Online Technologies in STEM Education

Zi-Yu Liu (✉)
GuangXi Normal University, Guilin, China
`51995812@qq.com`

Elena Chubarkova, Marina Kharakhordina
Russian State Vocational Pedagogical University, Ekaterinburg, Russia

Abstract—STEM education has become the normative base for teaching natural sciences, physical-mathematical disciplines and engineering sciences in a number of countries. This technique has become the basis for a series of reforms for secondary and higher education in the USA, Australia, and some other countries. The method involves the integration of training in the fields of mathematics, technical specialties, scientific research and engineering. The widespread use of this technique and its active research throughout the world over the past ten years is due to the need to improve the quality of technical education and the ever-increasing rate of technological progress. This research is devoted to studying the impact of the STEM education introduction for 3rd year students of technical and pedagogical departments for improving the quality of training. The study involved two groups of students from two universities in Russia and China. The sample consisted of 316 people from each university, and the same amount was for control group to verify the results. The two study groups underwent training using two different STEM methodologies - "amalgam" and "interconnect", which involve varying degrees of integration of various academic subjects within the coordinated STEM education. Both study groups used online-education integrated with STEM that helped to significantly increase the involvement of students in the learning process. All three groups passed pre-tests and post-tests on the learning outcomes before and after the introduction of the STEM education. The average grades received by students on studied disciplines show that the STEM education increases the academic performance with the statistical error of the study exceeded. The introduction of the "interconnect" method, which implies a greater integration of subjects during the training, showed provably higher results than the "amalgam" method. However, this study cannot be used to assess the quality and capabilities of each of these methods, since such an assessment requires additional research.

Keywords—Online education; online STEM courses; STEM education.

1 Introduction

The phenomenon of the STEM education dates back to the early 1990s and then developed rapidly over two decades. Nowadays, STEM education has become a

methodological base for studying the disciplines of the natural science in most countries of Europe, many countries of Asia, Australia and the USA [1-4]. The abbreviation STEM (Science, technology, engineering, and mathematics) indicates the main direction of disciplines' integration to the learning process. The rapid technological development and the spread of practices previously considered as extremely rare and specialized require integration of such techniques [5]. Let us say, robotics, gene research, and other specialized scientific research are now available not only for students, but schoolchildren as well [4-6]. The introduction of network technologies, cloud-based services, big data, as well as virtual and augmented reality into pedagogical practice has dramatically increased learning opportunities. It became possible to teach not only faster and deeper, but also to implement the concept of lifelong learning, as well as complete immersion in the learning process and the availability of training not only in classes, but at any student's whereabouts [5,7]. The high need for specialists able to solve real-world technology problems immediately after graduation, without additional training or practice, has raised the question of preparing adequate technical personnel very sharply.

Initially, STEM was considered as a learning system for real practice, focused not on more or less abstract knowledge, but on the creation of a natural practical experience for students [1, 8]. A face-to-face training with the teacher played main role in this process [2,8]. If in the traditional practice, teaching is performed mainly in classrooms, then in this case students work more closely with the teacher, who conducts the student's practical actions, monitors the correctness of his steps, monitors the observance of safety rules and shares personal experience of using theoretical scientific knowledge [2,9]. A huge potential of STEM augmented by online teaching methods has been identified already in the first decade of the method existence. On the one hand, the remote learning, basically, seems to contradict this method [10, 11]. On the other hand, it allows increasing the effectiveness of training and the number of students [12]. This is a critical issue for many countries, as there is a need in a sufficient number of specialists and the demand for them in the economy is very high.

The training of teachers who would be able to use this method in practice is one of the main problems of the STEM education. If the problem is easy to solve for universities [13], then for school education the training of STEM teachers is now one of the most important tasks in many countries [5,14]. Special training systems for teachers, international knowledge and resources sharing funds are being created for quickly exchange of teaching materials, course design, skills training system, etc. [13, 15, 16]. Researchers point out that in reality the STEM methodology came from successful people living in a prosperous society. However, this method must be introduced in conditions of rather limited resources, lack of time and teachers' necessary skills and knowledge to create and design student-training programs [5]. According to Radloff and Guzey [17], video information plays an important role in advancing the process of studying and improving the STEM methodology. The online courses can include the use of YouTube videos, as well as special videos posted in the cloud-based resources with limited access, recorded classroom lessons according to the STEM methodology, also, teacher's comments and solutions to their tasks online in Records [18]. All these types of video materials are widely used in structured STEM programs developed and

implemented by European and American universities [19, 20]. Researchers note that the video materials are the most popular and easy to perceive by the latest generations of students who are already accustomed to this format of presenting information in general on the Internet [21].Videos act as an incorporating aspects of visible personal experience into the learning process [17].

More and more research is devoted to the role of VR and AR in STEM education, especially when it is conducted online [10, 22]. AR acts as markers and tags in the performance of educational tasks and the study of objects from personal experience. Thus, AR even allows doing what is impossible to do "face to face" with the teacher in the classroom: to observe the subject from the inside or in chemical and atomic bonds; to monitor the ongoing physical process in slow motion at different stages; to study a subject or process from different perspectives simultaneously [3,18]. Likewise, AR mechanisms make it easy to implement hints in the process of completing tasks or finding answers to a task in the real world. They facilitate collaborative interaction in solving real problems and anyways are perceived better than the traditional slide as a way of delivering educational information [22]. Virtual reality makes it possible to completely transfer all aspects of gaining real experience and even do the task yourself (with such technical capabilities) in the virtual world (op. Cit.), However, many researchers indicate that VR mechanisms are even dangerous for STEM as simulate all real experience. Thus, the experience quality completely depends on 1) the quality of the simulation, 2) its accuracy under all the factors involved, and 3) the unpredictable nature of an individual perception, which will affect the obtaining and consolidation of the experience [23]. Both VR and AR make it possible to transfer the STEM online to a much greater extent and with better results.

Some controversial questions in online STEM courses are no clear answer yet. Particularly, a number of studies indicate that e-learning is less effective for groups of students at increased risk of underperforming or expelling from the educational process and their chances of getting a degree are reduced [24,25]. Such risk groups include women, "people of colour" and Afro-American students, representatives of non-traditional social groups, students from low-income families, and those who are the first university-student in a family [12, 25, 26]. Moreover, according to the available statistical data, the representatives of these risk groups make up from half to the vast majority of students from a number of institutions in the USA, some European countries, and many Asian countries [12]. Most of those students try to obtain technical specialties, and for them STEM is the prevailing teaching method that may provide results of the highest quality. A number of studies show that the critical factors for increasing the effectiveness of training for these risk groups are financial assistance and the availability of the right teaching methods that increase motivation and support learning levels that are not assumed by regular courses [12, 21, 27]. "Scaffolding" is a separate area among such teaching methods, there [28, 29], that separates of the educational process into smaller stages and more active support student when moving from one such stage to another. Studies show that this method gives a noticeably relevant increase in the quality of education and reduces the number of risk groups' representatives who leave before graduation or receive lower grades than they could.

2   Materials and Methods

The study involved two groups of students from Kazan Federal University (Russia) and GuangXi Normal University (China). The study groups equally consisted of 316 students each, to eliminate the influence of national and state affiliation from the study. Each group equally included third-year students from both universities of typologically close departments, namely natural history and physical-mathematical sciences. A control group included 316 students of a similar age equally from both universities that they were not trained with the STEM education.

Both study groups used the STEM education and almost completely similar educational and research materials, and teaching methods. The use of two STEM techniques: "amalgam" and "interconnect" was the only difference between the study groups. Thus, "amalgam" technique implies intersections between disciplines only when they naturally meet with each other in solving real problems. "Interconnector" technique emphasizes the connections between different disciplines, included to STEM program, and each lesson indicated related connections and topics for other disciplines, even if they did not meet directly in practice [7].

The online STEM courses are created by the most affordable means of online communication in accordance with the structure published and developed by a number of researchers and based on the existing programs of teaching engineering, physical-mathematical and natural sciences at the above-mentioned universities. No changes to these programs were made in order to maintain the structure of training and the implementation of university programs. The training materials and the work of the teachers who accompanied the online course were structured to stick to the main principles of STEM [4]:

- Forming of a visual representation of the studied material, firstly possible to remember, and reproduced in the laboratory or classroom;
- Creating an intersection between different subjects, for which joint recordings of various subjects' teachers were used with a parallel explanation and providing the principles of various devices, the use of mathematical calculations to prepare experiments or develop real operating devices, describe natural phenomena, etc.;
- Providing as much information as possible on each topic for students' independently choose of the training form that considers the personal training characteristics of a particular student [30].

As an online digital environment for the STEM, there was used educational materials in the form of annotated teaching aids, divided into training segments with teacher comments, special educational tasks as text files, graphic information and three-dimensional models of the objects available for viewing in a browser. The educational information was available as on a special server of each university reachable for students, as well as on the public cloud-based servers Drop Box and Google Drive. All materials were divided into topics of individual lessons, and teachers provided direct links and indicated logical connections that allowed students to immediately switch to educational materials of other subjects that complemented as part of STEM-coordination. Training

materials were available on both a computer and mobile devices. Direct contact with the teacher, as well as special means of academic performance rating, throughout the study, were performed with the help of social networks, in particular Facebook. Social networks and specially created network groups were used for classes and experiments discussing; creating temporary groups of participants working on a project; generating online reporting on student performance and participation in educational and project groups; for personal consultation with a teacher or sharing interesting student materials found by students. Teachers, as well as senior students and team leaders were constantly moderating the learning process, materials posting, and discussions for excluding unnecessary files and messages that are not related to the educational process in the communication flow.

The study lasted for a month and a half (30 academic days), involving a full range of online services and opportunities to continue successful learning outside the classroom. Students were using the online STEM courses mainly to get a wider involvement in classes, to get access to more teaching materials, or to study missed laboratory classes and practices.

The use of the STEM education showed a number of problems, already at the initial stage, and the solution was precisely in online-education. Firstly, there were a number of practical limitations affecting a wider involvement of students in the learning process and in the personal experiments, also the use of materials, the preparation of laboratory samples, etc. An insufficient amount of materials, teaching means, instruments and tools for large groups was such a limitation, which at the same time made teaching groups of more than 10-12 people very challenging. Therefore, the STEM learning process in the classroom anyways was in a form of collaborative learning, the group's general participation in the experiment or working under sample. Thus, some students had no possibility of direct, participation, and could only observe. Majority of students could participate only in part of the actions sequence provided by the educational material. Significant difficulty was also in the proper time use for explanations, considering the individual characteristics of all students, different types of perception and speed of thinking and memorizing. It was quite difficult for teacher to accompany each student and the group as a whole with the active involvement of the entire group members. If during a regular classroom collaborative learning the group can share tasks and experience, then for STEM practice the teachers' participation is critical, as they control the result achievement, as well as, the observance of safety and other aspects of the experience.

As many researchers indicate [5, 11, 15, 17], one of the main problems in implementing STEM is teachers' lacking of necessary training, skills and experience of using this methodology. The training materials of new formats are to be created. Those could be video recording of experiments or the process of working samples creating, etc. However, it requires specific skills that not all teachers have.

The use of e-learning acted as a buffer that damped all the problems described above, allowing students to connect the experience gained in the classroom with the experience of more thoughtful and detailed perception of the same material later. Thus, the already acquired experience was streamlined and its fixation was more durable.

The results of the study were assessed using the pre-test and post-test, carried out before and after the study. Tests were carried out in the form of an average assessment received by students of both study groups, as well as a control group on STEM program subjects. The grades obtained by each student were averaged based on the usual assessment methods for both universities involved. Grades for disciplines were brought together and the arithmetic mean was calculated, and then put on a ten-point scale for the convenience of reflecting the results and simplifying their subsequent processing. The adequacy of such an assessment method is confirmed by the previously coordinated programs with a homogeneous assessment system and thematic dividing throughout the academic semester used for different subjects.

To conduct a pre-test, the results of academic performance for a similar period of study time were used (one and a half months, 30 academic days, the same number of topics studied in the same set of subjects).

3 Results

The data on pre-tests and post-tests of all the studied groups were summarized in one graph per each group in order to make the result of using the STEM technique more graphically noticeable. It should be especially noted that the majority of students in all three groups receive overall average grades that is widely spread in pedagogical practice. The pre-test results of all three can be considered identical - the differences between groups were not beyond the statistical error. Thus, all factors affecting academic performance for all three groups were similar and had no different. Natural discrepancies between individual performances in groups were virtually erased by averaging grades of studied subjects and when assessing the overall average score for the entire program. Meanwhile, there can be noticed more staidly manifest over longer time changes, which affect all disciplines simultaneously [7].

There is significant difference in the results for groups of students who received various grades on pre-tests and post-tests. Thus, Figure 1 shows that the difference in the pre-testing and post-testing for those who received an average score of 3–4 points and 7–8 points are within the study error, while the largest differences for groups were 5–6 points and 9–10 points. If the second result can be explained by rapid increase academic performance with applying the STEM, then an increase of average scores is not clear to the end. It might be the result of the "migration" of those who received lower grades on a pre-test, and improved academic performance through e-learning. This hypothesis is supported as the number of those received the lowest scores critically and relevantly decreased (Figure 1, group 1–2 points).
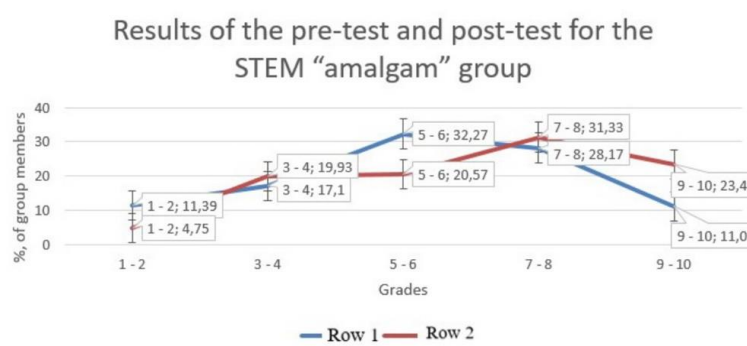
Fig. 1. Results of the pre-test and post-test for the STEM "amalgam" group

The results presented in Figure 2 are especially important as somehow reflect the differences between two types of STEM education. The graph shows a group for which the interaction between STEM subjects was much higher and teachers constantly drew and emphasized interdisciplinary parallels. We consider that the difference in results lays in changes of training quality in all groups, they are relevant, and are not within statistical error. Thus, the use of the STEM "interconnector" methodology increased the average performance of all subjects in the study group. Moreover, the number of students who received an average grade below 7 points decreased in all selected, and the number of students with the highest marks increased. Thus, the constant accentuation of interdisciplinary relations might stimulate the study and automatic memorizing of material related to not only the studied subject, but also the coordinated. Meanwhile, there were no really radical changes in the quality of training. The most noticeable results are for the group with highest grades (from 15.19% in the pre-test to 28.16% in the post-test, which shows an increase of 81.06%) and for group with 3-4 points (13.61% of all participants in the pre-test, 6.96% in the post-test, the total increase is 95%). However, such significant results are partly due to the method of calculation, as both groups are very small in comparison to others., The difference in academic performance for the groups with average grades of 5–6 points and 7–8 points tends to statistical error, although it goes beyond its (30.64% and 22.16% for the two groups mentioned).
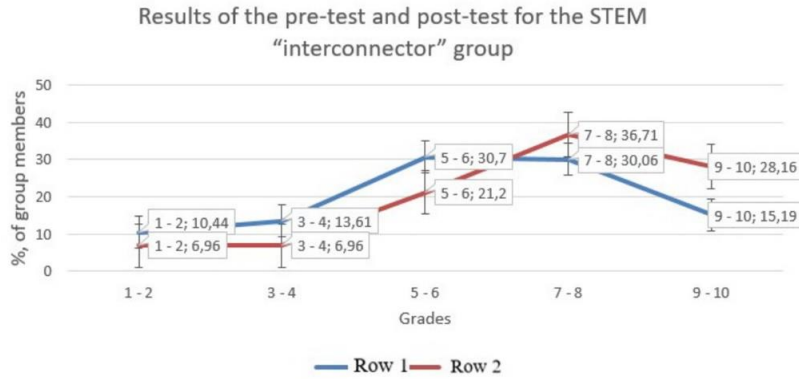
Fig. 2. Results of the pre-test and post-test for the STEM "interconnector" group

According to Figure 3, the results of the knowledge testing in the control group showed the distribution of grades extremely close in both tests. The differences between the two tests for the entire group are mainly within the statistical error. Thus, we can conclude that the level of knowledge assimilation and academic performance in the control group was stable and approximately and also it was not affected by any additional factors. Therefore, the discrepancies in the pre-test and post-test in the studied groups are associated precisely with the use of the STEM education that influenced the change in performance for both groups.
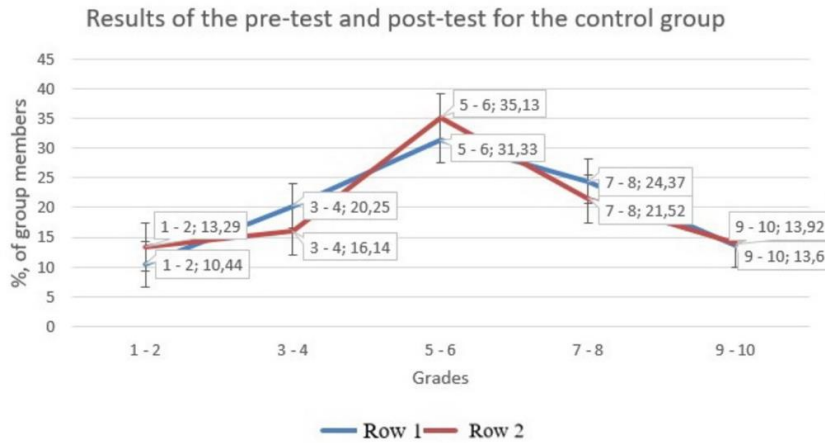

Fig. 3. Results of the pre-test and post-test for the control group

Figures 1 and 2 show that the largest number of studied groups students had average grades, according to averaged indicators for the entire set of STEM subjects. However, a comparing of the data obtained, both studied groups had a significant shift in the peak of the graph (percentage of students) towards higher grades. There was no critical change in the quality of training, the tendency of most students to average scores is

persistently maintained, but the number of students received high marks significantly increased.

4 Discussion

STEM education is widely used for deepening the teaching of technical subjects. However, there is currently no single opinion on the essence of STEM technique. Some researchers associate it with contextual teaching and learning as experiential learning and mixing basic skills with real-life training [26]. The STEM range of problems cannot be understood in a mono-disciplinary context as it requires studying the impact of the methodology immediately on a group of disciplines. Therefore, our study as well as most researchers tries to evaluate students' average performance, rather than the effectiveness of a particular discipline [5]. The STEM methodology has been developing from the concept of STEM education, used to determine the quality of different subjects' involvement in the teaching process for technical specialties and training scientists. This term was understood as the ability to apply scientific content for solving real problems. Now, STEM is generally understood as a methodology for problem-oriented learning [4]. STEM was designed to bridge the gap in pedagogy between theory and practice in solving increasingly complicated and complex tasks.

Among the definitions given to this technique, a number of more complete ones can be distinguished. Determining the essence of the methodology in this case is very important for the formation of practical training programs and determining their effectiveness. Particularly, STEM is a problem-solving method, based on the principles of scientific thinking, mathematical concepts and procedures, and also incorporates engineering strategies for applying appropriate technologies. A general definition of STEM indicates that it is a "phenomenon of an interdisciplinary nature with a very blurry ideological background and a specific core oriented toward solving problems in the real world". Thus, very numerous variants of STEM methods are used, which can be divided according to the principles of methodology. This separation is based on the depth of integration of various subjects within the training - from a very superficial as with "amalgam" (the intersection of different sciences only where they have common points) and to full integration, when all disciplines are studied as a whole, and learning is integrated and coordinated through the sharing of knowledge from all areas to solve real problems. Therefore, STEM is often considered a part of problem-oriented teaching methods [7].

Meanwhile, we were not able to find studies comparing effectiveness of different STEM approaches, possibly due to its high complexity and the lack of clear criteria for assessing the integral interaction between different components of a single disciplines' complex. Attempts to create a single STEM program have not yet been made, and teachers can use the approaches that they themselves choose and the ideology that they consider more acceptable for their work. This problem requires further study and careful development of individual methods and technologies within the STEM education, which will provide a number of optimal ways to create specific training programs in the future.

The STEM is usually implied as the use of a number of specific elements in educational programs: active learning strategies; full students' involvement strategies; training based on experience and personal work; statement of open tasks and training questions with on correct answer or solution; integration with the real life needs, modern practice [19]. Some studies also emphasize that the effectiveness of STEM as a holistic methodology largely depends on the correct system of the final assessment of student results [19].

Researches on online STEM courses have three main directions. Firstly, researchers are trying to highlight some common grounds for the effectiveness of such programs and on their basis develop a universal methodology or structure that would allow creating working and easy-to-implement training sequences [3,11,23,30]. Secondly, methods for assessing the real effectiveness of such programs are being studied, in particular, evaluation teachers' work, whose role in STEM is especially great [2,20]. Thirdly, there is a discussion about the boundaries of using online STEM courses and how actually such an approach can be applied to this teaching methodology [6,26]. According to the majority of researchers, online-education is not able to completely replace work in the classroom and laboratory, and attempts to teach mainly online lead to low effectiveness, rapid dropout and students usually do not achieve their academic goals [25]. Meanwhile, online-education improves the quality of class collaboration that naturally occurs while working on a project within STEM education and simultaneously provides an opportunity to extend the time of interaction between participants through online communication and information exchange [11,18]. Online-education does not replace the main elements of STEM, but makes easier sharing of the information between the participants and the teacher in the learning process. It also speeds up the response and feedback to student actions, makes it possible to conduct wider contextual research, which is very important for solving real problems and implementing of existing projects.

5   Conclusion

The study was devoted to studying the impact of online STEM courses on the students' academic performance from two universities. The study was also to determine the presence or absence of relevant differences in learning outcomes when applying two different STEM methodologies, so-called "amalgam" and "interconnect". These problems are practically not studied, despite the extremely active development of research in the field of STEM, around the world. The study was carried out using a pre-test and a post-test of academic performance in two study groups who were using online learning for STEM according to the two indicated methodologies. Meanwhile, the technique was not applied for the control group. The study showed unambiguously higher learning outcomes for groups with applying the STEM methodology; moreover, relevant differences in the quality of two methodologies were noticed. The group trained with the "interconnect" methodology demonstrated higher results.

The study can be used by teachers for their practical activities within selected STEM methodology, and can also serve as the basis for further studies of various programs of integrated teaching in natural sciences using this method.

6 Acknowledgement

7 References

[1] Brown, R., Ernst, J., DeLuca, B., Kelly, D. (2017). STEM curricula. Technology and Engineering Teacher, 77(1): 26-40.

[2] Hoeg, D.G., Bencze, J.L. (2017). Values underpinning STEM education in the USA: An analysis of the Next Generation Science Standards. Science Education, 101(2): 278-301. https://doi.org/10.1002/sce.21260

[3] Larson, R.C., Murray, M.E. (2017). STEM education: Inferring promising systems changes from experiences with MIT BLOSSOMS. Systems Research and Behavioral Science, 34(3): 289-303. https://doi.org/10.1002/sres.2411

[4] Martín-Páez, T., Aguilera, D., Perales-Palacios, F.J., Vílchez-González, J.M. (2019). What are we talking about when we talk about STEM education? A review of literature. Science Education, 103(4): 799-822. https://doi.org/10.1002/sce.21522

[5] Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. International Journal of Technology and Design Education, 26(1): 61-79. https://doi.org/10.1007/s10798-015-9300-9

[6] Gazan, R., MacLean, K., Wahl, N. (2018). Participative resources, practices, and information literacy standards in online STEM education. International Journal on Innovations in Online Education, 2(4): 1-19. https://doi.org/10.1615/intjinnovonlineedu.2019029571

[7] Hobbs, L., Clark, J.C., Plant, B. (2018). Successful students–STEM program: Teacher learning through a multifaceted vision for STEM education. In Jorgensen, R., Larkin, R. (Eds.), STEM education in the junior secondary. Springer, Singapore, pp. 133-168. https://doi.org/10.1007/978-981-10-5448-8_8

[8] Ardissone, A.N., Oli, M.W., Rice, K.C., Galindo, S., Urrets-Zavalia, M., Wysocki, A.F., Triplett, E.W., Drew, J.C. (2019). Successful integration of face-to-face bootcamp lab courses in a hybrid online STEM program. Journal of Microbiology & Biology Education, 20(3): 49. https://doi.org/10.1128/jmbe.v20i3.1769

[9] Keil, M.J., Rupley, W.H., Nichols, J.A., Nichols, W.D., Paige, D., Rasinski, T.V. (2016). Teachers' perceptions of engagement and effectiveness of school community partnerships: NASA's online STEM professional development. Journal of Studies in Education, 6(2): 1-23. https://doi.org/10.5296/jse.v6i2.9185

[10] Pellas, N., Kazanidis, I., Konstantinou, N., Georgiou, G. (2017). Exploring the educational potential of three-dimensional multi-user virtual worlds for STEM education: A mixed-method systematic literature review. Education and Information Technologies, 22(5): 2235-2279. https://doi.org/10.1007/s10639-016-9537-2

[11] Ruan, J., Wu, B., Gu, X. (2019). Design of an online STEM teacher-training environment: An authentic learning perspective. In Society for Information Technology & Teacher Education International Conference. Association for the Advancement of Computing in Education (AACE), pp. 2029-2038.

[12] Wladis, C., Conway, K.M., Hachey, A.C. (2015). The online STEM classroom – Who succeeds? An exploration of the impact of ethnicity, gender, and non-traditional student characteristics in the community college context. Community College Review, 43(2): 142-164. https://doi.org/10.1177/0091552115571729

[13] Chai, C.S. (2019). Teacher professional development for science, technology, engineering and mathematics (STEM) education: A review from the perspectives of technological pedagogical content (TPACK). The Asia-Pacific Education Researcher, 28(1): 5-13. https://doi.org/10.1007/s40299-018-0400-7

[14] Tekerek, B., Karakaya, F. (2018). STEM education awareness of pre-service science teachers. International Online Journal of Education and Teaching, 5(2): 348-359.

[15] Dede, C., Eisenkraft, A., Frumin, K., Hartley, A. (2016). Teacher learning in the digital age: Online professional development in STEM education. Harvard Education Press.

[16] Harasim, L. (2017). Learning theory and online technologies. Taylor & Francis.

[17] Radloff, J., Guzey, S. (2017). Investigating changes in preservice teachers' conceptions of STEM education following video analysis and reflection. School Science and Mathematics, 117(3-4): 158-167. https://doi.org/10.1111/ssm.12218

[18] Symons, D., Redman, C., Blannin, J. (2017). Mobile technologies supporting professional learning communities within pre-service teacher STEM education. In IFIP World Conference on Computers in Education. Springer, Cham, pp. 87-96. https://doi.org/10.1007/978-3-319-74310-3_11

[19] Chen, B., Bastedo, K., Howard, W. (2018). Exploring design elements for online STEM courses: Active learning, engagement & assessment design. Online Learning, 22(2): 59-75. https://doi.org/10.24059/olj.v22i2.1369

[20] Durovic, G., Dlab, M.H., Hoic-Bozic, N. (2019). A model of an online evaluation system for STEM education. In 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO). IEEE, pp. 677-680. https://doi.org/10.23919/mipro.2019.8756675

[21] Hall, A., Miro, D. (2016). A study of student engagement in project-based learning across multiple approaches to STEM education programs. School Science and Mathematics, 116(6): 310-319. https://doi.org/10.1111/ssm.12182

[22] Al-Azawi, R., Albadi, A., Moghaddas, R., Westlake, J. (2019). Exploring the potential of using augmented reality and virtual reality for STEM education. In International Workshop on Learning Technology for Education in Cloud. Springer, Cham, pp. 36-44. https://doi.org/10.1007/978-3-030-20798-4_4

[23] Marouli, C., Lytras, M., Papadopoulou, P. (2016). Design guidelines for massive open online courses (MOOCS) in STEM: Methodological considerations towards active participatory teaching and learning. In EDULEARN16 Proceedings. IATED, pp. 5686-5693. https://doi.org/10.21125/edulearn.2016.2359

[24] Dickerson, J., Kubasko Jr D.S., Winslow, J. (2018). Online and international field experiences in STEM education: Frameworks for program globalization and growth. In Wang, V.X. (Ed.), Handbook of Research on Positive Scholarship for Global K-20 Education. IGI Global, pp. 49-61. https://doi.org/10.4018/978-1-5225-5667-1.ch004

[25] Drew, J.C., Galindo-Gonzalez, S., Ardissone, A.N., Triplett, E.W. (2016). Broadening participation of women and underrepresented minorities in STEM through a hybrid online

transfer program. CBE—Life Sciences Education, 15(3): ar50. https://doi.org/10.1187/cbe. 16-01-0065

[26] Mohammadi, A., Grosskopf, K., Killingsworth, J. (2020). Workforce development through online experiential learning for STEM education. Adult Learning, 31(1); 27-35. https://doi. org/10.1177/1045159519854547

[27] Hachey, A.C., Wladis, C., Conway, K. (2015). Prior online course experience and GPA as predictors of subsequent online STEM course outcomes. The Internet and Higher Education, 25: 11-17. https://doi.org/10.1016/j.iheduc.2014.10.003

[28] Kim, N.J., Belland, B.R., Walker, A.E. (2018). Effectiveness of computer-based scaffolding in the context of problem-based learning for STEM education: Bayesian meta-analysis. Educational Psychology Review, 30: 397-429. https://doi.org/10.1007/s10648-017-9419-1

[29] Wu, B., Hu, Y., Wang, M. (2019). Scaffolding design thinking in online STEM preservice teacher training. British Journal of Educational Technology, 50(5): 2271-2287. https://doi. org/10.1111/bjet.12873

[30] Ebner, M., Schön, S., Khalil, M. (2016). Maker-MOOC–How to foster STEM education with an open online course on creative digital development and construction with children. In International Conference on Interactive Collaborative Learning. Springer, Cham, pp. 229-236. https://doi.org/10.1007/978-3-319-50340-0_19

8 Authors

Liu Zi-Yu is from School of Foreign Language, GuangXi Normal University, Guilin, China.

Chubarkova Elena Vitalevna, PhD, Director of the Institute of Information Systems, Russian State Vocational Pedagogical University, Ekaterinburg, Russia.

Kharakhordina Marina Viktorovna is from Russian State Vocational Pedagogical University, Ekaterinburg, Russia.