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APPLICATION OF THE STEAM CONCEPT IN A FLIPPED CLASSROOM

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*Abstract***:** The interdisciplinary STEAM concept enables a learning experience by implementing a set of different skills (problem-solving, critical thinking, creativity, etc.) with the use of technology. Considering that hybrid teaching models are becoming more prevalent at all levels of education, our interest was the application of the STEAM concept in a flipped classroom (FC). Our theoretical research aims to present the possible ways and effects of applying the FC to the STEAM concept. By reinterpreting and critically analyzing several scientific research papers (theoretical and empirical) on the application of this model in the STEAM concept, we conclude that the FC can be applied effectively. Compared to the usual ways of realizing the STEAM concept by applying the FC, the potential of ICT is used more, time is used more rationally, and the development of various student skills is achieved more intensively. By using technology in the preparatory phase of the FC, before coming to school, students acquire knowledge at the level of memorization and understanding, according to Bloom's taxonomy of knowledge. This enables students to be engaged in acquiring knowledge at higher levels of Bloom's taxonomy through a variety of more complex tasks in the interdisciplinary STEAM concept. The importance and pedagogical implications of the application of a FC in the STEAM concept are particularly reflected in the possibility of increasing the efficiency of teaching.

Keywords: STEAM, interdisciplinary approach, flipped classroom, hybrid learning, effective teaching

INTRODUCTION

The use of new technological tools represents a global challenge in various aspects of everyday life. As technology and artificial intelligence continue to develop, their importance in society is increasing. Educational systems around the world face the important task of ensuring the development of specific skills and

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knowledge that will enable students to successfully cope with the challenges of the rapidly advancing technological environment. Most countries have already revised their educational goals, moving towards competency-based standards. The interdisciplinary STEAM approach to education is focused on acquiring student competencies necessary for the 21st century. This approach encourages the integration of multiple disciplines (science, technology, engineering, art, and mathematics). This contributes to a better understanding of complex problems and the development of innovative solutions. Besides a different approach, today's educational trends require the improvement or change of traditional teaching methods. How a teacher communicates knowledge unilaterally to students is less likely to make an educational impact on students, who are already familiar with the culture of acquiring various pieces of knowledge from the internet and communicating with people in various communities online (Jung & Hong, 2020:42). Using the potential of using technology in teaching and learning comes to the fore, especially by organizing blended and hybrid classes. The innovative FC teaching model has been used in the world for years, and in Serbian educational practice it represents the most recognizable concept of hybrid teaching (ZVKOV, 2021: 12).

This work was created with the desire to investigate the application of the STEAM concept in an FC based on the available literature. There is no data on this kind of research in Serbia. Most of the research in the world relates to the application of STEM concepts in an FC. Not wanting to limit ourselves only to STEM, the paper explores the application of the wider STEAM concept, which, in addition to the interdisciplinary connection of science, technology, engineering and mathematics, also includes art. The STEAM approach can achieve a more interesting and realistic learning experience because the creativity of students is included through art, which contributes to increasing the motivation of students to learn scientific content (Irwanto & Ananda, 2022). The importance of this topic is reflected in the need to make the application of the STEAM concept even more efficient, using the most modern communication and technological achievements by applying hybrid teaching models, such as an FC. We expect that the findings and results we have reached will help practitioners in applying the STEAM concept of learning, and give theorists and researchers guidelines and material for further theoretical research on this topic.

METHOD

In accordance with the main goal of the research – determining the possible ways and effects of applying the flipped classroom to the STEAM concept, the following research tasks were formulated:

1) to explore how the STEAM concept is applied in the FC; and
2) to explore the effects of applying the STEAM concept in the FC.

The research was carried out using a descriptive method and a content analysis procedure. After searching the databases of scientific papers on this topic, a reinterpretation and critical analysis of several research papers (theoretical and empirical) on the application of the STEM/STEAM concept in a FC was performed.

STEAM CONCEPT AND FLIPPED CLASSROOM

The transformation from the acquisition of scientific knowledge (through various subjects) to the STEM concept (interdisciplinary connection of science, technology, engineering, and mathematics) began in the USA, where it was identified as a significant national reform in the curricula at all educational levels to prepare students for the global economy of the 21st century (Yakman & Lee, 2012: 1072). The STEM/STEAM concept is successfully applied in some European countries, and over time it has become an integral part of the educational programs of the 21st century (Erkan & Duran, 2023: 2177). Interdisciplinary connection was extended to art and the next step was the integration of language, that is, the expansion of the concept into STREAM (Science, Technology, Reading, Engineering, Art, and Mathematics).

The interdisciplinary approach represents a holistic approach to learning that enables students to face problems that require multiple and overlapping solutions and apply everyday situations knowledge. Learning is organized on significant topics and problems, without taking into consideration the boundaries (and equal representation) of subjects (Blagdanić & Banđur, 2018: 279). Students are enabled to experience and apply real learning, they not only acquire knowledge but are also able to apply that knowledge in their everyday lives (Widya et al., 2019: 335). It is of great importance because it provides an approach relevant to real-life situations, during which students need to connect knowledge from different areas to adequately approach solving different problems in personal, professional, and social life. Communication, cooperation, critical thinking, solving complex problems, and creativity are considered key competencies of the 21st century (Hwang et al., 2015: 457). Their development is largely possible in this kind of the learning concept. A large comprehensive analysis of 225 research papers on the STEM concept of education (Freeman et al., 2014) showed that the exam results are about 6% better with the application of active learning by applying the STEM concept than in classes where active learning was applied via the traditional teaching.

During the implementation of the STEM approach, according to Erkan and Duran (2023), certain problems were observed, such as the quantity of the existing curriculum, situations when a class size is too large, the time allotted for implementation is not enough, problems related to communication between groups of students during teamwork, etc. The mentioned problems and the difficulties caused by these problems indicate that STEM education cannot be implemented effectively enough in many learning environments so there is a need for new teaching environments. Within these goals, one of the models being discussed and whose development is studied is the FC model (Erkan & Duran, 2023). In an FC, with the help of technology, online teaching and face-to-face work in school are combined. Activities, that traditionally took place in a classroom, now take place outside a classroom and vice versa (Bergmann & Sams, 2012; Bishop & Verleger, 2013). In this model, students first learn new content at home, often using online resources such as videos, multimedia presentations, or texts, and then use the time at school to apply what they have learned through discussions, projects, experiments, and other activities that allow deeper understanding and engagement. Lower levels of cognitive activities (according to Bloom's taxonomy – memory and understanding) happen at home, while at school attention is directed to higher levels of knowledge (application, analysis, evaluation, and creation) (Plageras et al., 2022; Widya et al., 2019). Instead of explaining new curricular content, teachers point students to different sources of information and encourage them to think critically about what they learn. Even an experiment a student performs according to (video) instructions from a teacher, and then records the results and tries to explain what he or she observed, can be a way of preparing students at home (Blagdanić & Banđur, 2018). The essence of the FC is to create a stimulating environment for learning by one's own abilities and interests, outside of classic classrooms (Bojović & Stojkanović, 2022).

Research confirms the successful application of the FC when learning the STEAM subjects (Bergmann & Sams, 2012; Hwang & Lai, 2017; Chaipidech & Srisawasdi, 2017; Milovanović, Cekić-Jovanović, & Ristanović, 2022). As the number of courses taught in blended/hybrid learning environments increases, researchers recommend more research on the best methods of combining technology-assisted learning with face-to-face instruction (face-to-face learning) (Dori et al., 2020). According to Bergmann and Sams (2012), the FC is not only about using online tools but also about interactive activities during learning. The student is at the center of an active learning process, while the teacher provides support where needed. The teacher's role is collaborative and mentoring, providing support through an individualized approach to students (Bishop & Verleger, 2013). The STEAM concept, which is applied in an educational environment where a student is at the center, with the effective use

of technology, can be considered today as an example of educational models that lead to the change in educational systems, just like the FC. In the same way, it can be said that the FC model and STEAM education overlap in terms of giving great importance to the use of technology and activating students in the learning process, as well as developing students' competencies for the 21st century. Physics teachers (86%) and students (78%), in the course of research in Indonesia (Puspitasari et al., 2020:179), stated that they need a STEM integrated FC e-module because it benefits the improvement of critical thinking skills. Primary school teachers, according to the research by Cekić-Jovanović and Gajić (Cekić-Jovanović & Gajić 2022: 194), realize the importance of connecting related content of different subjects for the overall development of students' personalities and the acquisition of high-quality knowledge. They have positive attitudes about STEAM education and often apply modern technology and mathematics in STEAM for the preparation of materials, research activities, and the individualization of the teaching process.

WAYS OF APPLYING THE STEAM CONCEPT IN A FLIPPED CLASSROOM

Learning scientific content is most often carried out through research and experimental teaching, where students observe phenomena and draw conclusions based on the results of experiments. This type of research experimental teaching, with interactive lectures, in a study with high school students in Thailand, was compared with the traditional learning (via textbooks and PP presentations) and with research-based teaching in the FC (via videos and computer simulations on mobile phones). The results showed that the students who studied in a traditional way had the worst results on the test, followed by students who were taught through research and experimental teaching. The best results were achieved by students who studied in an FC while using technology and research and experiment. According to the authors, the integration of the FC in inquiry-based teaching, with the technological assistance of mobile devices and simulations as learning tools, can help students understand scientific content best (Chaipidech & Srisawasdi, 2017).

Nowadays, different models of the FC (Puthanveedu, 2022) are applied in the world, and some of them are particularly suitable for using the STEAM concept: the classic FC (learning lessons at home, working on assignments in a class); discussion-oriented (assigning content for learning at home, discussions in a class); demonstration-focused (demonstration principles in content, practice in classes); group-oriented (students look at materials and teach each other in class) and others. Even a false-flipped classroom model (where students watch video lessons in class) was studies at a STEM high school in the US.

The findings indicated that teachers used an expanded understanding of the FC model by allowing their students to watch videos in class. One of the biggest challenges these teachers faced was finding and creating videos to use in their classrooms (Kirklin, 2019).

We noticed that during the experimental programs, the integration of project learning and FC with the STEAM concept was most often applied (Aydın & Mutlu, 2023, Dori et al., 2020, Plageras et al., 2022, Sholahuddin et al., 2023). In project learning, students perform a series of activities needed to solve problems, with the application of appropriate strategies. Project-based learning often involves exploring a real-world problem that does not have a single solution. The process of project learning takes place through the joint work of teams of students through the analysis and search of possible solutions, the selection of the optimal solution, the defense and explanation of the chosen solution, and the intellectual product or artifact related to the aspect of real life. A key advantage of project-based learning is that the students themselves must actively acquire the knowledge they need to acquire related to the concepts being covered, rather than simply summarizing the material from the class. (Dori et al., 2020: 3). The FC complements project-based learning by allowing students to acquire background information with educational videos presented as homework before coming to the classroom, so they can focus on applying the basic concepts from the videos in school. Students become active participants during class, improving cooperation and communication skills as they work together to solve problems, discuss ideas, and present their findings, all in line with the higher levels of Bloom's Taxonomy (Aydın & Mutlu, 2023:823). Through the STEM approach in the FC, individualized teaching can be achieved and at the same time collaborative activities can be organized.

THE EFFECTS OF APPLYING THE STEAM CONCEPT IN THE FLIPPED CLASSROOM

The research on the application of the STEAM concept in the FC took place at different levels of education by analyzing the various effects achieved. The study conducted in four elementary schools in Indonesia was inspired by students' high motivation to use devices and low motivation to learn (Kurnianto et al., 2019: 282). The FC model provided stimulation with the help of illustrative and contextual scientific video content and had a positive effect on students' motivation and inspiration for learning. (Kurnianto et al., 2019: 286; Wibawa & Kardipah, 2018: 1008). The use of technology as a learning support affects the motivation of teachers and students (Puspitasari et al., 2020:182) and helps them implement teaching and learning more effectively (Rahman et al., 2015).

Students are also motivated by the active application of knowledge in solving practical problems. This is the key in the STEAM concept so a classroom becomes a space for creative problem-solving and collaboration.

Authors Güliz Aydın and Osman Mutlu (2023: 823), conducting a quasi-experiment, compared the results of learning the science content of the 6th-grade students using project learning and project learning supported by the FC model with the results of students in the control group, who learned according to the traditional science curriculum at school. The results showed that there was a significant statistical difference between the experimental groups and the control group in the academic achievements and the durability of knowledge, but without a significant difference in student innovation (Aydın & Mutlu, 2023: 823). A STEAM-based learning approach can provide a boost to students in learning activities by improving students' scientific, technological, engineering, artistic, and mathematical skills. It is expected that using a STEAM approach to learning will prepare students to face future challenges (Albar et al., 2021: 130). The scientific literacy of students in a class that applied project-based learning in an FC was better than with students who only applied project-based learning (Sholahuddin et al., 2023: 239). All research indicators reach the high to very high category, except for the possibility of proposing a hypothesis, which is in the middle category, so it can be concluded that such teaching takes place more efficiently and effectively. The effectiveness and efficiency of the FC, with the use of the Edmodo application in teaching science and promoting active and independent learning among elementary school students, was confirmed by Sze Yean (2019: 331).

The experimental application of the FC did not show better learning outcomes in all studies. A quasi-experimental study in Turkey (Taş, et al., 2022: 335) showed no significant statistical difference between using the FC in learning the science content among the 5th-grade students on science procedural skills and student academic achievement. Applying STEM education in an FC demonstrated a contribution to the development of students' competencies for the 21st century (Fung et al., 2022: 7). According to Plageras (Plageras et al., 2022: 1), it affects the ability to learn and understand scientific concepts, cognitive skills, and promotes students' creativity. By applying STEAMification as a specifically developed model of the STEAM approach in an FC, positive effects were achieved on the development of creative thinking skills and creative innovation (Wannapiroon & Petsangsri, 2020:1654). In one study, it was determined, based on the opinion of the teachers, that students' critical thinking skills were improved by receiving the e-module, which uses the STEM integrated approach of the FC (Puspitasari et al., 2020: 182). As the most significant conclusion of the research, Dori and her colleagues (2020: 11) emphasize the strengthening of cooperation among students, which is reflected in teamwork to solve problems during class through project learning in an FC.

The results of the analysis of STEM students' perceptions of the FC show that the main advantages for students (according to their perception) are: the flexibility of learning from videos (77%), better understanding of the content (73%), advantage due to previous knowledge in the class (34%), and the motivation to study (29%). Among the disadvantages mentioned by the students are: technical problems (34%) (related to the Internet, software, etc.), the lack of immediate feedback, and that they prefer shorter videos (Ramírez et al., 2014: 121). The study conducted in China on the application of the STEAM concept in a combined online and offline teaching environment showed a significantly positive effect on student learning satisfaction, although online teaching resources showed a positive, but insignificant, effect on learning satisfaction (Cai, 2023:72). The qualitative research results (Erkan & Duran, 2023: 2175) revealed that students found the activities useful, educational and fun. According to the results obtained from the study, the use of STEM activities supported by the FC model is recommended at all levels of education (Erkan & Duran, 2023: 2175).

CONCLUSION

The STEAM concept in the FC is most often applied through project-based learning globally. For the application of the STEAM concept, the application of other FC models is suitable, such as: classic FC, discussion-oriented, demonstration-focused, group-oriented, and even the false-FC model. Applying the STEAM concept in an FC increases students' motivation and enables engagement and good cooperation between students. The results of the presented research on the application of the STEAM concept in the FC confirm greater success in student achievement on test than with the traditional teaching. The same applies to the application of research, experimental, and project teaching in STEAM without the use of a FC. Students understand the content better and achieve better results on knowledge tests in a flipped classroom, and the teaching is more effective compared to the usual methods of STEAM teaching (Cf. Aydın & Mutlu, 2023; Dori et al., 2020; Freeman et al., 2014; Sze Yean, 2019; Sholahuddin et al., 2023). An exception is the study in Turkey which did not show a significant statistical difference between the experimental groups (Taş, et al., 2022: 335). The application of the STEAM concept in an FC affects the development of students' competencies for the 21st century, especially the development of critical thinking, solving complex problems, and creativity.

Through the theoretical analysis, we came to the conclusion that the STEAM concept can be successfully applied in an FC. We can assume that its application in teaching practice would lead to positive teaching effects and learn-

ing outcomes. Also, it would be useful to organize empirical research, with the aim of examining the effects of the implementation in schools in Serbia.

REFERENCES

Albar, J., Wardani, S., & Sarwi, S. (2021). The Effect of Flipped Classroom Based STEAM Approach on Mastery of Concepts and Interpersonal Intelligence in Online Learning. *Journal of Primary Education*, 10(2), 12–140. Available at: https://doi.org/10.15294/jpe.v10i1.47301

Aydın, G. & Mutlu, O. (2023). Project-based learning and the flipped classroom model supported project-based learning's impact on academic success, retention, and individual innovation competence. *International Journal of Contemporary Educational Research,* 10(4), 823–833. Available at: https://doi.org/10.52380/ijcer.2023.10.4.532

Bergmann, J. & Sams, A. (2012). *Flip your classroom – Reach every student, in every class, every day*, Eugene, OR, USA: International Society for Technology in Education.

Bishop, J. L. & Verleger, M. A. (2013). The flipped classroom: A survey of the research, *2013 ASEE Annual Conference & Exposition*. DOI 10.18260/1-2—22585

Blagdanić, S. & Banđur, V. (2018). *Metodika nastave prirode i društva*, Beograd: BIGZ školstvo d.o.o. & Učiteljski fakultet Univerziteta u Beogradu.

Bojović, Ž. & Stojkanović, J. (2022). Izokrenuta učionica – Model hibridne nastave. *Zbornik radova Pedagoškog fakulteta u Užicu*, 25/24.

Cai, J. (2023). Evaluation of Blended Teaching in STEAM Education Using Structural Equation Model Questionnaire Technology. *International Journal of Emerging Technologies in Learning (iJET*), 18(19), 72–83. Availabe at: https://doi.org/10.3991/ijet.v18i19.43873

Cekić-Jovanović, O. & Gajić, N. (2022). Attitudes of Primary School Teachers about the Importance, Place, and Role of Modern Technology and Mathematics in STEAM Eduction, *Uzdanica*, XIX: 183–197.

Chaipidech, P. & Srisawasdi, N. (2017). A Flipped Inquiry-based Learning with Mobility to Improving Students' Learning Performance in Science: A Comparative Study. *Workshop Proceedings of the 25th International Conference on Computers in Education*, New Zealand: Asia-Pacific Society for Computers in Education

Dori, Y. J., Kohen, Z. & Rizowy, B. (2020). Mathematics for Computer Science: A Flipped Classroom with an Optional Project. *EURASIA Journal of Mathematics, Science and Technology Education*, 16(12), em1915. Available at: https://doi.org/10.29333/ejmste/9149

Erkan, H., & Duran, M. (2023). The effects of STEM activities conducted with the flipped learning model on primary school students' scientific creativity, attitudes and perceptions towards STEM. *Science Insights Education Frontiers*, 15(1): 2175–2225.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science,

engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–8415.

Fung, C., Poon, K., & Ng, S. (2022). Fostering student teachers' 21st century skills by using flipped learning by teaching in STEM education. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(12), em2204

Jung, Y., K., & Hong, H. (2020). A Theoretical Need for Applying Flipped Learning to STEAM Education. *Journal of Problem-Based Learning*, 7(1): 42–49. Available at: https://doi.org/10.24313/jpbl.2020.00213

Hwang, G. J., Lai, C. L., & Wang, S. Y. (2015). Seamless flipped learning: a mobile technology-enhanced flipped classroom with effective learning strategies. *J. Comput. Educ*, 2, 449–473. Available at: https://doi.org/10.1007/s40692-015-0043-0

Hwang, G. J., & Lai, C. L. (2017). Facilitating and Bridging Out-of-Class and In-Class Learning: An Interactive E-Book Based Flipped Learning Approach for Match Courses. *Educational Technology & Society*, 20, 184–197.

Irwanto, I. & Ananda, L. R. (2022). A systematic literature review of STEAM education in the last decade. *Science Mathematics and International Conference 2022 AIP Conf. Proc*. 2982, 040020-1–040020-9. Available at: https://doi.org/10.1063/5.0182945

Kirklin, S. M. (2019). *Muddy Flipping: Teachers' Experiences with the Flipped Classroom Model in a STEM Middle School*, Edgewood College ProQuest Dissertation & Theses, 2019. 13895475.

Kurnianto, B., Wiyanto, W., & Haryani, S. (2019). Critical Thinking Skills and Learning Outcomes by Improving Motivation in the Model of Flipped Classroom. *Journal of Primary Education*, 8(6), 282–291.

Milovanović, A., Cekić-Jovanović, O., & Ristanović, D. (2022). Prednosti primene modela izokrenute učionice u nastavi Prirode i društva. *Inovacije u nastavi*, XXXV, 2022/3, 44–62.

Plageras, A., Xenakis. A., Vavougios, D., & Kalovrektis, K. (2022). *Evaluation of a Blend Teaching Model Based on Flipped Classroom and STEAM Approach to Boost Applied Science Concepts Understanding in Technology Education*, 16th International Technology, Education and Development Conference, Spain, NTED2022 Proceedings.

Puspitasari, R. D., Herlina, K., & Suyatna, A. (2020). A Need Analysis of STEM-integrated Flipped Classroom E-module to Improve Critical Thinking Skills. *Indonesian Journal of Science and Mathematics Education*, 03(2), 178–184.

Puthanveedu, L. (2022). *7 Unique Flipped Classroom Examples and Models – Flipping 21st Century Learning*. Available at: https://ahaslides.com/blog/7-unique-flipped-classroom-examples-and-models/

Rahman, A. A., Zaid, N. M., Abdullah, Z., Mohamed, H., & Aris, B. (2015). Emerging project based learning in flipped classroom: Technology used to increase students' engagement, *3rd International Conference on Information and Communication Technology(ICoICT),* Nusa Dua, Bali, Indonesia, 212–215.

Ramírez, D., Hinojosa, C., & Rodríguez, F. (2014). Advantages and Disadvantages of Flipped Classroom: STEM Students' Perceptions. *7th International Conference of*

Education, Research and Innovation, 17–19 November, Seville, Spain, *ICERI2014 Proceedings*, 121–127.

Sholahuddin, E., Anjuni, N., Leny, & Faikhamta, C. (2023). Project-based and flipped learning in the classroom: A strategy for enhancing students' scientific literacy. *European Journal of Educational Research*, 12(1), 23 –251. Available at: https://doi.org/10.12973/eu-jer.12.1.239

Sze Yean, L. (2019). Promoting Active Learning and Independent Learning among Primary School Student Using Flipped Classroom. *International Journal of Education, Psychology and Counseling*, 4(30), 324–341.

Taş, E., Güler, H. Sarıgöl, J. Tepe, B., & Demirci, F. (2022). The Impact of the Argumentation-Flipped Learning Model on the Achievements and Scientific Process Skills of Students. *Participatory Educational Research* (PER), 9(6), 335–357.

Wannapiroon, N. & Petsangsri, S. (2020). Effects of STEAMification Model in Flipped Classroom Learning Environment on Creative Thinking and Creative Innovation, *TEM Journal*, 9(4), 1647–1655.

Wibawa, B. & Kardipah, S. (2018). The Flipped-Blended Model for STEM Education to Improve Students' Performances. *International Journal of Engineering & Technology,* 7 (29), 1006–1009.

Widya, W., Rifandi, R., & Rahmi, Y. L. (2019). STEM education to fulfill the 21st century demand: a literature review. *Journal of Physics: Conf. Series* 1317.

Yakman, G., & Lee, H. (2012). Exploring the Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. *Journal of the Korean Association for Science Education*, 32(6), 1072–1086.

ZVKOV. (2021). *Onlajn i hibridno učenje – Dugoročna stremljenja i kratkoročne smernice*. Available at: https://ceo.edu.rs/wp-content/uploads/2021/03/SMERNICEOnlajnHibridnaPripremnaNastava.pdf