The concept of "STEM education" is a set of components, namely: "science", "technology", "engineering" and "mathematics" (STEM) (SPECIALIZED STEM SECONDARY SCHOOLS, 2018). Powerful global organizations and foundations (NATIONAL ACADEMY OF ENGINEERING AND NATIONAL RESEARCH COUNCIL, 2014; THE OPEN UNIVERSITY, 2020) support the development of STEM education, forasmuch as it promotes critical thinking, fosters creativity and gives crisis thinking skills, problem-solving skills. It is a simultaneous opportunity to study, practice, work, enjoy this activity, and what is more - all this contributes to the development of innovative education and economic development. The problems of gender inequality in STEM education are also relevant; in some developed countries, they have become the subject of consideration of world organizations (PARTNERSHIP, 2020).

The purpose of STEM education is to improve educational content, to adapt education to the demands of the modern labor market. The investigations are conducted on ways of interaction of participants of STEM education, adaptation of educational programs which will promote understanding, motivation and results of pupils. Going beyond their classrooms, teachers have the opportunity to collaborate in order to enrich their own pedagogical knowledge and skills, to help participants in the educational process connect STEM subjects with the future of students in the modern world.

In the modern labor market, there is a great demand for specialists in high-tech industries; consequently, it is promising to actively implement in the education system a set of training specialists in the space of STEM (LESSEIG, 2016; ČUHLOVÁ, 2019). These are primarily qualified specialists in the field of computer technology, cybersecurity, healthcare, artificial intelligence. And it is STEM education that works to prepare graduates who are able to find their place in the modern world faster and more efficiently.

STEM education is also a way to prepare people with a creative and flexible mindset who are trained to navigate quickly in crisis situations. The combination of such knowledge and skills with the scientific base provided in the framework of STEM education forms the ability to find extraordinary good solutions. That is, the training of future specialists is underway; they are creative, they cannot only offer their own ideas, but also implement them.

**Aims**

The purpose of the research is diagnosing the prospects for the development of STEM education at secondary educational institutions and establishing the relevance of the content and evaluation of the preparatory course for teachers in the field of STEM education, as well as determining the ranking of training topics for those professionals.
Based on the purpose outlined, it is planned to perform the following research objectives, namely:

- to establish what knowledge and skills are considered effective for work in STEM education by teachers of secondary educational institutions and teachers who plan to work in the field of STEM education.
- to assess the relevance and ranking of educational topics for teachers who plan to work in order to implement the principles of STEM in the modern secondary education system.

**LITERATURE REVIEW**

The latest pedagogical investigations on STEM education have revealed that the first positions represent the thesis about the numerous advantages and importance of STEM education as a type of education for society, the economy, and the upbringing of a modern harmonious personality (BANKS, BARLEX, 2014; HUDSON, 2015). Since 2010, the idea of teaching the methodology of scientific knowledge, engineering, mathematics, technology at the level of secondary educational institution has been formed in pedagogy, combining it into one subject (HOOKER, 2017). Specially trained STEM teachers (JAYASHREE, 2017; DUCKWORTH, YEAGER, 2015) could teach in a curriculum based on the concept and ideology of STEM education. The basic reason for the integration of STEM at the level of discipline in high school is the response to the acute demand in the labor market, the professional aspirations of modern youth, the situation in the labor market and economic requirements (KELLEY, KNOWLES, 2016; AYDIN, ZHU, 2017).

The basics of curriculum formation and the structure of STEM education in secondary, higher and postgraduate education have been investigated (BOGHIAN, 2018); technical means and technological conditions of school education reform have been considered (DZVINCHUK, 2020). The degree of readiness of schools to transform curricula and carry out continuous professional training is calculated (KLOSER, 2014; HARAFONOVA, 2017), as well as to develop curricula for training students with useful knowledge and skills for the society (KIKI-PAPADAKIS, CHAIMALA, 2016; ZHERNOVA, 2018).

Since the beginning of the XXI century, the introduction of STEM education system in the educational process around the world is actively introduced with the support of the National Science Foundation (Specialized STEM Secondary Schools, 2018). Attention was focused on inclusive education, as well as the possibility of a teacher’s “cyclical” work over several years in the same classrooms. Also, the introduction of a wide range of digital courses gives students the opportunity to master the material of colleges while studying at secondary school (National Academy of Engineering, 2014).

The proposed research continues the experience of previous experiments on the problems of qualified pedagogical personnel, who have to work with STEM education at secondary school institutions (SHULMAN, 2018), the features of introducing innovations and the latest pedagogical knowledge of STEM pedagogy in working with rehabilitation and inclusive education (BURNETT, JAYARAM, 2012). Such investigations are dedicated to the introduction of new thematic plans and curricula in secondary schools, which would be adapted to the requirements of STEM (PURANIK, 2020).

In pedagogy, algorithms for the implementation of STEM education in educational institutions of all levels have been considered, as well as innovative teaching methods (SENTHILKUMAR, KANNAPPA, 2017) and the conditions for the introduction of non-discriminatory research programs, as well as the introduction of social-cultural programs in order to adapt teachers to new educational conditions and forms (BOGHIAN, 2019; SALGUR, 2013).

The issues of introducing professional training of teachers in the field of STEM education remain unresolved, as well as studying of secondary education workers’ own vision of the concept, main content and components of STEM education courses. In addition, the emergence of a new direction – STEAM education also requires consideration of its effectiveness in the modern educational paradigm.
METHODS

A set of methods has been used to effectively conduct the research. For the purpose of the experiment, diagnostic methods have been applied. In the course of the pedagogical experiment, the methods of questionnaires and observations have been also used. The experiment involved students of advanced training courses for teachers who expressed a desire to participate in the introduction of STEM guidelines in their institution (Courses of preschool teachers and teachers of the Faculty of Pedagogical and Social Education of Mykolaiv National University, Ukraine).

The method of pedagogical experiment was used for two months of 2020-2021 academic year (October - November 2020) during continuous training sessions (without leaving work). The method of the experiment has been used to determine how important the ideological guidelines are, as well as ideas about the content of the thematic component, roles, problem positions that form the modern concept of STEM education in Ukraine as an Eastern European country. The conceptual approach to the principles of STEM education and the teachers' own understanding of the content and tasks of STEM should determine the content and form of preparatory courses for secondary school teachers in the system of modern education. It has been also investigated how effective introducing STEM education courses into continuing education courses for secondary school teachers is. Methods of observation and questionnaires have been supplementary in the pedagogical experiment. Statistical methods have been used to assess the results of the experiment.

The process of defining the basic topics and assessing the systematic introduction of STEM education in the secondary educational institution with the active participation of teachers described in the academic paper has been considered in the conditions of the experiment from the standpoint of observation. The method of observation is empirical; consequently, it cannot directly determine the experience of introducing STEM education into the practice of secondary school as a systemic change.

Totally, 30 course participants have been involved in the experiment. These are employees of three educational institutions, namely: University College - G1 (College of Mykolaiv National University named after V.O. Sukhomlynsky, Mykolaiv, Ukraine), employees of advanced training courses working in parallel with secondary education institutions as teachers - G2 (employees of the department of social pedagogy and social work of MNU, employees of the department of pedagogy and inclusive education, MNU, Mykolaiv, Ukraine, teachers of secondary schools of Mykolaiv) and teachers of municipal secondary school - G3 (Mykolaiv comprehensive secondary school of I-III degrees No 26, Mykolaiv, Ukraine). All participants were divided into groups according to their place of work.

The courses are continuous, that is, they involve study and work in parallel. All respondents have been grouped into 3 groups: according to the previous questionnaire and selected topics to master. Each group consisted of 10 people. The core component in the groups is the work on drawing up curricula for STEM education at the secondary educational institution, consideration of ways to implement and organize the STEM learning process, the formation of a system of new STEM disciplines. Work on the formation of a new training course - STEM education and STEM literacy for educators and teachers of secondary educational institution was also taking into account.

- Stage 1. Preliminary questionnaires are conducted to determine the professional, gender and age characteristics of respondents who make up study groups in STEM education courses and participate in a pedagogical experiment. Training and practical material for the courses have been prepared, preliminary consultations have been held with the specialists who will lead these courses; training classrooms have been prepared and equipped.

- Stage 2. At this stage, in parallel, a survey is conducted in groups in order to assess the content and problems of the latest pedagogical research in the field of STEM education and the level of its perception and assessment in the field of school education.

- Stage 3. At the final stage, a re-survey on the relevance of educational topics for teachers who plan to work in the STEM education system is conducted, as well as...
determining the monitoring of progress, if any, in the study groups that have participated in the experiment.

Regarding the difficulties and problematic positions encountered during the research and in the process of conducting the experiment, quite significant time costs should be mentioned (2 months without separation of members of a course from work); it is impossible to determine the reasons for changes in respondents’ assessments; there are no opportunities for qualitative in-depth research.

RESULTS
It has been proposed to include three core topics in the content of the training course related to STEM education, namely: interdisciplinary correlations in the framework of STEM, innovative teaching practices for the implementation of STEM education and involvement of course participants in evaluating the effectiveness and formation of thematic blocks and priorities of the course on STEM education. It is also connected with the educational context, which would allow the professional and semantic evolution of STEM education, to which the students of the courses, secondary education teachers would be directly involved.

Table 1. Demographic and qualification characteristics of respondents (author’s development)

| Age          | G1 | G2 | G3 |
|--------------|----|----|----|
| 18-23        | 1  | 0  | 3  |
| 24-40        | 6  | 4  | 5  |
| 40-60        | 3  | 6  | 2  |

| Gender       | Female | Male |
|--------------|--------|------|
| G1           | 6      | 4    |
| G2           | 9      | 1    |
| G3           | 8      | 2    |

| Received qualification | Teacher of Maths | Teacher of Computer sciences | Information technology specialist in education | Teacher of physics and astronomy | Teacher of Biology and Ecology | “Finance”, economist | Teacher of Geography and Ecology | Social work specialist |
|------------------------|------------------|-----------------------------|-----------------------------------------------|-----------------------------|-------------------------|-----------------|-------------------------------|----------------------|
| G1                     | 3                | 3                           | 1                                             | 2                             | 1                       | 1               | 1                             | 1                    |
| G2                     | 2                | 2                           | 1                                             | 0                             | 0                       | 2               | 1                             | 1                    |
| G3                     | 1                | 2                           | 0                                             | 0                             | 0                       | 0               | 1                             | 2                    |

| Work experience (years) | 1-3 | 4-10 | 11-20 | 21 and more |
|-------------------------|-----|------|-------|-------------|
| G1                      | 1   | 6    | 3     | 0           |
| G2                      | 0   | 4    | 5     | 2           |
| G3                      | 0   | 0    | 1     | 0           |

| Total                   | 10  | 10   | 10    |

Source: Search data.

Also, a survey has been introduced on the opinion of teachers participating in the experiment on the relevance of the proposed topics for the study of STEM education.

Table 2. Rating of relevance of educational topics for teachers who plan to work in the system of STEM education (author’s development)

| No | Educational topic                  | G1 | G2 | G3 |
|----|-----------------------------------|----|----|----|
| 1. | Interdisciplinary correlations     | 80 | 63 | 68 |
| 2. | Training practices                 | 78 | 30 | 57 |
| 3. | Ability to solve problems          | 80 | 78 | 57 |
| 4. | Experience of students             | 67 | 28 | 17 |
| 5. | Skills of the XXI century          | 55 | 17 | 45 |
| 6. | Ability to work in partnership     | 24 | 54 | 16 |
| 7. | Crisis management                  | 30 | 27 | 38 |
| 8. | Technologies                       | 17 | 27 | 17 |
| 9. | Teacher’s needs                    | 14 | 16 | 15 |

Source: Search data.

Stage 2. After conducting basic training, a survey was performed for the participants of the experiment. They have been asked to choose from the list submitted for consideration the
most relevant topics, concepts, range of knowledge that, in their opinion, will be necessary in the further introduction of STEM education. The result was measured as a percentage.

Table 3. Assessment of the need for knowledge and skills required for work in STEM education and training at secondary educational institutions (author’s development)

| No. | Skills, knowledge                                | Concept content                                                                                                                                                                                                 | G1 | G2 | G3 |
|-----|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|
| 1.  | Interdisciplinary, integrated curriculum        | The curriculum in several subjects, designed for STEM education, the integration of several technological complexes to the basic concept of mathematics, physics, Formal and non-formal education, including literature, foreign languages, social studies. | 46 | 24 | 40 |
| 2.  | Training practices required for implementing the STEM field in the educational process | Teachers’ ability to make decisions, plan teaching and learning, the ability to intensify students’ activity, innovative discourse; training aimed at the interests of students. Constant awareness of teachers about the demand for reformed and ambitious teaching practices. | 39 | 23 | 35 |
| 3.  | Use of new technological discoveries            | Active involvement of pedagogical, information and communication technologies.                                                                                                                                                                                      | 50 | 18 | 35 |
| 4.  | Standards, disciplinary content of STEM subjects | New practices in teaching mathematics, natural sciences, technology, research. The complex included in the main content, curriculum, sequence of forms of education.                                                                                                                 | 28 | 25 | 22 |
| 5.  | Problems and difficulties of STEM education     | Lack of common understanding of STEM education, lack of educational resources, the emergence of a privileged position of mathematics and science over the corpus of humanities. STEM education curricula are inconsistent with school curricula, administrative system and instructional practices. | 20 | 26 | 30 |
| 6.  | Skills of the XXI century                       | Opportunities for all participants in the educational process to develop and practice such modern skills as crisis management, cooperation and collaboration, critical thinking, creativity, innovation and adjustment to work, transfer of ideas and results. | 43 | 27 | 33 |
| 7.  | Leading guidelines of STEM education           | Development of STEM literacy in the society, promotion of global citizenship and economic power of the program.                                                                                                                                                          | 34 | 28 | 40 |

Source: Search data.

Stage 3. While organizing topics for learning in organized groups, there is an active discussion of potential relationships between the responsibilities of all participants in the process of STEM education. There is a definition of the role positions to be performed by secondary school teachers, guided by the guidelines of STEM education. The presented data show that certain topics and issues are more visible and significant for the participants, and professional development in groups contributes to the development of individual thematic ratings and the concept of STEM education.

Table 4. Rating of relevance of educational topics for teachers who plan to work in the system of STEM education (author’s development)

| No. | Educational topic          | G1 (%) | G2 (%) | G3 (%) |
|-----|----------------------------|--------|--------|--------|
| 1.  | Interdisciplinary correlations | 89     | 69     | 72     |
| 2.  | Training practices         | 83     | 33     | 60     |
| 3.  | Ability to solve problems  | 83     | 83     | 60     |
| 4.  | Learning experience of students | 72     | 33     | 20     |
| 5.  | Skills of the XXI century  | 60     | 20     | 50     |
| 6.  | Ability to work in partnership | 28     | 60     | 20     |
| 7.  | Crisis management          | 33     | 33     | 40     |
| 8.  | Technologies               | 22     | 30     | 20     |
| 9.  | Teacher’s needs            | 17     | 20     | 17     |

Source: Search data.

After undergoing a system of training on topics selected by each group, one can see the relationship between the acquisition of knowledge and experience - increasing the level of STEM literacy. Ideas about the relevance of the proposed topics were formed during the implementation of STEM training activities. In addition, differences were found between
teachers of educational institutions of different forms of ownership, methodologists of courses in the perception of the importance of STEM topics.

**DISCUSSION**

The body of research on the introduction of STEM education system is based on the main components and elements identified in the scientific works of modern teachers (KELLEY, KNOWLES, 2016; IVANOVA, 2020). However, the very idea of STEM contributes to the emergence of various concepts, coordinate systems, programs and schools of STEM. And this leads to the emergence of innovations and motivates the understanding of such innovative pedagogical practices. Our research has shown that even if teachers and methodologists know about STEM, have a certain set of ideas, they differently assess a range of topics and problems in education. They can understand this innovation somewhat differently than their colleagues. This may relate to the content of STEM education introduced in secondary school, or the nature of the introduction of innovations, professional roles, and qualification guidelines.

There are studies that determine the usefulness of STEM for teachers’ training. This is primarily the stimulation of innovations introduced in secondary education, the study of supply and demand for the most relevant professions for students (BURNETT, JAYARAM, 2012; HOOKER, 2017). Our study also confirms the need to introduce STEM education in the framework of general secondary education. However, for this it is necessary to constantly train teachers, pedagogical staff, specialists in STEM education and work on creating innovative approaches, continuous improvement of pedagogical skills.

A number of researchers (HOLMLUND at al, 2018) have conducted a study of how teachers and professors of higher education interpret their own concept of “STEM” in the context of 12 criteria (Interdisciplinary, Instructional practices, Real-world problem solving, Students’ learning experiences, Twenty-first century skills, Standards, Partnerships, Challenges and problems, Equity, Technology, Value, Teachers’ needs). They have established that the completion of advanced training courses in the field of STEM forms a positive attitude to the principles of STEM in the participants of advanced training courses and contributes to the formation of the concept and own system for STEM pedagogy. In our research, 9 of the criteria proposed by Holmlund, were also used in the survey (2018). In fact, familiarizing of students with the topics and roles of STEM pedagogy as a system of learning contributes to a positive assessment of STEM (after the course the positive attitude increased by 5%) and helps teachers form their own concept and system of STEM education and implement it into the educational process at secondary education institutions.

**CONCLUSION**

The research conducted has revealed that the introduction of STEM in-service training for teachers, planning to continue working within this learning approach, affects the understanding of professional roles, knowledge structure and assessment of STEM. Collective work and a shared vision of opportunities for all students and ways to achieve them through the introduction of STEM, should be subject to a common understanding of teaching, thematic content, curriculum, evaluation criteria and developing a school structure. Prioritization in the implementation of STEM education, constant support of dialogue between interested parties from different contexts and professional roles, professional development contributes to the development of effective training programs and attributes of STEM.

In the course of the research, teachers in the field of secondary education have assessed the need for a system of knowledge and skills that are necessary for work in STEM education. Students of advanced training courses, presented in the research, had different impressions about the structure and systematic approach to STEM education. However, at the end of the experiment, this vision has become more systematic and harmonious, provided the implementation of this educational system can show prospects for further implementation of STEM education, provided that each institution can determine its own content, priorities and guidelines in approaches to STEM in secondary education.

The practical significance of the research lies in continuing the implementation of STEM education guidelines in the system of Eastern European secondary education, as well as
continuing the study of ratings and assessments by educators of the content, structure and guidelines of STEM education. Thus, according to investigations of Specialized STEM Secondary Schools (2018), in the traditional American education system (without the introduction of STEM), only 10% of eighth-graders achieve high results in the international TIMSS exam, while in countries where STEM education is active, things are better: in China, 25% of 8th graders and 32% in Singapore have achieved advanced level of science in the TIMSS exam.

The results obtained during the experiment, namely: improving the attitude of educators to the guidelines of STEM education (increasing the positive attitude by 5%) also raise issues about the possibility of differences in understanding the concept of “STEM education”, building of one’s own innovative practices on the basis of one STEM concept, which are created and understood in accordance with the requests of a particular educational institution. Successful examples of STEM education and ways of adapting a single common definition of STEM to different visions, concepts should be further investigated and explored. Attention should also be paid to the development of a new direction - STEAM education, where special attention is focused on the artistic component, which should also be part of such an educational approach.

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**Stem education in general secondary educational institutions**

Educação Stem em instituições de ensino médio em geral

Educação Stem en instituciones de educación secundaria general

**Resumo**

O objetivo do trabalho acadêmico é estabelecer a relevância do conteúdo e avaliação do curso preparatório para professores da área de educação STEM, bem como determinar a classificação de temas educacionais para os profissionais que pretendem atuar no sistema de educação STEM, para identificar os conhecimentos e habilidades necessários para trabalhar na educação STEM. A pesquisa da educação STEM é promissora, bem como a identificação dos conceitos mais eficazes da educação STEM, a formação de cursos de formação eficaz a fim de melhorar a qualificação de PROFESSORES na área do ensino médio. Promete também trabalhar a introdução dos princípios da educação a VAPOR no sistema educacional moderno na Europa Oriental, onde os conhecimentos e habilidades da esfera artística são adicionados à lista das principais áreas educacionais.

**Keywords:** STEM secondary school. STEM skills. STEM abilities. Vocational education. STEM education.

**Palavras-chave:** Escola secundária STEM. Habilidades STEM. Competência STEM. Ensino Vocacional. Educação STEM.

**Abstract**

The purpose of the academic paper is to establish the relevance of the content and assessment of the preparatory course for teachers in the field of STEM education, as well as to determine the rating of educational topics for those professionals who plan to work in the STEM education system; to identify the knowledge and skills needed to work in STEM education. Research of STEM education is promising as well as further identification of the most effective concepts of STEM education, the formation of effective training courses in order to improve STEM qualifications of teachers in the field of secondary education. It is also promising to work on the introduction of the principles of STEAM education into the modern education system in Eastern Europe, where knowledge and skills of the artistic sphere are added to the list of main educational areas.

**Keywords:** STEM secondary school. STEM skills. STEM abilities. Vocational education. STEM education.

**Palabras-clave:** Escuela secundaria STEM. Habilidades STEM. Competencia STEM. Enseñanza profesional. Educación STEM.

**Resumen**

El objetivo del trabajo académico es establecer la relevancia del contenido y la evaluación del curso preparatorio para los profesores en el campo de la educación STEM, así como determinar la calificación de los temas educativos para aquellos profesionales que planean trabajar en el sistema educativo STEM; identificar los conocimientos y habilidades necesarios para trabajar en la educación STEM. La investigación de la educación STEM es prometedora, así como una mayor identificación de los conceptos más efectivos de la educación STEM, la formación de cursos de formación eficaces con el fin de mejorar las calificaciones STEM de los profesores en el campo de la educación secundaria. También es prometedor trabajar en la introducción de los principios de la educación STEAM en el sistema educativo moderno de Europa del Este, donde los conocimientos y habilidades de la esfera artística se añaden a la lista de las principales áreas educativas.

**Palabras-clave:** Escuela secundaria STEM. Habilidades STEM. Competencia STEM. Enseñanza profesional. Educación STEM.