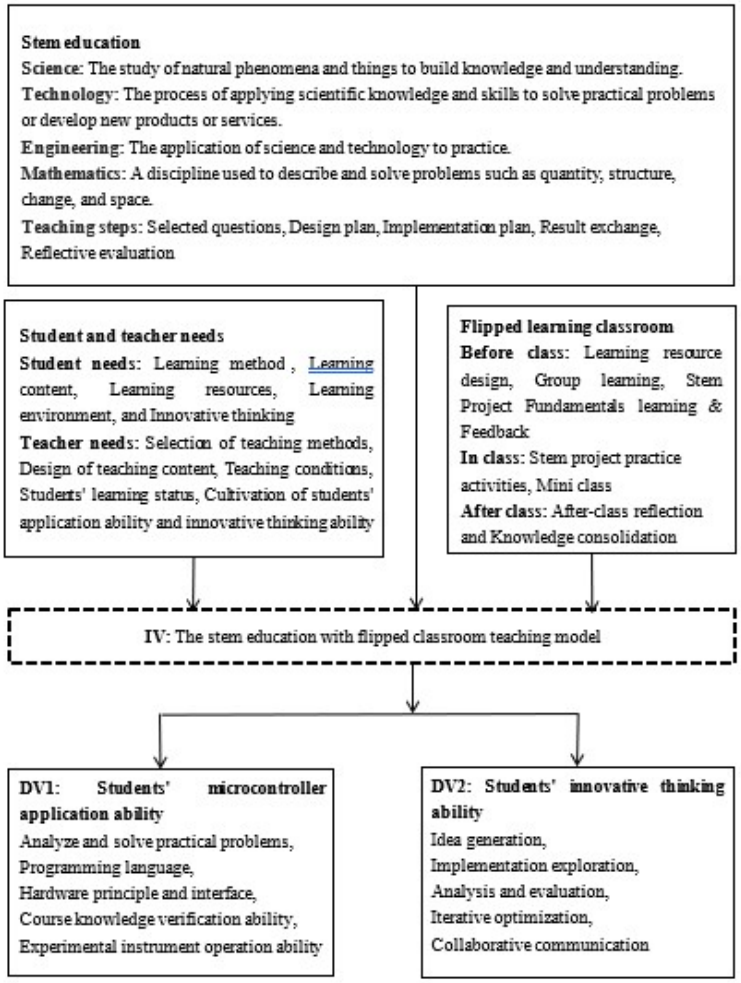

Figure 1: Research framework

RESEARCH METHODOLOGY

Study design

The study adopted both quantitative and qualitative approaches and was carried out in three phases; in phase 1, a needs assessment was done on 100 responded students through a questionnaire which was analyzed through means and standard deviation, while teacher needs were explored through interviewing five teachers and content analysis.

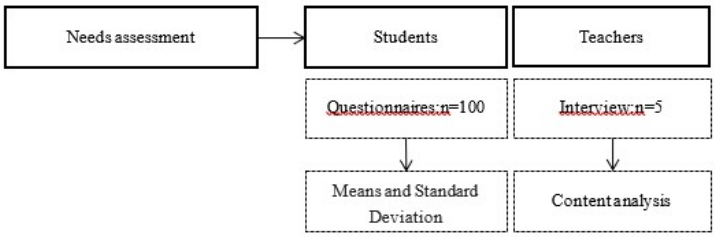

Figure 2: Needs assessment

In phase 2, flipped classroom model was developed and implemented with the help of a focus group interview with 6 experts. While in phase 3, the evaluation of the flipped classroom teaching model's effectiveness was studied through experimental design by applying the flip classroom model to the experimental group and then comparing it with those who learned using the traditional teaching method,

while results were drawn through applying MANOVA.

*Phase 1:*To find the student and teacher needs about the microcontroller course based on STEM education with flipped classroom teaching model.

In this stage, the focus is on teachers' and students' needs in microcontroller course teaching. The needs assessment is shown in Figure 2:

*Phase 2:*to develop STEM education with flipped classroom teaching model in the microcontroller course.

This stage mainly includes two aspects, one is the design of the Stem education with flipped classroom teaching model, and the other is the measurement tools analysis, as shown in Figure 3

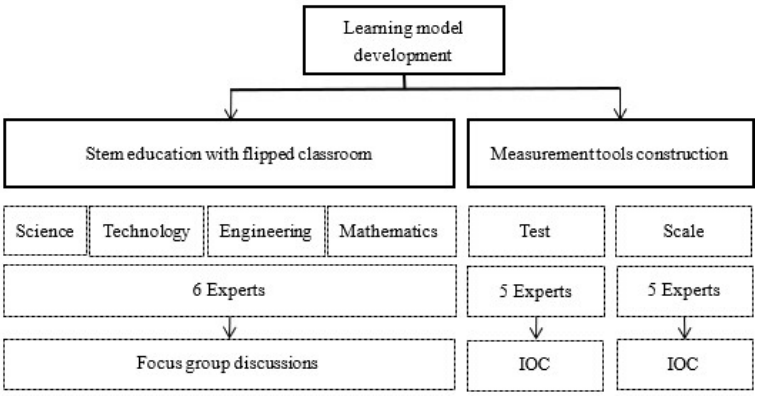

Figure 3: Learning model

*Phase 3:*To study the effect of STEM education with flipped classroom teaching model on students' microcontroller application ability and the innovative thinking ability The research implementation consists of three parts, namely, experimental design, participants, and data analysis methods. The implementation model is shown in Figure 4

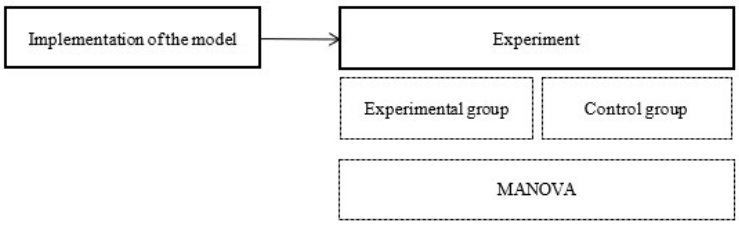

Figure 4: Implementation model

RESULTS OF THE STUDY

Most of the respondent teachers who were interviewed shared their practical teaching experience in this course in a way that there are a series of problems in the course teaching. They mentioned that teachers do not understand the students' learning situation and cannot achieve targeted teaching. Also, the curriculum teaching method is single, the teaching efficiency is not high, and it cannot promote students' autonomous ability and personality development. Furthermore, the teaching content has many knowledge points, the teaching hours are tense, and there is a lack of real project application in the enterprise industry, which is seriously disconnected from society, and it is unable to effectively cultivate students' innovation awareness and innovative thinking. Besides that, the classroom is teacher-centered, students passively accept, and there is a lack of interaction between teachers and students. The classroom is relatively dull. They further mentioned that emphasis is given to theoretical teaching while neglecting practice, especially comprehensive and design practice. So, it has not effectively improved students' practical

and innovative thinking abilities. They also add that the single curriculum evaluation mechanism cannot effectively support the achievement of curriculum ability cultivation. Respondent teachers also voiced that depending on the institution, students have limited access to hardware and equipment necessary for learning and experimenting with microcontrollers. Due to the above factors, as well as the strong practicality, high comprehensiveness, and abstract content of the course, the training effect on students' microcontroller application ability and innovative thinking ability is not significant during the teaching process, and the expected teaching objectives have not been achieved. Therefore, how to rely on various modern network information platform resources, optimize teaching content, design effective teaching models (teaching methods, teaching strategies, and teaching forms) to carry out the reform of the microcontroller course, and achieve the cultivation of students' knowledge application ability and innovative thinking ability, has become a problem that educators have been exploring and researching. There has also emerged microcontroller course in STEM education, flipped classroom teaching, and project-based teaching, and all have achieved certain results.

DISCUSSION

The study resulted that Classroom and STEM education using Microcontrollers application can make students think innovatively. Making students become innovators it is very valuable to the country. Consistent with scholars have said that innovative development has become an essential force for social development and human progress, as no country or nation can do without it in today's world of science and technology (Sweeney and Imaretska, 2015). As explored by Tu and Liu (2016), the Flipped Classroom Model enables students to learn at their own pace, fostering a deeper understanding and application of microcontroller concepts in the classroom. Developed countries worldwide have gained a leading position in science, technology, and the economy due to their emphasis on talent cultivation, especially innovative thinking talents (Z_punkt The Foresight Company the Centre for Research in Futures and Innovation, 2014). Innovative thinking refers to the using existing information in one's mind, through divergent and concentrated thinking, with the help of imagination, association, intuition, and inspiration, to generate new ideas and concepts (Runco and Jaeger, 2012). Innovative thinking contributes to professional learning and personal growth, cultivating high-level and top-notch talents and promoting talent power and technology power strategies (Barak and Dori, 2009).

Until now, the research of innovative thinking has received increasing attention from some psychologists and philosophers, and many educators have also begun to participate in it, with more and more research methods, the research results also provide a lot of valuable experience and information for talent cultivation. Among them, a large number of psychologists have emerged, and their research results still have a significant impact on current education today. For example, Guilford's "broad sense" and "narrow sense" creative views, where "narrow sense innovation" refers to the ability of people with innovative thinking ability to have universal characteristics, and "broad sense innovation" refers to the personality characteristics of innovative thinking (Xia and Yue, 2002).

In China, research on innovative thinking has also been going on for nearly a century, but if we look back, the thought of innovative thinking has already been reflected in ancient education. In China, heuristic teaching similar to the "midwifery" teaching of Socrates, a famous ancient Greek philosopher, appeared very early (Chen, 1996). In modern times, the famous educator Tao Xingzhi explicitly advocated the implementation of innovative thinking education in the field of education and carried out a series of educational practices to promote his own ideas, striving to expand innovative thinking education to various educations in society at that time (Wang and Yang, 2013).

CONCLUSION

The study concluded that in the process of building the microcontroller industry, the cultivation of education and innovative thinking is vital in the industry. Education is the foundation for technological research, innovation, and talent development, and a prosperous education system directly impacts a country's growth and development. Therefore, cultivating microcontroller application and innovative

thinking skills in students can increase the output of microcontroller professionals and promote the industry's sustainable development and core competitiveness through technological and product innovation. This approach ensures a steady supply of talent and continuous industry growth.

Recommendations

The following recommendations is given in light of the findings of the study:

- Teacher Professional Development may be emphasized by providing training and support to apprehend and address individual student learning needs. This can be achieved through workshops, mentoring, and collaboration with experienced educators.
- The adoption of diverse teaching strategies is required to be encouraged in the flipped classroom, i.e., interactive activities, group projects, and problem-solving exercises, to develop teaching efficacy and enhance students' engagement.
- Real-world project applications are to be integrated into the microcontroller development course to bridge the gap between academia and industry by involving partnerships with local companies as well as proposing internships for students to gain practical experience.
- The focus should be given to student-centered learning approaches, encouraging active participation and adopting an environment that encourages creativity and critical thinking.
- Emphasis should be given to practical hands-on experiences along with theoretical teaching. Provide opportunities for students to engage in inclusive design practice to improve their practical and innovative thinking abilities.
- A multi-dimensional evaluation mechanism is required to focus on assessing students' academic performance and the development of skills, higher-order activities, problem-solving abilities, and creativity.
- Ensure students have adequate access to essential hardware and equipment for microcontroller learning. Work together with institutions, local industries or practice virtual labs to provide wider access to resources.
- International perspectives are required to be introduced into the STEM education curriculum to expand students' understanding of global challenges and prospects in their field.

By addressing these identified problems and implementing the recommended strategies, the Flipped Classroom Model in the Microcontroller Development Course can be optimized to enhance STEM education and better prepare students for the challenges of the future.

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