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University Learners' Motivation and Experiences in Using Virtual Laboratories in a Physics Course

Motivation et expériences des apprenants universitaires dans l'utilisation de laboratoires virtuels dans un cours de physique

Gülgün Afacan Adanır, Azat Akmatbekova and Gulshat Muhametjanova

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Article abstract

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Motivation et expériences des apprenants universitaires dans l'utilisation de laboratoires virtuels dans un cours de physique

Gülgün Afacan Adanır, *Ankara University, Turkey*

Azat Akmatbekova*, Kyrgyz-Turkish Manas University, Kyrgyzstan*

Gulshat Muhametjanova*, Kyrgyz-Turkish Manas University, Kyrgyzstan*

Abstract

It is becoming necessary to examine learners' use of and experiences with virtual laboratories. Learners' interest and motivation to use virtual laboratories are important factors for the success of these platforms. This study was conducted to analyze Kyrgyz learners' use of virtual laboratories in a physics course at the university level. The study was performed in the 2019–2020 spring term at a state university in Kyrgyzstan. The study took a quantitative approach, with 376 Kyrgyz learner participants studying at the undergraduate level. The participants were divided into three groups: the first and second used different virtual laboratory platforms, while the third was involved in face-to-face labs. Quantitative data were collected using an online questionnaire which consisted of items related to demographic characteristics, motivation and experience, and physics laboratory attitudes. The results demonstrated differences among the groups regarding factors of motivation and experience. In addition, learners' physics laboratory attitudes differed with respect to gender and grade point average (GPA) factors.

Keywords: Virtual lab; Physics; Motivation; Experience; Attitude

Résumé

Il devient nécessaire d'examiner l'utilisation et les expériences des apprenants avec les laboratoires virtuels. L'intérêt et la motivation des apprenants à utiliser les laboratoires virtuels sont des facteurs importants pour le succès de ces plateformes. Cette étude a été menée pour analyser l'utilisation des laboratoires virtuels par les apprenants kirghizes dans un cours de physique au niveau universitaire. L'étude a été réalisée au cours de la session de printemps 2019-2020 dans une université d'État du Kirghizistan. L'étude a adopté une approche quantitative, avec 376 participants apprenants kirghizes étudiant au premier cycle universitaire. Les participants ont été répartis en trois groupes : le premier et le deuxième ont utilisé différentes plateformes de laboratoire virtuel, tandis que le troisième groupe a participé à des laboratoires en présentiel. Les données quantitatives ont été recueillies à l'aide d'un questionnaire en ligne comprenant des éléments relatifs aux caractéristiques démographiques, à la motivation et à l'expérience, ainsi qu'aux attitudes à l'égard des laboratoires de physique. Les résultats ont démontré des différences entre les groupes concernant les facteurs de motivation et d'expérience. De plus, les attitudes des apprenants en laboratoire de physique différaient en ce qui concerne les facteurs de genre et de moyenne pondérée cumulative (MPC).

Mots clés : Laboratoire virtuel ; Physique ; Motivation ; Expérience ; Attitude

Introduction

In the physics discipline, laboratories have active and important roles as learners need to detect hidden concepts, and comprehend and define related principles and theories, while employing high level learning skills (Bajpai, 2013). The discipline of physics has a close connection with instructional technologies since there exist several abstract concepts in the field. At the same time, there are limited materials in existing laboratories for conducting experiments in physics courses. Therefore, instructors need various technologies in order to demonstrate physics concepts and experiments (Gunawan et al., 2018).

One of the significant instructional technologies used in science education is the virtual laboratory, whose use has been increasing in physics courses. A virtual laboratory is defined as "a combination of hardware and software systems that allows [a user] to conduct physics related or other domains (e.g., chemistry, etc.) experiments without direct contact with an actual equipment" (Daineko et al., 2017, p. 40). In virtual laboratories, learners are provided virtual illustrations of objects which commonly exist in traditional laboratories. Hence, learners gain the opportunity to learn by doing in these virtual environments (Abou Faour & Ayoubi, 2017).

In a state university of Kyrgyzstan, virtual laboratory technologies have been employed in the context of a general physics course. Since Kyrgyzstan would be deemed a developing country, essential materials do not exist in all university laboratories. Virtual laboratories have become a significant solution, giving learners practical experience. Learners can study theoretical concepts through face-to-face or online sessions, and then perform experiments in real or virtual settings. Within this general physics course, learners have the chance to enter a web-based learning environment in which they can access interactive models, animations, constructors, videos, virtual laboratories, and online quizzes (Muhametjanova & Akmatbekova, 2019). Learners are provided with access to one of two different virtual laboratories: Tina and Multisim. With these platforms, there are virtual demonstrations of real experiments, and learners can then carry out their own experiments, choosing from various options.

It is becoming necessary to examine learners' use of and experience with virtual laboratories. Learners' interest and motivation are important factors for the success of these platforms (Estriegana et al., 2019). In the meantime, there is a lack of research into the situation in Kyrgyzstan for the purpose of investigating learners' motivation and experience regarding virtual laboratories. Thus, this study is one of the first of its kind. This study aimed to analyze university learners' motivation to use virtual laboratories and understand their related experiences and attitudes towards physics.

Literature Review

Practices are considered as inseparable processes during science education (Maulidah & Prima, 2018). Virtual laboratories have been developed as significant instructional technologies in order to provide implementation of practices in an online environment. Using virtual laboratories, students are allowed to be active in their learning, comprehend complex concepts more easily, and repeat demonstrations (Falode, 2018).

With virtual laboratories, instructors can design labs that illustrate physics concepts and learners can comprehend these concepts through related practice (Masril et al., 2018). Virtual laboratories bring several benefits for learners, instructors, and institutions: (a) experiments can be implemented in a time-effective manner, (b) dangerous experiments can be performed on secure platforms, (c) experiments which actually cannot be implemented in real-life settings can be conducted, (d) virtual laboratories may be less expensive than traditional laboratories, (e) they may allow learners to proceed at their preferred pace, and (f) they can present immediate feedback to learners (Aşiksoy & Islek, 2017).

The effects of using virtual laboratories in physics education have been analyzed in several studies. Ranjan (2017) investigated the effects of virtual laboratories on learners' development of concepts and skills in physics. The results of the study demonstrated that students' conceptual learning related to the photoelectric effect was higher in virtual laboratories than in real laboratories. Gunawan et al. (2017) examined the effects of virtual laboratories on learners' problem-solving abilities in the context of an electricity concept. According to study results, learners using virtual laboratories showed higher-level problem-solving skills as compared to those using traditional laboratories. Diani et al. (2018) analyzed whether virtual laboratories decreased learners' misconceptions about fluid material concepts. The results were positive, and learners' misconceptions diminished after the use of virtual laboratories. Yusuf and Widyaningsih (2020) analyzed learners' benefits after the implementation of virtual laboratories and found that there was an increase in learning quality and metacognitive skills in physics experiment courses.

Considering motivational and self-efficacy aspects, Dyrberg et al. (2017) proposed a framework for the assessment of learner motivation and experiences in virtual laboratories. Their framework mainly covered two major factors: task value and self-efficacy. Task value considers learners' perceived value of the task and covers four sub-constructs: "(1) attainment value: importance to do the task well, (2) intrinsic (interest) value: enjoyment while doing the task and interest in the content, (3) utility value: usefulness and relevance of the task, and (4) cost beliefs: effort and time to be invested" (Dyrberg et al., 2017, p. 362). Self-efficacy refers to an individual's perception of his own ability to conduct a task (Bandura, 1986). Higher values of these two major factors result in higher motivation to engage in virtual laboratories.

Attitude is defined as "a form of psychological state that determines the response of a stimulus in the form of action or behavior" (Saputra et al., 2020, p. 1). Attitudes towards courses have been investigated, and while positive attitudes have been shown to result in high performance, negative attitudes result in difficulties in learning (Mushinzimana & de la Croix Sinaruguliye, 2016). Attitudes toward physics can be divided into four categories: (a) having good emotions about physics, (b) having pleasure while learning physics, (c) comprehending problems, and (d) understanding experiments in learning physics (Sitotaw & Tadele, 2016). The literature has revealed that there is a lack of research analyzing learners' attitudes toward physics experiments (Saputra et al., 2020). On the other hand, it is essential to understand learners' attitudes to physics laboratories for the achievement of learners' motivations and learning in the field (Tanrıverdi & Demirbaş, 2012). In addition, laboratories are integrated components of physics courses. Hence, learners' attitudes towards physics laboratories needs to be investigated.

In the context of this study, the questionnaire proposed by Dyrberg et al. (2017) was deemed appropriate for analyzing Kyrgyz learners' motivation and experiences related to virtual laboratories. This survey had not been applied to Kyrgyz learners in prior studies. In this respect, our study is the first to present significant results about Kyrgyz learners' motivations and experiences in the use of virtual laboratories in a physics course. In addition, this study aimed to investigate Kyrgyz learners' attitudes towards physics laboratories while at the same time considering demographic characteristics. The corresponding results will be important for understanding learners' attitudes and hence motivations and learning in the physics field.

Methodology

Research Questions

The purpose of this study was to investigate Kyrgyz learners' use of virtual laboratories in a physics course at the university level. There were nine main research questions in the study:

1. In terms of Dyrberg et al.'s (2017) attainment factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use the Tina platform, and the ones who use Multisim?
2. In terms of Dyrberg et al.'s (2017) utility value factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?
3. In terms of Dyrberg et al.'s (2017) intrinsic interest value factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?

4. In terms of Dyrberg et al.'s (2017) cost beliefs value factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?
5. In terms of Dyrberg et al.'s (2017) self-efficacy factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?
6. Is there any difference in physics laboratory attitudes between learners who use a virtual lab program (Tina and Multisim) and learners who participate in face-to-face laboratories?
7. Do learners' physics laboratory attitudes differ according to their faculties?
8. Do learners' physics laboratory attitudes differ according to their genders?
9. Do learners' physics laboratory attitudes differ according to their GPA?

Research Design and Participants

The study was conducted during the 2019–2020 spring term and employed a quantitative approach. Quantitative data were gathered from university level learners registered to a state university of the Kyrgyz Republic. Before collecting data, informed consent was acquired from participants. Data were gathered through an online questionnaire, which consisted of demographic questions, items related to the use of virtual laboratories, and items to measure physics laboratory attitudes.

A total of 376 Kyrgyz learners studying at the undergraduate level participated. Demographic profiles of participants are provided in Table 1. Participants were studying in the engineering or science faculties. Of the participants, 36.7% used the Tina virtual lab, 32.2% used the Multisim virtual lab, and 31.1% used real (i.e., face-to-face) laboratories.

Table 1

Demographic Data of Participants

Characteristic	Category	*n*	%
Gender	Male	138	36.7
	Female	238	63.3
Faculty	Engineering	292	77.7
	Science	84	22.3
Laboratory type used	Tina virtual lab	138	36.7
	Multisim virtual lab	121	32.2
	Face-to-face lab	117	31.1

Note. $N = 376$.

Setting

This study was performed in the context of an undergraduate level general physics course in a state university in Kyrgyzstan. This course was provided in two different faculties: engineering and science.

In this general physics course, there were two hours of lectures and two hours of laboratory sessions each week and a total of 14 weeks in the course. In the theoretical sessions, learners were introduced to topics of general physics. In the laboratory sessions, learners conducted experiments on corresponding topics in either a traditional laboratory or by using applications in a virtual laboratory.

Learners were provided with one of two different virtual laboratory options: Tina or Multisim. Sample screenshots of these platforms are shown in Figures 1 and 2, respectively. In these platforms, learners were provided with virtual demonstrations of real experiments and then given the opportunity to conduct experiments choosing from among various experiment options.

Figure 1

Sample Tina Screen

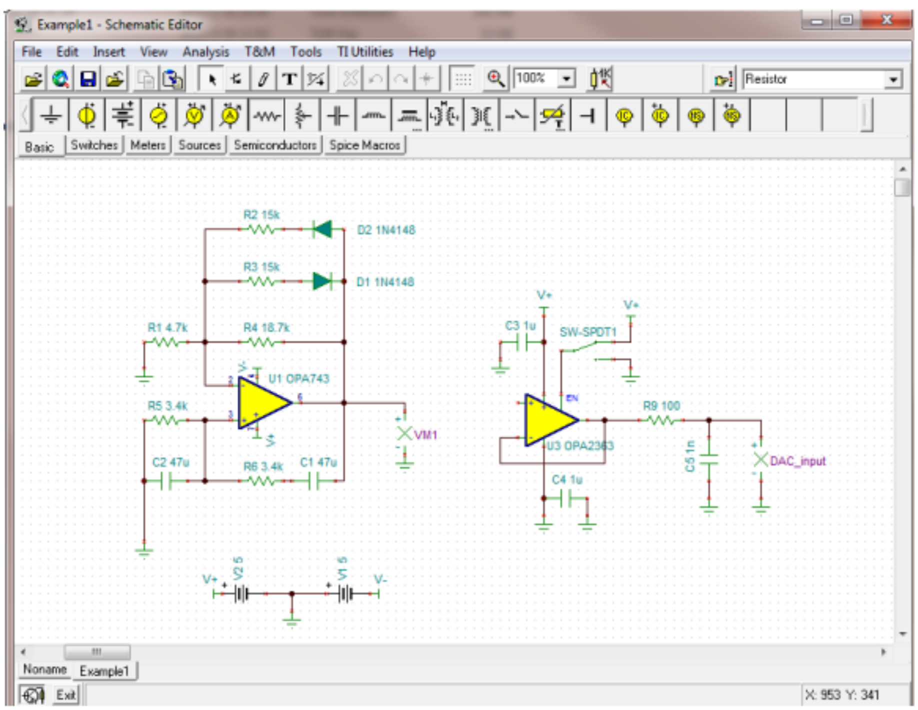
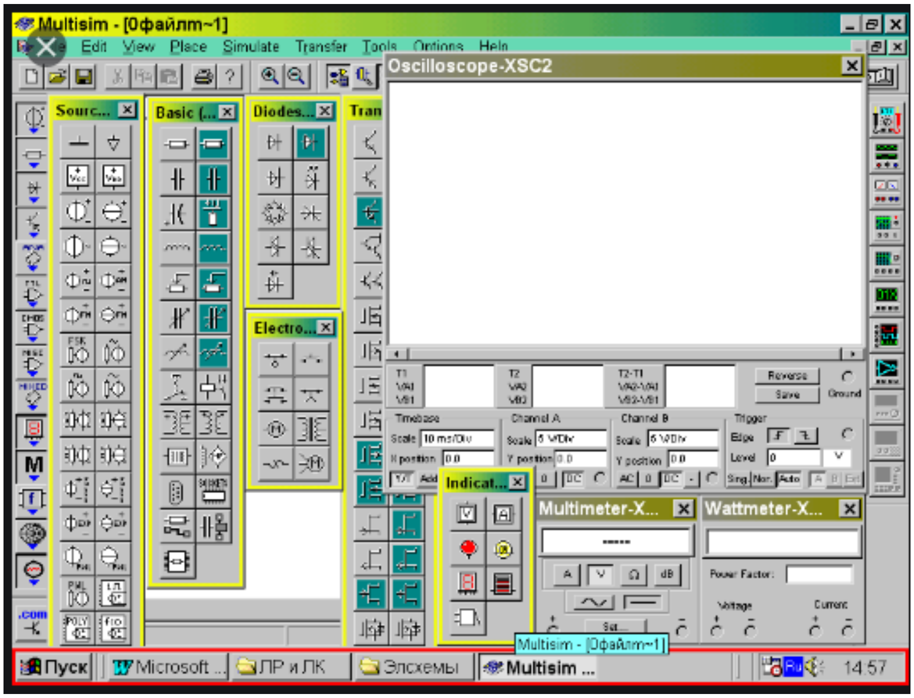


Figure 2

Sample Multisim Screen



Data Collection and Analysis

Data were gathered from participants through a questionnaire with three main sections. The first section covered five demographic questions. The second section involved questions related to task value, utility value, intrinsic interest value, cost beliefs, and self-efficacy. The third section consisted of the physics laboratory attitude scale. Items in the second and third sections were rated using a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*).

The questionnaire was prepared in an online platform, and a link to the questionnaire was sent to learners registered in the general physics course that term. The questionnaire was completed on a voluntary base. Quantitative data were analyzed using IBM SPSS Statistics (Version 22). In our inquiry, both descriptive and inferential analysis were employed.

Results

Chi-square tests were applied to investigate the difference of factors (i.e., attainment, utility value, intrinsic interest value, cost beliefs value, and self-efficacy) and laboratory attitudes among learners in the three groups. The results are provided in Table 2.

The chi-square results demonstrated that there was significant difference between the three groups with respect to the values of utility, intrinsic interest, and cost-belief.

Table 2

Chi-Square Results Related to Factors

Factor	Value	*df*	Asymptotic significance (2-sided)
Attainment	13.844[a]	8	.086
Utility value	36.392[a]	22	.028
Intrinsic interest value	28.148[a]	16	.030
Cost beliefs value	50.301[a]	24	.001
Self-efficacy	40.541[a]	34	.204
Physics laboratory attitude	148.090[a]	150	.529

Note. *N = 376.* [a]*0 cells (0.0%) have expected count less than 5.*

Research Question 1 (Attainment Factor)

The chi-square results demonstrated that there was no statistically significant difference between the three groups in terms of attainment factor.

Research Question 2 (Utility Value)

Post-hoc tests demonstrated that users of the Multisim program had significantly higher utility value scores compared to users of Tina. Furthermore, users of face-to-face laboratories had significantly higher utility value scores compared to users of Tina.

Research Question 3 (Intrinsic Interest Value)

Differences were seen in the results of post-hoc tests. Users of the Multisim program had significantly higher intrinsic interest compared to users of Tina. Moreover, users of face-to-face laboratories also had significantly higher intrinsic interest compared to users of Tina.

Research Question 4 (Cost Beliefs Value)

The post-hoc tests revealed that users of face-to-face laboratories had significantly higher cost beliefs value scores compared to users of Tina.

Research Question 5 (Self-Efficacy)

The chi-square results demonstrated no statistically significant difference between the three groups in terms of the self-efficacy factor.

Research Question 6 (Physics Laboratory Attitudes)

According to the chi-square results, there was no statistically significant difference between the three groups in terms of learners' attitudes towards the physics laboratory.

Furthermore, chi-square tests were applied to see whether learners' physics laboratory attitudes differed according to their faculties, genders, and GPAs. The results are provided in Table 3.

Table 3

Chi-Square Results With Respect to Learners' Faculty, Gender, and GPA

Demographic characteristic	Value	*df*	Asymptotic significance (2-sided)
Faculty	73.856[a]	75	.516
Gender	96.427[a]	75	.049
GPA	9.998[a]	4	.040

Note. *N = 376. [a]0 cells (0.0%) have expected count less than 5.*

Research Question 7 (Faculty)

The results demonstrated that there was no significant difference between learners studying in the engineering faculty versus those studying in the science faculty in terms of their physics laboratory attitudes.

Research Question 8 (Gender)

There was a statistically significant difference between male and female learners regarding their physics laboratory attitudes. Female learners' attitudes were found to be higher than male learners' attitudes.

Research Question 9 (GPA)

The results showed that learners' physics laboratory attitude differed according to their GPA. Learners with higher GPAs also had higher physics laboratory attitude values.

Discussion and Conclusion

This study investigated Kyrgyz learners' use of virtual laboratories in a physics course provided at the university level. The total number of participants was 376, all of whom were studying at the undergraduate level. Among the participants, one group used the Multisim virtual laboratory platform, one used the Tina virtual laboratory platform, and one was involved in face-to-face labs. Task value, self-efficacy, physics laboratory attitude levels, as well as course performance of learning groups were investigated.

According to the initial results, users had similar task value scores. Attainment value refers to the importance of doing the task well; students using Multisim, Tina, as well as a face-to-face laboratory perceived doing laboratory experiments well. Yet, Multisim and face-to-face laboratory users experienced more enjoyment while doing experiments in the context of the intrinsic interest factor, and they found the tasks useful and relevant in the context of the utility factor. In addition, learners using face-to-face laboratories demonstrated significantly higher cost beliefs value scores compared to users of the Tina program. These results are both similar and dissimilar to the study of Dyrberg et al. (2017), which found low task value scores of virtual lab users compared to traditional lab users. The similar level of task value scores in these virtual lab programs may have originated from instructional design issues. Therefore, there is a need to enhance the programs to attain better results. For instance, tasks in the Tina program can be improved by adding more experimental works or by integrating more joyful activities. In this way, learners could benefit more from the program.

Self-efficacy considers an individual’s perceived ability to perform a task. In this study, users of face-to-face laboratories and virtual laboratories were found to have similar self-efficacy scores. According to the literature, various findings have been seen in the results of other studies. For instance, Kolil et al. (2020) with an experimental self-efficacy framework found that both traditional and virtual laboratory users had low level experimental self-efficacy scores. Yet, the study of Ghatty (2013) revealed that learners using a virtual laboratory in a physics course experienced significant self-efficacy gains compared to learners using traditional laboratories. Further, this study also revealed that virtual laboratory users had similar self-efficacy scores compared to traditional laboratory users. This may be due to learners’ lack of technology knowledge and fear of performing experiments in a computer-based environment. This issue can be solved with student orientation sessions at the beginning of term. Furthermore, instructors can provide additional support to learners. In this way, learners may not hesitate to become involved in virtual laboratories. Moreover, some learners will increase their achievement when using virtual laboratories.

In the context of other research questions, learners’ physics laboratory attitudes were investigated according to the type of laboratories they were involved in and from the perspective of demographic characteristics. The findings revealed that learners’ physics laboratory attitudes did not change whether they used virtual or traditional laboratories. This implies that learner groups have similar motivation and achievement scores in physics courses. The same results can be seen in the study of Abou Faour and Ayoubi (2017), which found no significant attitude difference between virtual laboratory and face-to-face laboratory users in a physics course. Yet, the study of Tüysüz (2010) revealed that learners using a virtual laboratory demonstrated a higher-level attitude in comparison to traditional instructional methods. This can be explained by the existence of the benefits provided by virtual laboratories. For example, virtual laboratories provide opportunities to carry out dangerous experiments in safe environments and to perform experiments in schools that do not have sufficient laboratory equipment. Therefore, users of virtual laboratories showed higher motivation to perform experiments.

In this current study, there was not a significant physics laboratory attitude difference between learners studying in different faculties. That is, learners from both engineering and science showed similar motivation and achievement levels in the context of their physics laboratory courses. On the other hand, significant attitude differences were found between male and female learners. That is, female learners' attitudes were found to be higher than male learners' attitudes. In the study of Winkelmann et al. (2020), males and females demonstrated identical attitudes towards physics experiments conducted in an immersive virtual world. This study additionally revealed that learners having a higher GPA also had higher physics laboratory attitude values. This is an expected result since there is correlation between success and motivation. Similarly, Tüysüz (2010) focused on implementation of virtual laboratory applications and explored the direct correlation between learner performance and attitudes.

The results of this study are limited to the state university in Kyrgyzstan. Since the situation with the general information and communication technology (ICT) level of students varies depending on university, it is not possible to generalize the results of this study. Moreover, results showed that those students who used the Multisim virtual laboratory had generally higher utility value and intrinsic interest than students in the face-to-face group and in the Tina virtual laboratory. This might be explained by the fact that students using Multisim had higher ICT levels of literacy, and consequently, higher motivation to learn in general physics courses. Furthermore, the Multisim virtual laboratory is more user-friendly than the Tina virtual laboratory. The Tina platform is more complex and not user friendly. This may explain the lower motivation of students using Tina. In future studies, we suggest researchers compare students' achievement for groups from the same department and include a larger number of students, so they can be divided into 3 subgroups, each using a different virtual laboratory. Learning physics is a comprehensive task and having software such as Multisim and Tina offers an advantage to students of specific departments.

Overall, this study has shed light on learners' experiences and motivations in using virtual and face-to-face laboratories. The results demonstrate differences and similarities between Multisim, Tina, and face-to-face users. Yet, investigating and understanding learner experiences will allow instructors and developers to further improve the use of existing virtual laboratories. As a result, learners can benefit even more from this technology.

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Authors

Gülgün Afacan Adanır is an instructor at Ankara University Open and Distance Education Faculty. She received her PhD from the Middle East Technical University (METU) Information Systems in February 2016. Her research interests include distance education, learning analytics, e-government, and technology integration in education. ORCID: https://orcid.org/0000-0002-0832-1808 Email: gafacan@ankara.edu.tr

Azat Akmatbekova is an academic specialist in the department of Mathematics in Kyrgyz-Turkish Manas University, Kyrgyzstan after receiving her Bachelor of Science in Physics from Kyrgyz Russian Slyavic University, Bishkek, in 2000. Her research interests include physics education, e-learning, and instructional methodologies of STEM education. ORCID: https://orcid.org/0000-0003-3993-4938 Email: azat.akmatbekova@manas.edu.kg

Gulshat Muhametjanova is Assistant Professor at Applied Mathematics and Informatics department in Kyrgyz-Turkish Manas University. She received B.S. in Computer Engineering from Kyrgyz-Turkish Manas University in 2004 and a PhD in Computer Education and Instructional Technologies from METU in 2014. Her research interests include technology integration, e-learning, social networking. ORCID: https://orcid.org/0000-0001-9423-6302 Email: gulshat.muhametjanova@manas.edu.kg

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