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LEARNING STARTUPS AS A PROJECT BASED APPROACH IN STEM EDUCATION

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Abstract: *The paper is devoted to the issues of the project-based approach in STEM/STEAM education. STEM education (Science, Technology, Engineering, Mathematics) is an educational trend under conditions of which the curriculum includes enhanced natural science component with the use of innovative technologies. STEAM is a way to take the benefits of STEM by integrating it in and through the arts. The authors analyse the development of STEM/STEAM-education in Ukraine, compare competence level of educators and their level of using principles of STEM/STEAM education. The paper considers interdisciplinary aspects of STEM/STEAM education, in particular, implementation of robotics and 3D technology into the learning process as an important component of STEM education. The paper addresses the issue of gender equality, namely, wide involvement of girls and women in the IT field, STEM education in particular. The solution for attracting more women and girls to the STEM can be realized via incorporating Art and Design to the equation - to transform STEM into STEAM. The authors construct the model of engaging the Art component in creating the science-based methodological training system. The research also considers Learning StartUps as a project-based approach in STEAM education. The authors present examples of implementation of the project-based method in teaching 3D technology via Learning StartUps. Besides, the research shows how to involve Art and Design components in STEM education.*

Keywords: STEM/STEAM Education, Project-Based Learning, Learning StartUp, Robotics, 3D technology.

INTRODUCTION

The world where our children live and learn is rapidly changing. STEM education is one of the tools for training future specialists. STEM education is supported at a very high state level in developed countries (Tuzikova 2013).

The future is here, and it requires from us and our children to be well-versed in science, technology, engineering and mathematics (STEM). On the one hand, STEM education is the basis for training of specialists in the field of high technology.

On the other hand, STEM is becoming an increasingly important part for basic literacy in today's knowledge economy. Many countries (such as Australia, the United Kingdom, Denmark, Israel, China, Korea, Singapore, the United States and Japan) are developing national STEM education programmes.

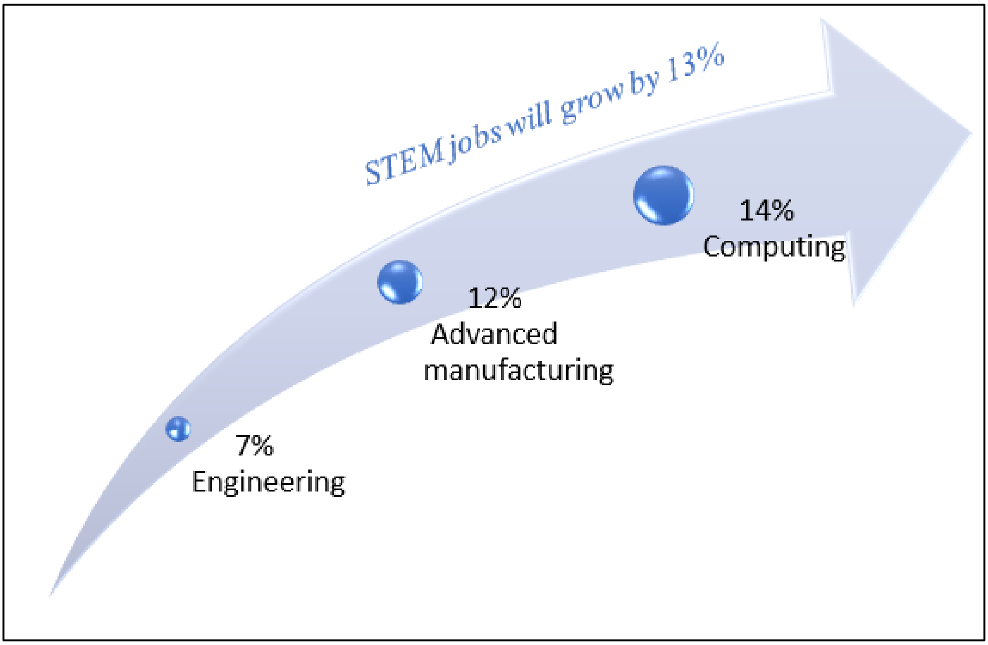

Figure 1. Estimated growth of STEM jobs between 2017 and 2027 in the USA
Source: Own work based on Education Commission of the States (http://vitalsigns.ecs.org/state/united-states/demand, accessed on 20 July 2019)

The survey of leading employers from around the world has contributed to the ranking of 10 high-demand competences up to 2020 with a prominent role in the ability and willingness to complex problem solving, critical thinking, creativity, management, coordination, cooperation, reflection, decision-making, service orientation, negotiation and cognitive flexibility. (Hassan, 2001).

The increase of all these high-demand competences is closely related to the STEM approach.

Forecast estimates show that in the period 2017-2027 the total number of STEM jobs will be increasing by 13%, compared with 9% of non-STEM jobs, especially in the sector of computing, engineering and advanced manufacturing (Figure 1). STEM occupations now account for 7% of all jobs across the Union, and the demand for STEM competences keeps growing.

However, in many parts of Europe, employers have difficulties hiring people with proper STEM skills, particularly ICT professionals. And the latest PISA data show that more than one in five 15-year olds in Europe are functionally illiterate in reading, maths and science. So, to keep Europe growing, we will need one more million researchers by 2020 (http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=key).

Unfortunately, Ukraine also has serious problems in this sphere. The Ukrainian innovation indicator as well as the level of technological availability of the labour force is one of the lowest compared with the rest of indicators of the country's competitiveness. These indicators are characteristics of the post-Soviet countries.

At the same time, innovation and modernized education and training are key priorities of the Europe 2020 strategy (Joint Report of the Council and the Commission on the implementation of the strategic framework for European cooperation in education and training (ET 2020), Official Journal C 417/25 of 15.12.2015). Building capacities and developing innovative ways of connecting science and society are priorities not only for many EU countries, but also for Ukraine. Schools are on the frontline in addressing this skills gap and mentioned above high-demand competences shortage by offering students the opportunity to learn STEM subjects to open up new career opportunities in existing and newly emerging sectors. These skills need to be developed from an early age. Schools should motivate children, with a special emphasis on girls, to learn maths and science. And we must help them to imagine working in these fields.

So, training future school teachers is strongly needed for many EU countries, and also for Ukraine.

National Pedagogical Dragomanov University introduces STEM approaches to the teaching-learning process too. There is preparation of the future Computer Science teachers via STEM approaches at the Faculty of Informatics. Also there are robotics laboratory and 3d printing laboratory to support STEM disciplines.

Research Focus: The focus of the research is on the project-based approach in STEM/STEAM education and interdisciplinary aspects of STEM/STEAM education, in particular the implementation of interdisciplinary links between STEM subjects, robotics and 3D technology. The research also considers Learning

StartUps as the project-based approach in STEM/STEAM education and shows examples of implementing the project-based method via Learning StartUps.

Research goal. Analysis of the implementation of STEM/STEAM education in Ukraine; comparison of the competence level of educators and their level of using STEM/STEAM education principles. Statement of the need in implementation robotics and 3D technology into the learning process as an important component of STEM education via Learning StartUps.

This paper addresses the following questions:

- analysis of the theoretical research background;
- analysis of the STEM/STEAM education as the most important educational trend among educators;
- rationale for importance of project-based approaches in STEM/STEAM education;
- comparison of the competence level of educators and their level of using STEM education principles;
- analysis of the StartUps in general;
- statement of the need in implementation of Learning StartUps as the project approach in STEM education.

The research also considers real-world examples of the implementation of Learning StartUps as the project-based approach in STEM/STEAM education.

Research methods. The authors use the following research methods and tools for the investigation (2017-2019 years):

- document and content analysis;
- analysis of the research papers;
- survey of the Ukrainian educators;
- learning process observation;
- experimental research of implementation of the project-based method in teaching 3D technology via learning StartUps;
- comparing of the research results.

342 Ukrainian educators (PhD students in the field of education, school teachers and university teachers from different Ukrainian regions) have taken part in the questionnaire. The questionnaire was designed during the project purposed to determine the competence level of educators and their level of using STEM/STEAM education principles.

42 Ukrainian students from the Faculty of Informatics (National Pedagogical Dragomanov University) have been involved in the experimental research. There were the Computer Science students (14 persons) and future Computer Science teachers (28 persons).

1. THE THEORETICAL BACKGROUNDS OF THE RESEARCH

1.1. STEM/STEAM education as the most important educational trend

STEM is a concept and educational system used by developed countries in various educational sectors to develop the skills needed for children and young people to be successful in the 21st century and contribute to the innovative development of the country as a whole. This concept originated on the request of business (primarily large corporations), which needed the most advanced professionals (Morze, Strutynska, & Umryk, 2018). The concept has involved a combination of different sciences, technologies, engineering and mathematical thinking (Figure 2).

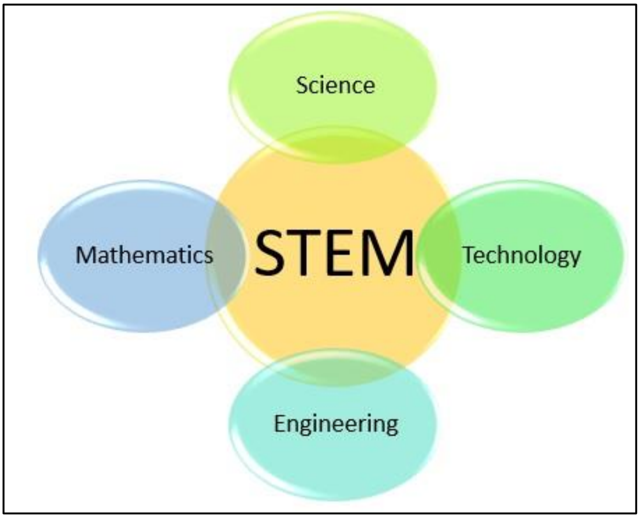

Figure 2. STEM education
Source: Own work

Interdisciplinarity is very important for STEM education. Interdisciplinarity in education is considered a pedagogical innovation (Volodchenko, Stryzhak & Khrapach, 2016). A key pedagogical problem of the development of STEM-oriented curricula is related to the component integration technology. On the one hand, this is about close disciplines. On the other hand, they are independent ontologies. Science is a way to know and understand the world around. Technology is a way of improving the world that is sensitive to social changes. Engineering is to create and improve devices to solve real-world problems. And mathematics is to describe the world, "analysis of the world and real-world problems in terms of numbers" (Meeth, 1978).

STEM education is based on the use of tools and equipment related to technical modelling, energy, electrical engineering, computer science, information and communication technologies (ICT), scientific research in the field of energy saving technologies, automation, robotics, intelligent systems, radio engineering, radio electronics, radio electronics, aerospace, etc. (Barna & Balyk, 2017).

The foreign experience shows that the introduction of STEM education is changing the economy of the country as a whole, making it more innovative and competitive. According to relevant research, attracting only 1% of the population to the STEM professions can increase the country's GDP to $ 50 billion. The need in STEM professionals is growing two times faster than in other professions as STEM develops inclinations to research and creative activity, experimentation, team work skills, contributes to the formation of analytical, critical and innovative thinking (Institute of Education Content Modernization, 2018). In addition, it is predicted that 75% of the emerging professions will require STEM skills (Balyk, Barna & Schmiger, 2017).

Ukraine has great potential for the development of STEM education. This is evidenced by the materials of the World Economic Forum (Position of Ukraine in the Global Competitiveness Index 2017-2018, 2018) In particular, according to the quality of maths and science education, Ukraine is 27th of 137 countries (the statistics for 2017-2018).

Now the Ukrainian education is in the process of developing new standards and the concept of a new school. However, despite the fact that STEM approaches are implemented in many Ukrainian educational institutions, nowadays it is mainly out-of-school STEM education, i.e., various Olympiads of Natural and Mathematical Direction, activities of the Small Academy of Sciences, various scientific competitions and events for students (Intel Techno Ukraine, Intel Eco Ukraine, Ukrainian Festival of Innovation Projects "Sikorsky Challenge"), science picnics, hackathons, etc.

Therefore, reforming the natural-mathematical and engineering education on the basis of adaptation of foreign experience and proven practices of STEM education implementation is urgent (Barna & Balyk, 2017).

Some steps have already been taken in Ukraine. In particular, in 2015, STEM education coalition was formed in Ukraine. Key objectives of the coalition are (Memorandum on establishment of STEM-education Coalition, 2015):

- vocational guidance;
- implementation of programmes on innovative teaching methods in educational institutions;

– providing pupils and students with opportunities to conduct research and experimental work with the use of the modern equipment;

– competitions and Olympiads for self-realization;

– development of the international cooperation.

The results of the conducted research state that now STEM education is an educational trend. The research was conducted by the authors in two stages at an interval of one year by interviewing the Ukrainian target group educators (University teachers, school teachers, PhD Students in the field of education and students (future teachers) from different Ukrainian regions) to determine their willingness to integrate STEM education principles into the learning process.

159 Ukrainian educators have taken part in the first survey (during 2 months – July-August 2018). This was the first stage of the research.

It is important to note that the largest group of respondents are belonging to Computer Sciences and IT-related fields (71,8% of the participants). The distribution of respondents by educational role is shown in Figure 3.

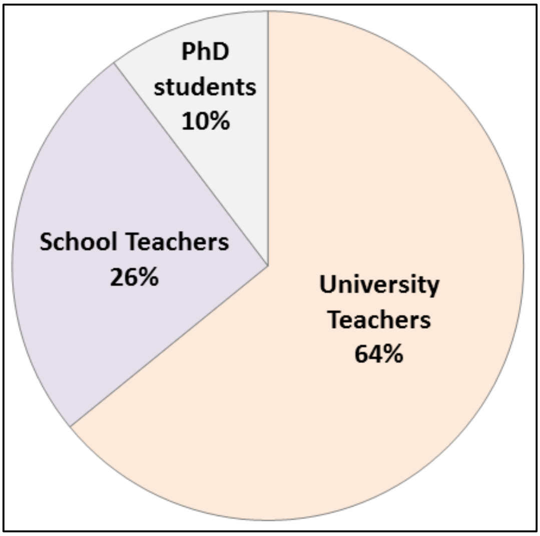

Figure 3. Distribution of respondents by educational role (2018 year - first stage of research)
Source: Own work

As we can see from Figure 3, the largest group of respondents is University teachers (64% of the participants –102 people). The number of school teachers is 41 people (26% of the participants). The smallest group of participants is PhD students in the field of education (10% of the participants – 16 people).

183 Ukrainian educators have taken part in the next survey (during 3 months – April-June 2019). This was the second stage of the research.

The largest group of respondents are belonging to Computer Sciences and IT-related fields (71,6% of the participants). The distribution of respondents by educational role is shown in Figure 4.

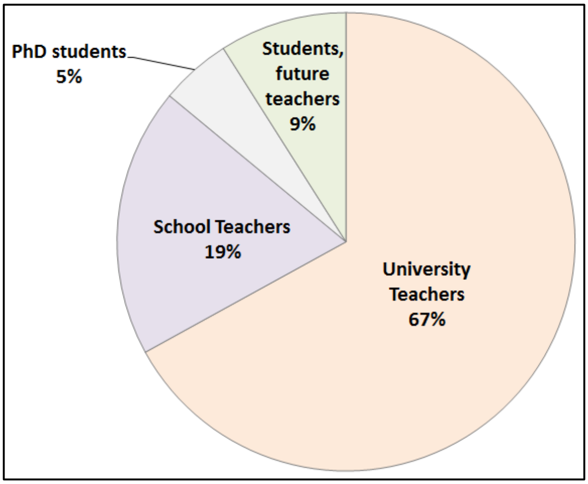

Figure 4. Distribution of respondents by educational role (2019 year - second stage of research)
Source: Own work

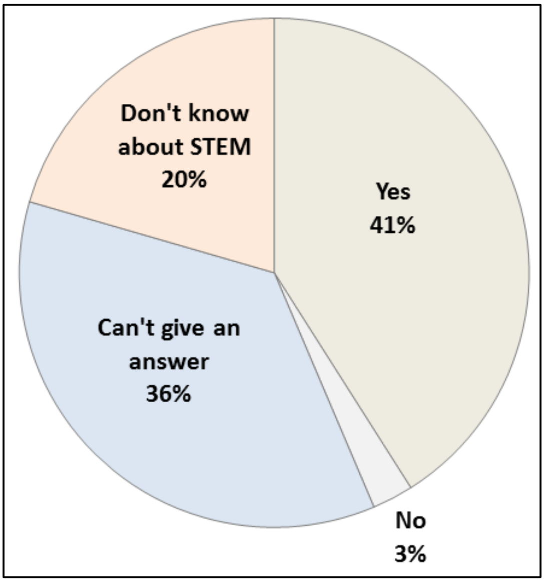

Figure 5. Survey responses on necessity to implement STEM education in Ukrainian educational institutions (2018 - first stage of the research)
Source: Own work

As we can see from Figure 4, the largest group of respondents is University teachers (67% of the participants – 123 people). The number of school teachers is 35 people (19% of the participants). The smallest groups of participants are PhD students in the field of Education (5% of the participants – 9 people) and students/future teachers (9% of the participants – 16 people).

The online questionnaire has been elaborated in the Ukrainian language by using Google Forms for gaining data on the Ukrainian educators' views and attitudes towards using the principles of STEM education in their professional activity. We have guaranteed participants that only anonymous data would be shared. Some important questions from both surveys are shown below.

Q.: *Do you think it is necessary to implement STEM education into the Ukrainian educational institutions?* (this question is from both surveys)

Survey responses on necessity to implement STEM education in the Ukrainian educational institutions are shown in Figure 5, Figure 6 (2018) and Figure 7, Figure 8 (2019):

Analysis of the data in Figure 5 has shown that probably most respondents do not have enough information about STEM education, because 20% of the participants do not know about STEM and 36% cannot answer this question (56% total).

Survey responses on necessity to implement STEM education in Ukrainian educational institutions distributed by educational role are shown in Figure 6 (2018 – first stage of the research).

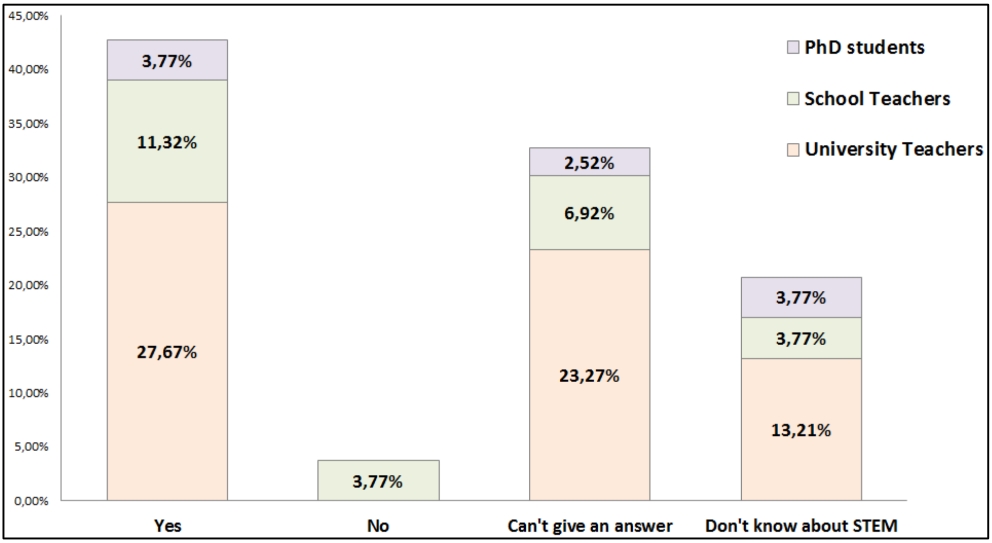

Figure 6. Survey responses on necessity to implement STEM education into Ukrainian educational institutions distributed by educational role (2018 year - first stage of research)
Source: Own work

Analysis of the data in Figure 7 has shown that probably most respondents still do not have enough information about STEM education, because 17% of the participants do not know about STEM and 24% cannot answer this question (41% total).

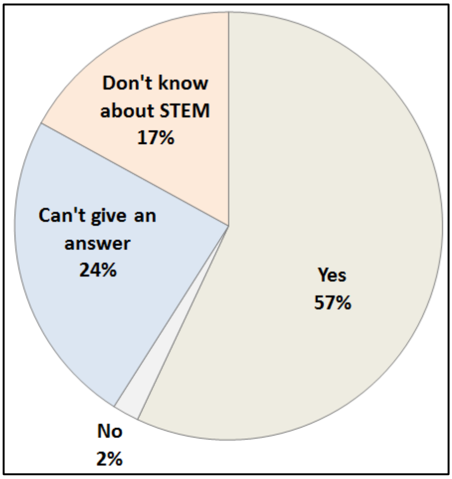

Figure 7. Survey responses on necessity to implement STEM education in Ukrainian educational institutions (2019 - second stage of the research)
Source: Own work

Survey responses on necessity to implement STEM education in Ukrainian educational institutions distributed by educational role are shown in Figure 8 (2019 – second stage of the research).

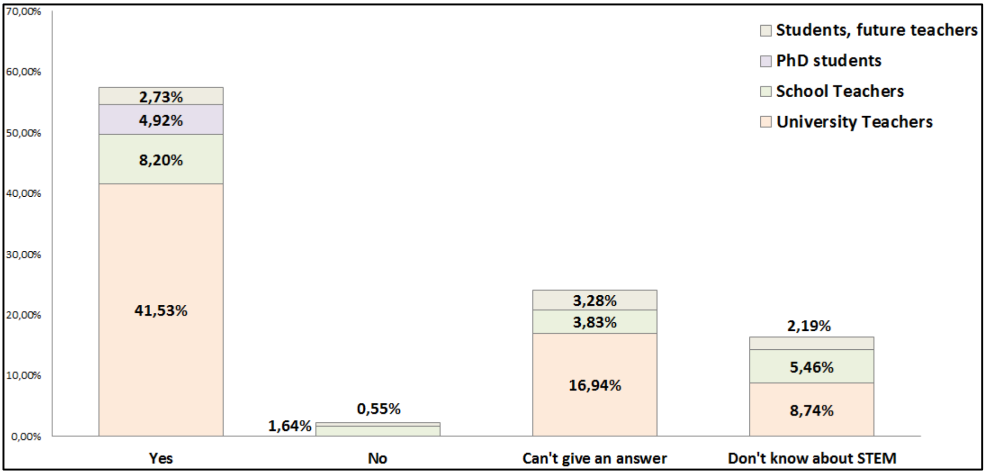

Figure 8. Survey responses on necessity to implement STEM education in-Ukrainian educational institutions distributed by educational role (2019 - second stage of the research)
Source: Own work

Comparing the results of both studies (in Figure 5, Figure 6 and Figure 7, Figure 8), we can make a conclusion about increasing readiness level of using the principles of STEM education, because more and more educators consider the necessity to implement STEM education into the Ukrainian educational institutions (from 41% in 2018 to 57% in 2019). At the same time, the research results (2019 year) as seen in Figure 7, Figure 8 show that 17% of respondents don't know about STEM, which is 3% less than the results of the previous survey (2018). These results are indicative of an increased interest in implementation STEM education in Ukrainian educational institutions in general (see in Figure 5, Figure 6 and Figure 7, Figure 8).

Also, our second stage of the survey (in 2019) shows how many respondents already use the STEM education principles in their professional activities (see below).

Q.*: Do you use the principles of STEM education in your professional activity?* (this question is only from the second survey of 2019 year)

Only 18% (33 out of 183 respondents) answered in the affirmative. The survey responses regarding using the principles of STEM education in their professional activity (distributed by educational role) are shown in Figure 9:

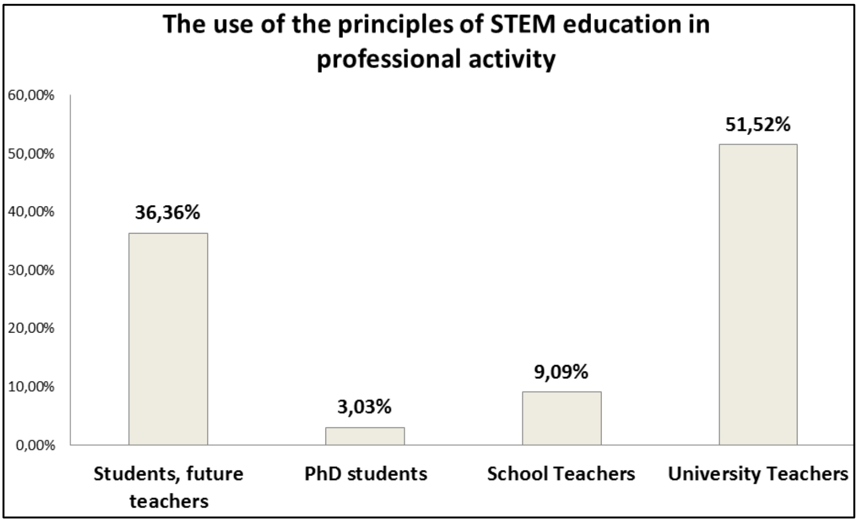

Figure 9. Survey responses regarding using the principles of STEM education in their professional activity distributed by educational role (2019 - second stage of the research)

Source: Own work

Thus, based on the abovementioned research, we can conclude that there is a need in making the Ukrainian educators familiar with the principles of STEM education, development of appropriate methodological materials for their retraining and advanced training. It is important for future teachers to include course modules related to teaching students with the use of STEM education principles. A significant number of affirmative answers (regarding their use of the principles of STEM education in their professional activity) among students and future teachers (36.36% - 12 people) are due to the fact that the majority of the respondents are master students employed in schools.

Let's consider interdisciplinary characteristics of STEM education in more detail. It is also important to involve the rapidly developing spheres to the main components of STEM education (science, mathematics and technology). We mean such areas as robotics and 3D technology. Robotics and 3D technology are versatile educational tools that are suitable for all ages (from elementary students to university students and academics). The use of educational robotics and 3D technology makes it possible to identify (at an early stage), students' technical inclinations and to develop them in this direction and in the direction of formation of STEM competences as a whole. Therefore, there is an issue of training specialists in the field of robotics and 3D technology, and in particular, training of future robotics teachers.

Analysis of recent research and publications is provided below. Despite the fact that at present there are many works (devoted to the use of STEM education) by both domestic and foreign scientists (N.R. Balyk, O.V. Barna, S.M. Brevus, V.Y. Velychko, S.A. Halchenko, M.A. Gladun, L.S. Globa, K.D. Huliaiev, S.M. Dziuba, V.V. Kamyshyn, E.Y. Klimova, O.B. Komova, O.V. Lisovy, N.V. Morze, L.H. Nikolenko, R.V. Norchevsky, M.A. Popova, V.V. Prychodniuk, M.N. Rybalko, O.Y. Stryzhak, I.S. Chernetsky, H.P. Shmyger, M. Harrison, D. Langdon, B. Means, E. Peters-Burton, N. Morel, J. Confrey, A. House, etc.), theoretical analysis of scientific works of leading researchers in the field of education and review of their experience (Morze, Ghladun & Dziuba, 2018) could show a necessity of creating a scientifically grounded methodological system for teaching of Basics of Robotics and 3D printing as a component of STEM education (Figure 10).

Considering STEM education as a science, mathematics and technology training, we should not forget also about the humanities. When this is about STEM education, there is often the question of gender equality while notice fields only for male or female. From an early age, girls and boys consciously and unconsciously prepared for different activities, interests and skills.

On the one hand, gender equality is a key priority set in the Member States and Associated countries in the European Research Area. The study conducted by the UNESCO Institute of Statistics shows that only 28% of the world's researchers are women (*en.unesco.org/genderequality, accessed on 20 July 2019*). That's why it is important that EU has the 'Women in Research and Innovation' campaign, which is a part of a wider strategy for gender equality in research and innovation (EU Prize for Women Innovators, gender equality in Horizon 2020 etc).

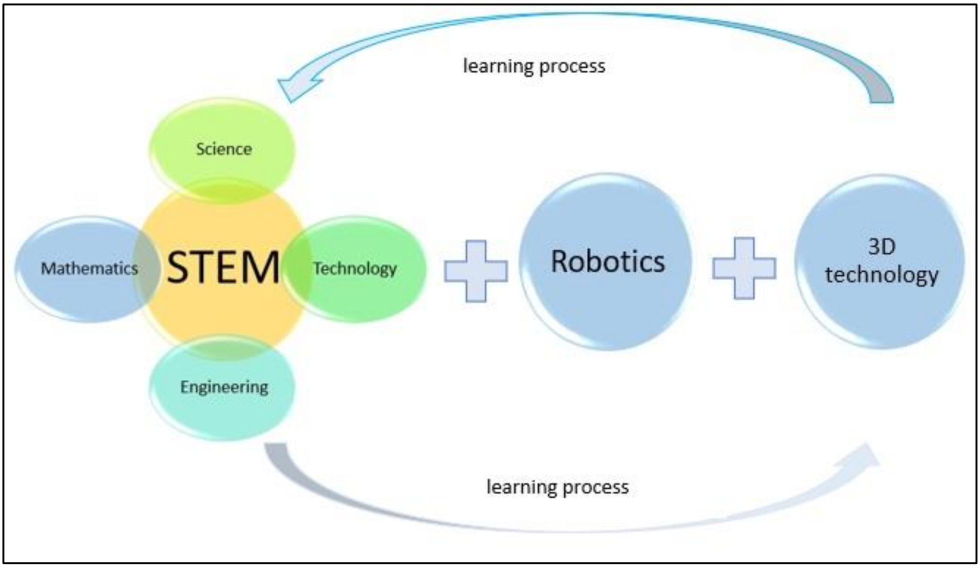

Figure 10. Implementation robotics and 3D technology into the learning process as an important component of STEM education
Source: Own work

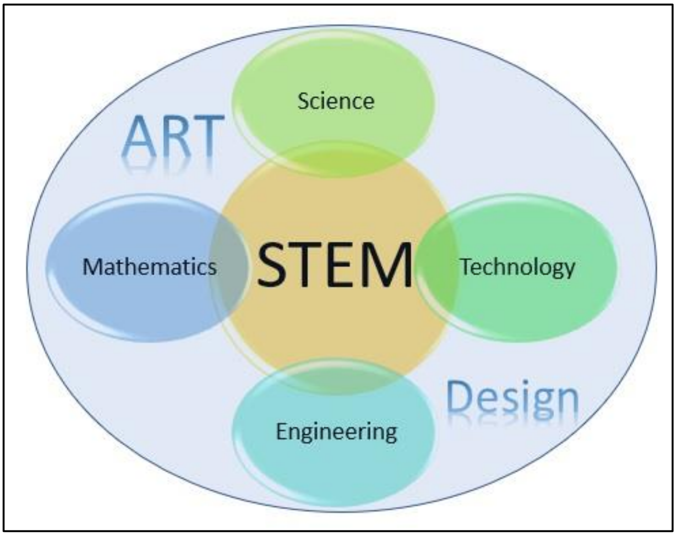

Figure 11. Transformation of STEM into STEAM
Source: Own work

On the other hand, there is a need in wide involvement of girls and women in the STEAM field. According to Labor Department statistics women hold only 16% of the nation's engineering jobs, 25.6% of Computer and mathematical occupations, 16.3% of jobs in Chemical area (U.S. Bureau of Labor Statistics, 2018, https://tinyurl.com/ybcqflfb, *accessed on 09 September 2019*). The solution to attract more women and girls to the STEM can be realized via adding Art and Design to the equation — to transform STEM into STEAM (Figure 11).

As mentioned above, Ukraine also has serious problems in these spheres.

According to the Ministry of Justice of Ukraine for 2018, the percentage of women and men in the IT field was respectively 20% and 80%. We need to learn the best EU practices in STEAM education and gender equality.

Universities are on the frontline in addressing these problems by offering students the opportunity to learn STEAM subjects. These skills need to be developed from an early age. Schools should motivate children, with a special emphasis on girls, to learn maths and science. We must help them to imagine working in these fields. Training of future school teachers, school teachers and school leaders is strongly needed for many EU countries, and also for Ukraine.

The experiment carried out within the research shows a necessity in the use of Art and Design components in creating a scientifically grounded methodological system for teaching of Basics of Robotics and 3D printing as a part of STEM education (Figure 12).

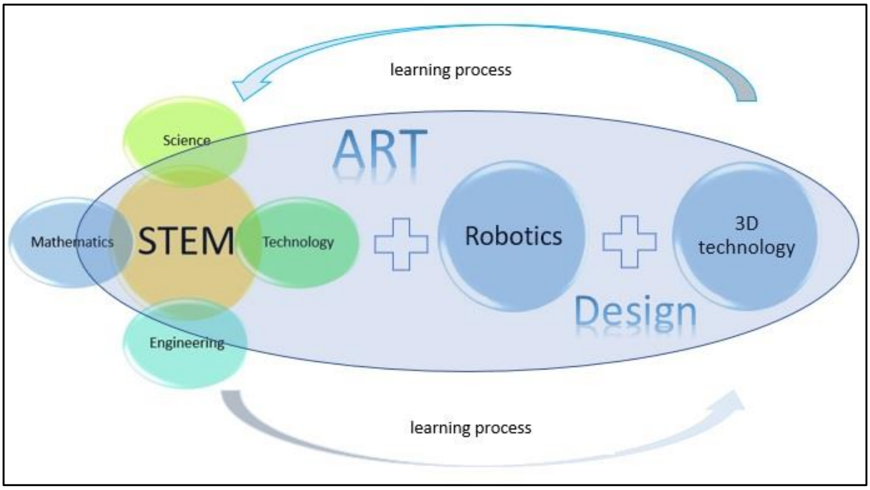

Figure 12. Use of Art and Design components in creating a scientifically grounded methodological system for teaching Basics of Robotics and 3D printing as part of STEM education

Source: Own work

More examples of creating the methodological system for teaching Basics of Robotics and 3D technology as part of STEM education (with the involvement of the Art and Design components) will be considered in the following parts of this research.

1.2. Importance of a project-based approach in STEM education

The Project-based Method (Project-Based Learning) is an active education technique on the basis of activation of educational and cognitive activity of pupils and students with maximum approximation to life (Movchan, 2016).

Project-Based Learning (PBL) makes a link between scientific practices and the real world (Hasni, Bousadra, Belletête, Benabdallah, Nicole & Dumais, 2016).

Besides, the application of the project-based approach in the learning process promotes the formation of students' teamwork skills, development of independent search and creative activity, the formation of cross-curricular competences.

One of the main goal of PBL is modelling real-world problems. Challenge is to get students to understand that issues in the real-world are rarely connected to only one subject. That's why the use of PBL in STEM education allows students to develop this interdisciplinary view. There was the reason for implementing PBL in teaching 3D technology. Some aspects of this experiment are considered below.

In the first year of 3D technology course (academic year 2017/2018), 16 bachelor students, future computer science teachers (in their 4th year) from the Faculty of Informatics (National Pedagogical Dragomanov University) have participated in the experiment. At the beginning of this course they were asked to do a medium-term individual project (duration 2 months). The main stages of the project are following:

1. *Project definition phase.* The goal is to study theoretical and practical aspects of using 3D printing technology.

2. *Planning*:

- determination of the sequence of the research stages (search for information about 3D printing technology, learning of software operations and creation of 3D models, making database of 3D models, familiarization with the principles of 3D printer operations, and printing of models);
- identification of information sources, collection means, data processing methods (analysis of scientific articles, Internet sources, documentation on the research topic, aligning the sources, creation of the information materials database);
- forms and means of presenting the research results (preparation of posters on the research subject, exhibitions of printed 3D models, presentations and speeches on the research results).

3. *Project implementation* (according to the sequence of the research stages).

4. *Project presentation* (presentation, demonstration of 3D models and 3D printer operation).

5. *Project implementation summary.*

The example of 3D-model designed by the student (Olexandr Pistiulga) is shown in Figure 13:

Figure 13. The example of 3D-model designed by the student (Olexandr Pistyulga)
Source: Own work

The experiment had a very positive effect on increasing students' motivation for studying. In addition, the students have mastered the latest technology (3D technology in general, 3D modelling, 3D printing etc.).
After good experiment results we have decided to use our previous experience for the next academic year and to expand it to teach 3D technology via learning StartUp projects. The example of learning StartUp project will be considered below (p. 2.2).

2. Learning StartUps as a project based approach in STEM education

2.1. StartUps in general. Examples of the famous Ukrainian Startups

The concept of a "Start Up" emerged for the first time in the 1930s in the United States, when two students, William Hewlett and David Packard, started a small company (now it is the world-renowned Hewlett-Packard company – HP). It was the first StartUp.

There are many definitions of the term "StartUp" in the scientific literature. Scientists interpret the term as (Vitlina, 2017):

- newly formed organization engaged in the development of new goods or services under conditions of extreme uncertainty;

- process of entry into market of a newly established enterprise with an innovative project, usually within short time and with minimal investment;
- new company in the initial stage of its development, which is created to realize a promising idea in order to generate high profits;
- temporary structure for sourcing of a large-scale, reproducible and cost-effective business model;
- company with a short history of operating activities;
- new companies that are under development and in the process of growing their business on the basis of new innovative ideas or emerging technologies;
- newly established company that owns prototypes try to organize production and launch of products to the market.

The most famous examples of startups in the world are: Airbnb, Amazon, Apple, Dropbox, Facebook, Google, Instagram, Microsoft, Paypal, Ryanair, Twitter, Youtube, Xiaomi, Uber etc.

Startup consists of three components, i.e., idea, team and funding (Figure 14).

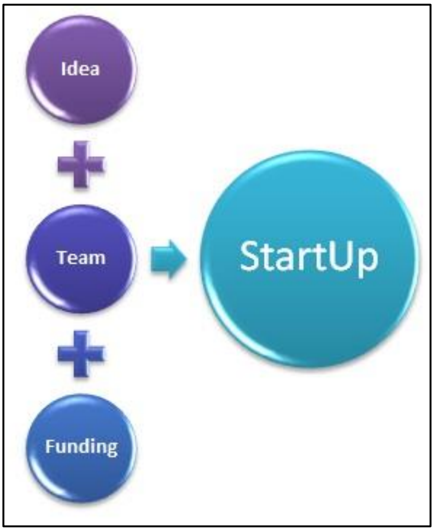

Figure 14. The components of StartUp
Source: Own work based on Oksenyuk, 2018

The main startup components are described in more detail in the study (Oksenyuk, 2018).

According to international of startup technologies experts, there are 5 stages of startup development (Figure 15), (Salamzadeh, Aidin & Kawamorita Kesim, 2015; Paschen, 2017; Oksenyuk, 2018).

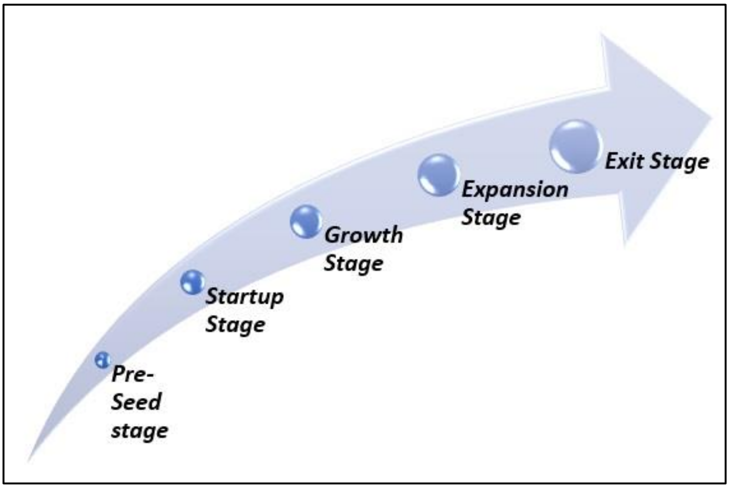

Figure 15. The 5 stages of startup development

Source: Own work based on Salamzadeh, Aidin & Kawamorita Kesim, 2015; Paschen, 2017; Oksenyuk, 2018

1. ***Pre-Seed stage***: A clear idea and understanding of target audience needs. Then it is necessary to study the market, prepare an action plan, develop a project prototype, search for investors.

2. ***Startup Stage***: An investor has already been found, the product can be marketed. It is necessary to prove its superiority over analogues. This is the time of many risks.

3. ***Growth Stage***: Startup stage where a project has survived in competition. The project is in demand and occupies a market niche established in the business plan.

4. ***Expansion Stage***: Business plan have been achieved. And the business is expanding to other markets, through the purchase of other startups in particular. The company's positions are no longer in danger, the products are in stable demand, and revenues are gradually increasing.

5. ***Exit Stage***: Project exit of the initial investors in the face of venture funds, and subsequent sale of the project. The company has reached the pinnacle of its own development. The investors abandon their stake in this business and selling it strategically to the strategic players.

The Ukrainian startups participate in the international conferences and exhibitions. It should be noted that 8 Ukrainian teams participated in the Consumer Electronics Show held in January 2017 in Las Vegas. The Ukrainian developers take part and win prizes of the international events: Eurasia Mobile Challenge, Mobile World Congress, etc. (Oksenyuk, 2018).

The most famous Ukrainian startups in the world are:

- **Viewdle** (2006 year): Startup on the development of image recognition and computer vision (Computer Vision). In 2012, Google has bought the Ukrainian startup Viewdle and used its development to search for images within the service (https://www.google.com.ua/imghp?hl).
- **Grammarly** (2009 year): The world's most popular educational service, i.e., the application for checking grammar and spelling in English (https://www.grammarly.com).
- **Augmented Pixels** (2010 year): Startup of augmented reality technologies. The company is among the largest suppliers (such as Apple, Google, Microsoft and Sony) of components for computer vision systems (Computer Vision). The system allows machines to detect, track and classify objects (https://augmentedpixels.com).
- **SolarGaps** (2015 year): Smart blinds with built-in solar panels. SolarGaps get solar power directly from the window. You can manage them with your smartphone. In this case the slats are automatically adjusted in such a way that it works as efficiently as possible even in different periods of the day (https://solargaps.com).
- **Ecoisme** (2015 year): Digital home energy management system with elements of gamification and socialization (https://ecoisme.com).
- **Kwambio** (2016 year): 3D printing of ceramic products. In April 2019, Kwambio, together with the WeFund Ventures Foundation, launched ADAM project. The main project goal is 3D printing of the bones and organs, as well as the creation of a virtual human body atlas from 3D scanned images of CT and MRIs (http://kwambio.com/#/).
- **Technovator** (2016 year): Wireless charging for mobile devices (https://technovator.co).

Thus, Ukraine can equally compete with the developed countries and become one of the leading players. The key to this is the considerable intellectual potential and sufficiently high standards of higher technical education in our country.

2.2. The example of students' learning StartUps via teaching 3D technology

Students of the Faculty of Informatics (National Pedagogical Dragomanov University) were asked to create Learning StartUp projects during the 2nd year of teaching the 3D technology course (2018-2019 academic year) to develop their technical creativity and entrepreneurial competence.

26 students have participated in the experimental research: 14 Bachelor Computer Science students (3rd year of studying) and 12 Master students, future Computer Science teachers (2nd year of studying).

At the beginning of the course, they were asked to do the medium-term group StartUp project (during one semester). Of course, it was difficult to implement all the stages of a real startup discussed in Section 2.1 within the learning process, so we have chosen the pre-seed stage for the creation of Learning StartUps.

Summarizing our own experience and research findings (Ghavrysh, 2016), we have defined the main stages of learning StartUp project. There are following:

1. ***Analysis of the Learning StartUp***:
   - description of the project idea (content of the proposed idea, difference between the product and existing analogues and substitutes);
   - description of the product design technology by which the project idea can be implemented;
   - development, production and testing of a product prototype.
2. ***Market analysis of possible sales of the products***:
   - list of technical and economic properties and characteristics of the product;
   - description of target groups of potential product consumers (market strategy development).
3. ***Organization of the Learning StartUp***:
   - drawing up a plan (schedule) for implementation of the Learning StartUp;
   - calculation of needs for fixed assets and intangible assets;
   - calculation of the planned production volume of the potential product, the total initial costs of launching the project and the estimated overall economic costs necessary for its implementation;
   - analysis of projected gains and losses and risks.
4. ***Presentation of the Learning StartUp results*** (presentation, demonstration of the product, its main characteristics, calculations of the planned volume of production, profitability of StartUp, etc).
5. ***Summarizing up the performance of the Learning StartUp***.

During the 2018-2019 academic year, some Learning StartUps were developed by students of the Faculty of Informatics (National Pedagogical Dragomanov University) through the teaching of “3D technology”. There is an example of the Learning StartUp “3D Puzzle” with the use of 3D printing technology. Students completed all stages of the Learning StartUp, provided relevant materials (idea definition, technology analysis, market analysis, StartUp organization steps, and additional profit analysis).

The most important components of the **Learning StartUp "3D Puzzle"** is shown below:

1. ***Idea***:

– 3D models making of recycled plastic (puzzles, toys, household items, various accessories, etc.);

– custom printing of lost / broken parts;

– technology of 3D printing using eco-friendly plastic.

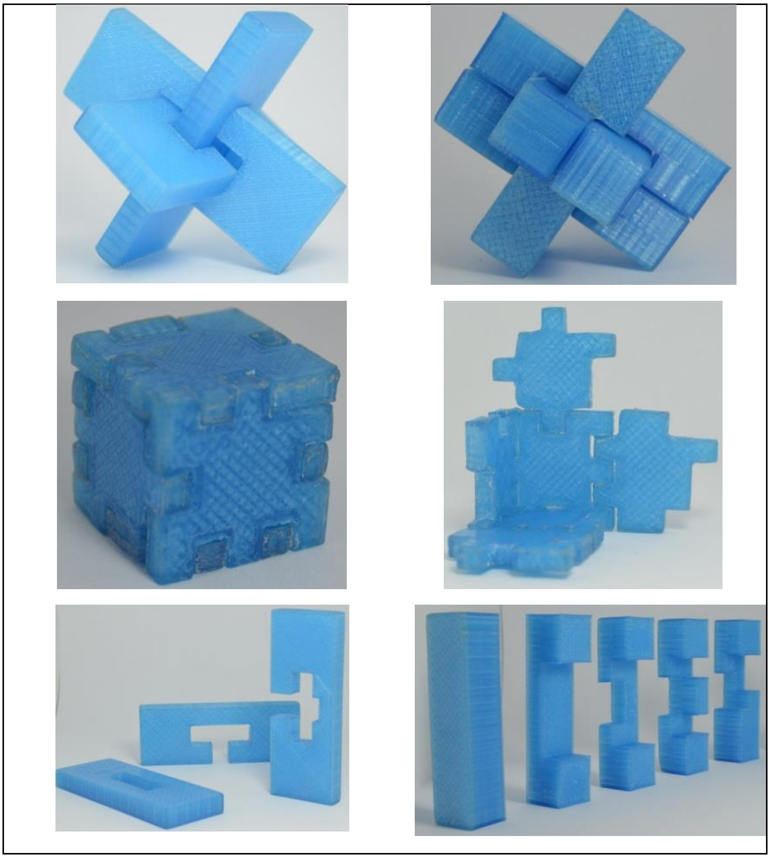

Figure 16. 3D models prototype of the Learning StartUp designed by female students (Marina Aksanyuk, Maria Semenova, and Anastasia Chorna, 2018)
Source: Own work

2. ***Analysis of technology for implementation of StartUp project***:

– analysis of different 3D printing technologies with regard to their cost, equipment cost (3D printer) printing time, etc. – opted for FDM technology;

– analysis of different types of printing plastics with regard to cost, durability, environmental friendliness and other characteristics – opted for PLA plastic eco-friendly ;

– analysis of the software for 3D modelling and 3D printing – opted for Blender and Cura;

– technical analysis of plastic processing equipment – opted for eco-project Precious Plastic (https://preciousplastic.com).

3. *Design, production and testing of a product prototype*:

– designing 3D models of several prototypes – 3D Puzzles (see in Figure 16);

– preparation of the working environment and 3D printed prototypes (determining the time of printing, consumption of plastic, electricity, etc.).

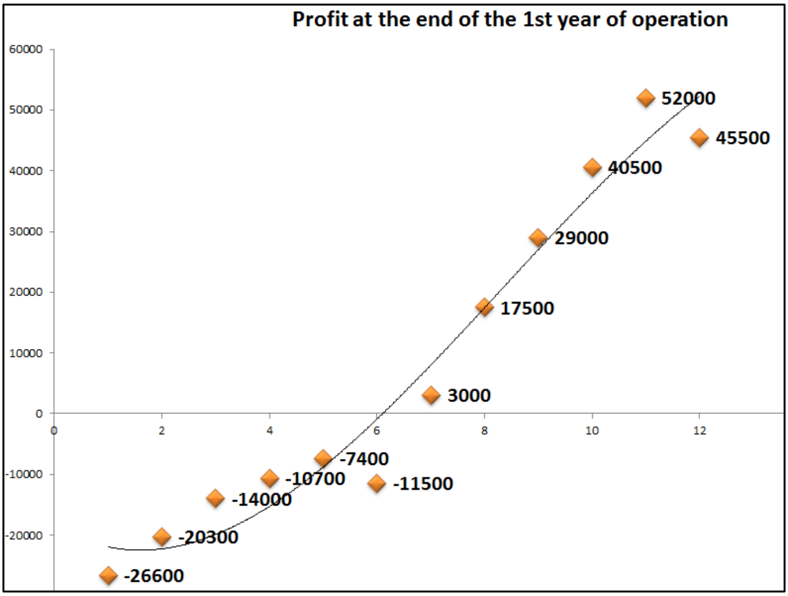

Figure 17. Planning profit at the end of the 1st year of operation
Source: Own work based on Learning StartUp "3D Puzzle" by female students (Marina Aksanyuk, Maria Semenova, and Anastasia Chorna, 2018)

4. *Market analysis of possible sales of products*:

– Target customers are:

– recycling companies;

– customers with custom orders;

– enterprises where recycled plastic is used.

5. ***Profit analysis***:

– the analysis of the profitability of this StartUp showed that the company will start to make profit at the end of the 1st year of operation (taking into account the purchase of plastic processing equipment), see Figure 17:

Figure 18. shows materials that were submitted to present the results of the Learning StartUp "3D Puzzle":

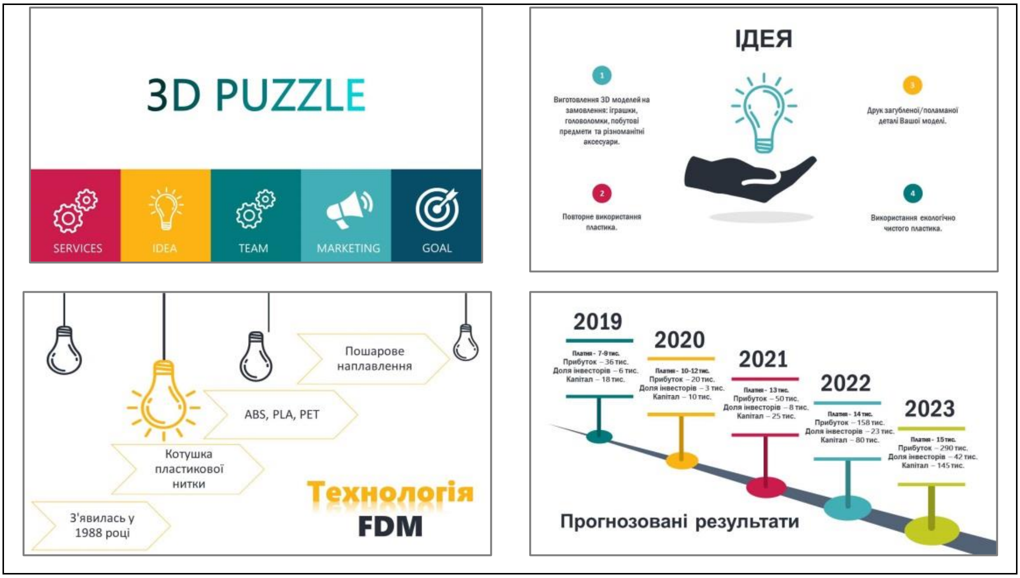

Figure 18. Some parts from the presentation of the Learning StartUp "3D Puzzle" designed by female students (Marina Aksanyuk, Maria Semenova, and Anastasia Chorna)

Source: Own work based on Learning StartUp "3D Puzzle" by female students (Marina Aksanyuk, Maria Semenova, and Anastasia Chorna, 2018)

According to the results of the evaluation of the Learning StartUps of the students, it can be argued that the vast majority of students, involved in the experiment (76%), have acquired skills in using 3D technology and knowledge about designing of the StartUp project. The research results also show a significant increase of students' motivation for studying. The increase in student motivation was confirmed by the fact that the number of students consulting with the teacher at off-hours doubled.

For the next year we are planning to involve students (designers of the best Learning StartUps) to participate in Ukrainian Festival of Innovation Projects "Sikorsky Challenge" (https://www.sikorskychallenge.com).

3. DISCUSSION

According to the research conducted, the authors propose ways to improve learning process with implementation of the Learning StartUps as the project-based approach in STEM/STEAM-education. The following issues (research results) have arisen.

a) expanding the experience of the use of Learning StartUps to increase students' motivation for other disciplines such as programming, information technology, robotics, etc.;

b) research on gender equality, namely, wide involvement of girls and women in the IT field, particularly in STEM education;

c) incorporating of the Art and Design components in the construction of the scientifically-based methodological system for teaching various disciplines, including the basics of robotics and 3D technology, as a component of STEM education;

d) including of individual components of the Learning StartUp in the final student thesis.

4. CONCLUSIONS AND PERSPECTIVES FOR FURTHER RESEARCH

The present needs require systematic training in the field of STEM / STEAM-education, that is confirmed by the experience and relevant research of the Ukrainian and foreign scientists.

The result of the research is the comparison of competence level of educators and their level of using STEM education principles for 2017-2019. Due to this, there are conclusions about increasing competence level of using STEM education principles in Ukraine, but more and more educators consider necessity to implement STEM education into the Ukrainian educational institutions (from 41% in 2018 to 57% in 2019).

Overcoming of the STEM/STEAM-gap requires correct identification of areas for further research which include awareness improvement and development of techniques for using the STEM/STEAM approach in the learning process, understanding of the conditions for the interdisciplinary aspects of STEM/STEAM education, in particular the implementation of robotics and 3D technology in the learning process as modern and important components of STEM education.

In addition, there is an issue of gender equality, namely, the wide involvement of girls and women in the IT field, particularly in STEM education. The research constructs the model of incorporating Art and Design components in creating the science-based methodological training system to address this issue.

The experimental research also provides Learning StartUps as a project-based approach in STEM education and describe examples of such StartUps. The research results also show a significant increase of students' motivation for studying.

Therefore, quality upgrading of STEM education could be reached through updating of the curriculum for future teachers of Computer Science, mathematics, physics and the implementation of interdisciplinary links between STEM disciplines, robotics, 3D technology and related fields.

Perspectives for further research are:

- increase of the awareness of educators regarding the interdisciplinary aspects of the STEM/STEAM-education;
- elaboration of a new survey for the Ukrainian educators to define their needs in STEM/STEAM-education;
- development of a scientifically grounded methodical educational system with the use of Learning StartUp;
- involvement of students, who are designers of the best Learning StartUps, into participation in different innovation projects such as Ukrainian Festival of Innovation projects “Sikorsky Challenge”;
- exploring ways to engage female students in STEM / STEAM-education;
- expanding the experience of the use of Learning StartUps to increase students’ motivation for other disciplines such as programming, information technology, robotics, etc.

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