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# Cognitive barriers in learning: impact of digitalization and global competencies on stress resilience and attention

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**ABSTRACT**

One of the key cornerstones for educators is addressing various communicative barriers in student learning. The aim of this study was to determine the impact of a virtual reality (VR)-based model on several cognitive barriers, specifically focusing on students' stress resilience and attention levels. A sample from two universities was utilized: Abai Kazakh National Pedagogical University and First Moscow State Medical University named after I.M. Sechenov, comprising a total of 138 students. The experimental component involved the VR program "sustainable development and cognitive barriers" (SDCB). The study examined changes in two barriers related to stress and inattention. The results indicate a positive impact. The pre-intervention stress resilience level (43.56) and the post-intervention level (9.02) show a significant difference with a positive trend at p=0.001. A similar trend is observed in the context of attentiveness characteristics: p=0.000. Considering the stratification approach, differences within the experimental group before and after the intervention were also analyzed based on specific characteristics. No significant relationships were found between the strata and the variable. This article will be valuable for educators, psychologists, policymakers, and other interested parties.



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## 1. INTRODUCTION

The contemporary context of global processes intensifies pressure on various members of the educational community. Ongoing restructuring, social disparity, political instability, and other factors create a range of challenges for higher education [1], [2]. Among these, it is important to highlight cognitive barriers, which are defined as a combination of factors hindering students' effective learning and information processing [3]. This article will examine two aspects of cognitive challenges: stress resilience and attentiveness.

Several definitions of stress resilience exist. A fundamental definition [4] describes stress as a non-specific reaction of the organism to any harmful external stimuli. In contrast, stress resilience is understood as the ability to resist stress in this context. The theoretical approach to fundamental concepts of stress has evolved to classify stress according to the level of organismal organization, stress-response systems, and effects. Both animals and humans experience physiological (with functional losses and disorders) and psychological (e.g., depression) stress [5]. The complex nature of psychological stress, which has evolved more intricately in humans as complex organisms, has led to more detailed studies not only of stress as a state but also of responses capable of mitigating it [6], [7]. When discussing attentiveness, it is important to recognize that loss of concentration is a common phenomenon among various groups. Preventive measures to reduce negative reactions to inattention can significantly help overcome this cognitive barrier [8], [9].

Several theories explain the principles of human responses to stress and the varying degrees of stress resilience. According to cognitive-behavioral theory, thoughts, beliefs, and life experiences determine stress responses at a given time [10]. For example, the adaptation process for military personnel after combat is more individualized and relies on life experience. This theory emphasizes shifting a person's outlook from negative to more positive or realistic perspectives [11]. Additionally, it is posited that systematic exposure to stress can be transmitted within a social context, suggesting that one person can transmit stress to others, irrespective of general or immutable predictors [12].

Learning processes are also systematically accompanied by stress-related factors. Competition among applicants for admission escalates into contests for optimal scores, participation in competitive processes, or even recognition within the educational community [13]. Furthermore, the formation of discomfort before significant academic milestones, such as certification exams throughout the academic year, is related to inattention [14]. On the other hand, it is also important to consider the context of stress resilience and learning. Continuous efforts to enhance knowledge and presentations, sometimes involving large audiences, can also cause discomfort for students, who are not immune to occasional errors influenced by external factors [15]. This includes the social climate, which can impact emotional well-being. Interaction with peers and various educators can disorient and cause anxiety for learners [16].

Narrowing the scope of research, it is essential to focus on the study of the impact of stress resilience and attentiveness through the lens of education, with an emphasis on sustainable development. It is necessary to enhance the understanding of potential cognitive challenges students will face in the future. Contemporary environmental issues related to climate change and anthropogenic factors highlight the relevance of this study at various educational levels [17]. The demand for leading specialists is increasing, and the latest statements regarding the sustainable development goals [18] once again underscore the essential integration of socially responsible principles into every sector. The sustainable development goals, adopted in 2015, laid the foundation for the work of organizations and individuals to address the planet's major economic, environmental, and social challenges [19]. Key aspects of this strategy include the universality and multi-stakeholder approach proposed by the United Nations, as well as the realistic attainability of achievements for each country according to adaptability [20]. Moreover, the work towards these goals extends beyond global practices and involves the daily efforts of each individual, impacting the respondent's academic perspective [21].

A specific area of research should focus on the careful regulation of stress resilience and attentiveness within the educational field during the adaptation phase of first-year students. Topuzov *et al.* [22] demonstrated that stress resilience is a key factor in the successful adaptation of first-year students to university life, which also affects attentiveness, perception, and other cognitive functions. This issue is particularly exacerbated in the context of international student migration. Research indicates that students with diverse specializations respond differently to activities related to stress resilience and attentiveness. Experience suggests that incorporating physical and mental practices, such as yoga or meditation, is especially beneficial for first- and second-year students [23], [24]. Significant attention should be given to enhancing the authenticity of instructional methods and integrating unconventional educational methods into everyday practice [25]. It is also crucial to develop long-term practical programs and work on students' self-confidence in their knowledge, exemplified by systematic reflection practices [26].

Considering this issue from the perspective of regional research specifics, particularly in the context of higher education in Kazakhstan, it is important to note that the primary focus shifted following the outbreak of the COVID-19 pandemic. Gritsenko *et al.* [27] indicate that the pandemic led to a deterioration in students' psycho-emotional and cognitive states due to the abrupt changes in the style and format of the educational process, among other factors. However, the majority of current research is concentrated on the psychodiagnostics model of identifying gaps in stress resilience and attentiveness among respondents, yet it does not provide unified solutions to this problem [28]–[30]. This study considers the context of integrating digital tools into various educational processes to test their impact on the effectiveness of overcoming cognitive barriers faced by students. The novelty of this article lies in the empirical confirmation of the effectiveness of the author's program in significantly increasing the levels of stress resistance and conscious attention of students, as evidenced by reliable statistical changes after the intervention, as well as in proving the absence of the influence of external factors on the results, which indicates the universality and reliability of the implemented methodology. The demonstrated effectiveness of these tools on other psychological aspects within the educational process justifies the implementation of an experiment aimed at assessing their efficacy in addressing issues related to stress-induced pressure and attentiveness among students [31], [32].

The objective of the study is to investigate the impact of a virtual reality (VR)-based model on a range of cognitive barriers, specifically focusing on students' stress resilience, attentiveness, and the development of global competencies. To achieve this, the manuscript outlines several tasks. First of all, to assess the levels of stress resilience, attentiveness, and global competencies among second-year students from two universities: Abai Kazakh National Pedagogical University and First Moscow State Medical

University named after I.M. Sechenov. Secondly, to integrate the author-developed virtual model into the educational process for the experimental sample. Thirdly, to evaluate the impact of the author-developed model on students' stress resilience, attentiveness, and development of global competencies. In this context, the null hypothesis of the study was formulated as: the virtual model does not influence the levels of stress resilience and attentiveness among students ($H_0$).

## 2. METHOD

### 2.1. Research design

Initially, the theoretical and methodological foundations of the concepts of "stress resilience" and "attentiveness" among students were analyzed, as well as the aspects influencing these states within the university setting. Approaches such as observation, analysis, synthesis, deduction, brainstorming, and discussion panels were employed. This stage lasted for 3 months. The second stage involved working with the sample and research elements. The focus was on ensuring uniform parameters for the experimental and control groups, including the number of participants, the educational process, and academic specialization. This stage lasted for 2 weeks and began at the start of the academic year. In the third stage, respondents were initially tested for stress resilience. Data were analyzed by segregated groups and compared for statistical differences in means. Testing was conducted simultaneously for all respondent groups on a single day. The fourth stage introduced the author-developed virtual course. The course, titled "sustainable development and cognitive barriers" (SDCB), was implemented. The program operated throughout the academic year, during students' elective time, which included one session per week every Friday. The academic year comprised 24 weeks, with one session of the course held each week. The program was based on four main components aimed at the organic integration of the curriculum and the enhancement of stress resilience and attentiveness among students in the experimental group, as seen in Figure 1. The control group continued their studies as usual and did not use the program implemented for the experimental group.

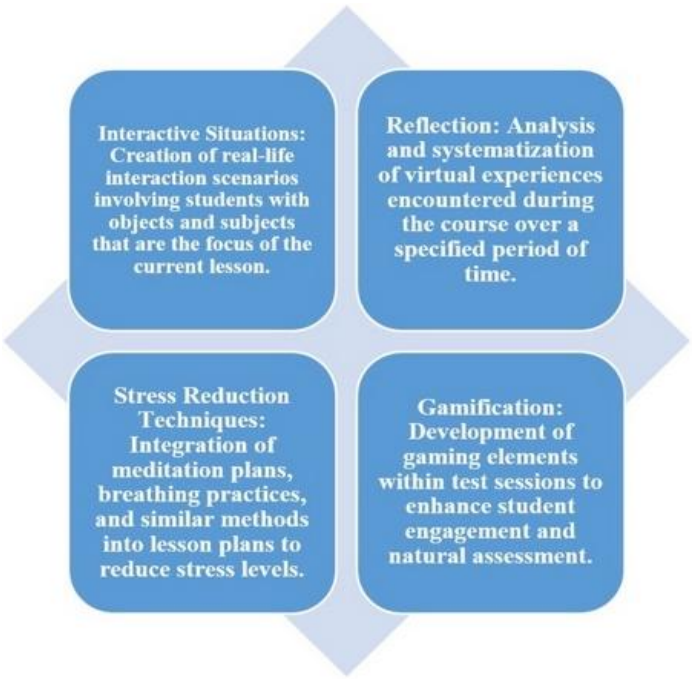


Figure 1. Instrumental principles of the author's SDCB program

The four components of the sessions were not always integrated simultaneously. Each session was built on interactive processes, which included gamification aspects during assessment moments or the initial introductory session on the topic. Additionally, the integration of meditation practices was incrementally implemented. Initially, this integration occurred once a month, and by the end of the course, it was included once every two weeks. The program was primarily divided into three levels of blocks, each reflecting a component of the sustainable development goals. Each session was based on a specific objective and

developed principles. Some topics, according to methodological standards, were divided into two or three separate lessons. Table 1 provides examples of specific sessions from different sections and periods of the program. In the fifth stage, following the implementation of the program, students underwent a repeat analysis of stress resilience and attention using a similar methodology. The research was conducted in several stages, spanning from May 2023 to May 2024.

Table 1. Examples of sessions based on the author's SDCB program

| Sustainable development goal | Sustainable development section | Learning objective of the session | Description of simulation | Component integration | Period of instruction |
|---|---|---|---|---|---|
|   | Social | Formation and development of an inclusive and equitable environment among students, ability to resolve inequality conflicts | Creation of 10 scenarios related to inequality conflicts. Declaration of the sustainable development goals provisions on discrimination in this context. Scenarios address issues such as: declaration of equal conditions and pay for men and women, use of feminine forms for referring to women, family planning, political and social issues, and work in an educational environment. | - Interactive scenarios<br>- Reflection | October, 2023 |
|   | Economic | Creation of knowledge and embodiment of an equitable vector of personal development in various dimensions of disproportion | Students encounter a series of interactive tasks, including the relocation (redistribution) of items to assist equal layers of the population. Additionally, students address tasks related to economic justice of specific provisions. Participants are divided into groups (4-5 people) and conduct a discussion panel on reducing disproportions in society. | - Interactive scenarios<br>- Gamification<br>- Stress reduction techniques | December, 2023 |
|   | Environmental (Part 2) | Encourage environmental awareness and responsibility for the surroundings | Participants face various situational problems related to climate issues. They have tasks to develop measures for mitigating these issues. Situations include waste sorting, energy conservation, and deforestation. | - Interactive scenarios<br>- Gamification | April, 2024 |

### 2.2. Tools

The program was developed with the support of the Department of Computer Science at both universities. The development of the program was based on the Unreal Engine, which included a critical feature for the current experiment: support for the program on mobile devices. The software used for development was Visual Studio. For 3D modeling of each simulation, the Blender application was utilized, along with content creation systems such as virtual reality toolkit (VRTK,) Headspace, and Calm. Testing was conducted using Unreal Engine automated testing. Additionally, tools for transferring simulations from oculus rift were employed in the creation of the platform. The program was unique and developed over a period of 5 months. The primary mediums for the program included students' mobile devices and VR headsets, as well as a designated area for implementation.

### 2.3. Sample

In this study, second-year students from the Abai Kazakh National Pedagogical University and the First Moscow State Medical University were involved. Participants were selected randomly using a random number generator from lists of second-year students identified by stochastic numbers. No additional selection criteria were imposed.

To further eliminate the influence of external variables on the experiment, a stratification method was employed. Students were analyzed and categorized based on four parameters: gender (male and female), marital status (married and single), experience with VR technologies (yes or no), and the presence of psychological disorders related to stress (yes or no). The experimental and control groups were also formed

using a random number generator, so that the number of representatives of each stratum (for example, women and men) in each of them was equal for further use of parametric statistical methods. If there were not enough participants to achieve each group sample equivalence, they were also randomly selected from the student lists and invited until the number of participants in the strata of each group was equal. A sample of 138 students was utilized; 69 participants in each experimental and control group with homogenous internal stratification, as shown in Table 2. This categorization was carried out before the participants were assigned to the experimental and control groups in order to ensure their homogeneity and as a form of stratification. The results of the experimental study were subsequently analyzed within each of these to avoid the influence of external factors.

Table 2. Distribution of the experimental and control group sample internal stratification (N=69)

| Variable | n | Percentage (%) |
|---|---|---|
| Gender | Woman | 29 |
| | Man | 40 |
| Marital status | Married | 18 |
| | Single | 51 |
| Experience with VR technologies | Yes | No |
| | 34 | 35 |
| Presence of stress-related psychological disorders | Yes | No |
| | 20 | 49 |

### 2.4. Survey

To assess stress resilience, the methodology by Kirsheva and Ryabchikova [33] was employed, specifically the personality stress resilience self-assessment test. The test comprises 18 questions and utilizes a Likert scale (from 1 to 3). A list of all questions is provided in Table 3. For the analysis of attentiveness, the mindful attention awareness scale (MAAS) [34] was used. This scale consists of 15 statements evaluated on a Likert scale (from 1 to 6). A list of all questions is provided in Table 4. Although originally developed to measure mindfulness, the conceptual definition of mindfulness in MAAS corresponds closely to the construct of attentiveness as defined in the present study. Therefore, these terms are used interchangeably in this context.

### 2.5. Statistical tools

The analysis was conducted using the IBM SPSS 20 software application. To support our conclusion, we have provided quantitative findings derived from the statistical analysis of stress resilience and attentiveness indicators in the pre- and post-tests. Additionally, a statistical analysis was conducted in terms of sample stratification and the interpretation of results in accordance with the characteristics of the sample.

Table 3. Self-assessment test of personality stress resilience [33]

| Statement | Rarely | Sometimes | Often |
|---|---|---|---|
| I feel that I am undervalued in the team. | 1 | 2 | 3 |
| I strive to work even when I am not entirely well. | 1 | 2 | 3 |
| I constantly worry about the quality of my work. | 1 | 2 | 3 |
| I tend to be aggressive. | 1 | 2 | 3 |
| I cannot tolerate criticism directed at me. | 1 | 2 | 3 |
| I can be irritable. | 1 | 2 | 3 |
| I try to be a leader wherever possible. | 1 | 2 | 3 |
| I am considered persistent and assertive. | 1 | 2 | 3 |
| I suffer from insomnia. | 1 | 2 | 3 |
| I can stand up to my adversaries. | 1 | 2 | 3 |
| I experience emotional and distressing reactions to unpleasant situations. | 1 | 2 | 3 |
| I do not have enough time to rest. | 1 | 2 | 3 |
| I encounter conflict situations. | 1 | 2 | 3 |
| I lack the authority to implement changes. | 1 | 2 | 3 |
| I do not have enough time to engage in my favorite activities. | 1 | 2 | 3 |
| I do everything quickly. | 1 | 2 | 3 |
| I fear that I will not get into college. | 1 | 2 | 3 |
| I act impulsively and then worry about my actions and decisions. | 1 | 2 | 3 |

Table 4. Mindful attention awareness scale [35]

| Statement | Almost always | Very frequently | Somewhat frequently | Somewhat infrequently | Very infrequently | Almost never |
|---|---|---|---|---|---|---|
| I could be experiencing some emotion and not be conscious of it until sometime later. | 1 | 2 | 3 | 4 | 5 | 6 |
| I break or spill things because of carelessness, not paying attention, or thinking of something else. | 1 | 2 | 3 | 4 | 5 | 6 |
| I find it difficult to stay focused on what's happening in the present. | 1 | 2 | 3 | 4 | 5 | 6 |
| I tend to walk quickly to get where I'm going without paying attention to what I experience along the way. | 1 | 2 | 3 | 4 | 5 | 6 |
| I tend not to notice feelings of physical tension or discomfort until they really grab my attention. | 1 | 2 | 3 | 4 | 5 | 6 |
| I forget a person's name almost as soon as I've been told it for the first time. | 1 | 2 | 3 | 4 | 5 | 6 |
| It seems I am "running on automatic", without much awareness of what I'm doing. | 1 | 2 | 3 | 4 | 5 | 6 |
| I rush through activities without being really attentive to them. | 1 | 2 | 3 | 4 | 5 | 6 |
| I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there. | 1 | 2 | 3 | 4 | 5 | 6 |
| I do jobs or tasks automatically, without being aware of what I'm doing. | 1 | 2 | 3 | 4 | 5 | 6 |
| I find myself listening to someone with one ear, doing something else at the same time. | 1 | 2 | 3 | 4 | 5 | 6 |
| I drive places on 'automatic pilot' and then wonder why I went there. | 1 | 2 | 3 | 4 | 5 | 6 |
| I find myself preoccupied with the future or the past. | 1 | 2 | 3 | 4 | 5 | 6 |
| I find myself doing things without paying attention. | 1 | 2 | 3 | 4 | 5 | 6 |
| I snack without being aware that I'm eating. | 1 | 2 | 3 | 4 | 5 | 6 |

### 2.6. Limitation

The research is based on an author-developed VR program, which means it may be tailored to address the needs of different universities or disciplines. The operational principle of the program was constructed through a systematic theoretical analysis by the authors. Given the program's focus, only aspects of stress resilience and attentiveness were considered; therefore, its impact on other factors was not thoroughly investigated. Additionally, among external variables, only a few subjective factors were considered, which the authors believe narrow the scope of the study. It is important to note the potential for insufficient institutional adaptability to fully implement the technology across the entire program, which could significantly diminish its effect. A potential challenge could also be the gradual decrease in the relevance of sustainable development within society, with a target date of 2030.

### 2.7. Ethical issues

The study was conducted with the involvement of psychologists, computer scientists, and the authors experiments. It was approved by the ethics committees of both universities where the research was carried out. Data regarding personal characteristics and medical conditions were kept confidential. Students provided informed consent for their participation in the experiment and data processing.

## 3. RESULTS

First and foremost, the obtained data were assessed for normality of distribution using the Kolmogorov-Smirnov test. The value of D=0.1049 is less than the critical value of D for testing two samples (D_critical=0.2916). Thus, the null hypothesis regarding the normality of data distribution cannot be rejected. Subsequently, the measurement of stress resilience and attentiveness was optimally tested for statistical significance of the differences between them using a paired t-test for independent samples, based on the assumption of normality in the distribution of the sample. The results of the analysis are presented in Tables 5 and 6, respectively.

The mean score of the experimental group on the stress resilience test was 43.56, while the control group maintained a level of 47.22. The observed difference in means is 3.66, and the statistical significance

with p=0.43 suggests that the stress resilience levels of the participating students do not have statistically significant differences. However, the interpretation of the results using the methodology indicates that this is an unsatisfactory parameter of stress resilience. In other words, it should be noted that students exhibit a low level of stress control and management.

Table 5. Analysis of statistical difference in student stress resilience levels following program implementation

| Assumption | F | Sig. | t | Df | Sig. (2-tailed) | Difference of means | Standard error of difference | 95% confidence interval | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| Equal variances assumed | 0.936 | 1.846 | 1.456 | 85 | 0.43 | 3.66 | 0.79 | 1.67 | 4 |
| Equal variances not assumed | | | 1.456 | 81.001 | 0.43 | 3.66 | 0.79 | 1.99 | 3.84 |

Table 6. Analysis of the statistical difference in students' levels of mindfulness due to program implementation

| Assumption | F | Sig. | t | Df | Sig. (2-tailed) | Difference of means | Standard error of difference | 95% confidence interval | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| Equal variances assumed | 0.821 | 1.589 | 1.067 | 85 | 0.84 | 0.2473 | 0.628 | 0.001 | 1.437 |
| Equal variances not assumed | | | 1.067 | 81.908 | 0.84 | 0.2473 | 0.628 | 0.039 | 1.038 |

As shown in Table 6, the statistical difference in levels of mindfulness is not significant. However, it is noteworthy that the experimental group exhibits a higher score, measured at 1.4783, compared to the control group's score of 1.231. This indicates that the level of attention among students in both groups can be considered almost identical and remains low.

Following the integration of the intervention, a re-evaluation was conducted to assess the dynamics of differences in stress resilience levels across the groups. The main results are summarized in Table 7. As shown, the statistical significance of the difference has increased substantially.

The mean stress resilience score for the experimental group decreased to 9.02, while the control group remained nearly unchanged at 40.19. According to Kirsheva and Ryabchikova [33] assessment methodology, lower scores indicate higher stress resistance. This result highlights a negative t-value (-5.1) with a p-value of 0.000, indicating that the mean value of the experimental group is significantly lower than that of the control group. Comparing the experimental group's pre-intervention (43.56) and post-intervention (9.02) scores reveals a significant improvement, with a p-value of 0.001. The 95% confidence interval for the mean difference (-31.17) is entirely below zero, confirming the direction and significance of this change. These results indicate that the level of stress resilience improved significantly following the implementation of the custom program. A similar trend can be observed in the context of attention characteristics analysis, as presented in Table 8.

Table 7. Analysis of the statistical difference in stress resilience levels among students after program implementation

| Assumption | F | Sig. | t | Df | Sig. (2-tailed) | Difference of means | Standard error of difference | 95% confidence interval | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| Equal variances assumed | 274.009 | 0.000 | -5.1 | 85 | 0.000 | -31.17 | -3.24 | -31.56 | -31.13 |
| Equal variances not assumed | | | -5.1 | 81.001 | 0.000 | -31.17 | -3.24 | -31.25 | -30.99 |

Table 8. Analysis of the statistical difference in students' mindfulness levels after program implementation

| Assumption | F | Sig. | t | Df | Sig. (2-tailed) | Difference of means | Standard error of difference | 95% confidence interval | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower | Upper |
| Equal variances assumed | 164.379 | 0.000 | 10.33 | 85 | 0.000 | 3.847 | 2.637 | 3.561 | 4.031 |
| Equal variances not assumed | | | 10.33 | 81.908 | 0.000 | 3.847 | 2.637 | 3.258 | 3.929 |

Similar dynamics can be observed in the analysis of mindfulness characteristics. As indicated by the t-test analysis, there are statistically significant differences in mindfulness scores between the experimental and control groups. Specifically, the mean score for the experimental group increased to 5.369, which underscores the statistical significance of the difference after the intervention (p=0.000). Given the stratification approach, differences within the experimental context group before and after the intervention were also analyzed, focusing on specific grouping criteria. To minimize the influence of external factors and potential additional dependencies, the data are presented in Tables 9 and 10.

The segmentation indicates the absence of specific dependencies related to external factors. It should be noted that the most optimal scores in enhancing stress resilience were observed among the male group (p=0.000) and among students with no prior experience with VR (p=0.000). However, none of these indicators showed significant deviation from the average value within the group. Thus, it can be asserted that certain external variables did not affect the results of the experiment.

It should also be noted that certain external factors did not influence the results of the mindfulness study. The highest scores were observed in the strata of male participants, those without experience in VR, and students with psychological stability. In this context, there is sufficient basis to reject the null hypothesis concerning the lack of impact of the virtual model on the levels of stress resilience and mindfulness within the studied sample.

Table 9. Stratification of results for the experimental group before and after intervention (stress resilience)

| Stratum | Before | | | After | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | SEM | Mean | SD | SEM | t | p |
| Women | 43 | 0.891 | 0.748 | 11.48 | 0.166 | 0.091 | -5.3 | 0.005 |
| Men | 42.12 | 0.784 | 0.181 | 6.92 | 0.109 | 0.048 | -3.23 | 0.000 |
| Married | 42.5 | 0.682 | 0.409 | 9.13 | 0.224 | 0.037 | -5.56 | 0.002 |
| Single | 44.62 | 0.85 | 0.478 | 8.91 | 0.199 | 0.078 | -5.88 | 0.000 |
| Experience with VR | 42.22 | 0.941 | 0.139 | 10.55 | 0.098 | 0.001 | -4.23 | 0.003 |
| No experience with VR | 45.9 | 0.782 | 0.478 | 7.49 | 0.123 | 0.03 | -4.76 | 0.000 |
| Psychological disorders related to stress | 43.7 | 0.529 | 0.378 | 9.38 | 0.048 | 0.073 | -5.6 | 0.002 |
| No psychological disorders related to stress | 43.42 | 0.823 | 0.278 | 8.66 | 0.128 | 0.056 | -3.91 | 0.000 |

Note: SD=standard deviation; SEM=standard error of the mean; t=student's t-test statistic; p=statistical significance value.

Table 10. Stratification of experimental group results before and after intervention (mindfulness)

| Stratum | Before | | | After | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | SEM | Mean | SD | SEM | T | p |
| Women | 1.333 | 0.883 | 0.149 | 5.012 | 0.163 | 0.072 | 5.61 | 0.000 |
| Men | 1.6236 | 0.748 | 0.193 | 5.726 | 0.028 | 0.022 | 3.24 | 0.000 |
| Married | 1.589 | 0.748 | 0.164 | 5.046 | 0.027 | 0.083 | 5.89 | 0.000 |
| Single | 1.3676 | 0.734 | 0.099 | 5.692 | 0.027 | 0.071 | 4.25 | 0.000 |
| Experience with VR | 1.7962 | 0.829 | 0.183 | 4.985 | 0.179 | 0.062 | 4.78 | 0.000 |
| No experience with VR | 1.1604 | 0.92 | 0.127 | 5.753 | 0.034 | 0.037 | 3.91 | 0.000 |
| Psychological disorders related to stress | 1.247 | 0.839 | 0.851 | 4.945 | 0.079 | 0.061 | 5.58 | 0.001 |
| No psychological disorders related to stress | 1.7096 | 0.839 | 0.829 | 5.793 | 0.07 | 0.063 | 3.22 | 0.001 |

Note: SD=standard deviation; SEM=standard error of the mean; t=student's t-test statistic; p=statistical significance value.

## 4. DISCUSSION

The results of the study confirm the effectiveness of the virtual model in enhancing students' levels of stress resilience and mindfulness. It is important to note that this type of work has been implemented for the first time in higher education institutions in Kazakhstan, which until recently had focused primarily on the psychodiagnostics of stress manifestations among students and the mitigation of cognitive barriers through stable practices and digitization. Studies conducted by Israeli researchers underscore this supportive research on effectiveness. In their experiments, VR training has been shown to reduce anxiety levels and positively affect individuals' psychological states. As explained by the authors, this is achieved through the creation of a more realistic and native environment that facilitates better understanding of complex topics and enhances confidence in one's knowledge [36]. The positive feedback on interactions with technology, in terms of increased self-confidence and stress resilience, was also reflected in the comments of the students themselves. Participants noted improvements in their pedagogical skills, better preparation for real classroom situations, and increased confidence in their cognitive abilities [37].

Among other supportive arguments for the positive effects of virtual interventions, it is important to highlight the enhancement of motivational components in learning, which impacts the effectiveness of material absorption and mitigates the emergence of undesirable cognitive barriers. The increased innovativeness allows for the modernization of methodological approaches to education and the adaptation of

learning contexts to the individualized needs of each student [38]. All these studies align with the findings of the current work and strengthen the impact of VR on the potential improvement of stress resilience and cognitive stability in students, including mindfulness processes. Moreover, such effectiveness is demonstrated in the analysis of memory and mindfulness. Coleman *et al.* [39] found that students who underwent training in virtual rooms significantly improved their concentration on tasks, with the improvement being particularly notable in tasks requiring simultaneous focus on multiple aspects of information. This was explained by the ability to simulate pedagogical conditions in real time and the formation of more precise algorithms for overcoming cognitive barriers. The presence of VR programs with various themes enhances memory function [40].

Important predictors of effectiveness include users' characteristics, such as previous experience with VR and individual differences in cognitive abilities, which affect the degree of sense of presence. All this underscores the significance of integrating additional testing practices for the model, as it accounts for the presence of specific barriers for each individual. As evidenced by the current analysis, certain socio-demographic characteristics of the respondents did not demonstrate a difference in the program's impact on stress resilience and attentiveness. However, it is important to consider that the limited scope of these factors currently does not allow for a generalized interpretation of the results. Additional factors that should be taken into account include attitudes toward the sustainable development goals (each of their components), experience in training participation, the presence of mental, psychological, and physical health issues, prior engagement with meditation and breathing practices, and other aspects that could provide a more comprehensive assessment of the program's effectiveness.

The significant benefits of implementing VR tools include advancing future educational specialists in their respective fields. Notably, several researchers identify the effectiveness of VR in educational pedagogical processes. This effectiveness is observed not only in the positive impact on students themselves but also in the potential to integrate algorithms or approaches into the future practices of educators. The potential of VR as an innovative technology for enhancing the quality of teacher training and improving teaching practices has been documented [41]–[43]. This is also explained by the fact that simulating real-world situations can help teachers avoid certain risks in the future. This involves working on an interpersonal level, where VR enables the exploration of possible scenarios and the development of approximate algorithms to help current students avoid cognitive barriers [44].

Concurrently, it is essential to account for potential risks or misperceptions associated with VR, which may distort the research outcomes. Several studies, particularly [45]–[47], have linked the impact of VR-based programs to the novelty of their application, especially in regions with lower educational quality. Consequently, the interaction effect may appear substantial and can be explained by an increased interest in such practices, which may significantly decline over a prolonged period. Moreover, material constraints should not be overlooked, as the implementation of VR-based programs requires substantial resources. Not all educational institutions can afford an optimal number of headsets, goggles, or the necessary technical specialists for the maintenance and support of such programs. Additional risks arise from the fact that, unlike traditional approaches or even massive open online courses (MOOCs), VR-based instruction is inherently limited to a relatively small sample due to financial and spatial constraints. Although the obtained results are statistically significant, further research on this topic could provide a deeper understanding of the actual impact of this model on mental health.

Thus, while the current model has been developed, it is heavily focused on the exploration of the subject matter. In this context, it is prudent to investigate further the potential for refining the program to account for pedagogical specifics such as communication and management. An interesting and potentially significant area for study remains the cognitive barrier of distraction. On one hand, Coleman *et al.* [39] demonstrate in their work that virtual models prevent distraction by immersing respondents in a more effective learning experience. Additionally, the insufficient exploration of this issue in the current model opens opportunities for studying the side effects of implementing four key algorithms, with significant attention given to sustainable development and stress reduction.

The negative effects of VR in the context of stress resilience are also highlighted. Fernández-Batanero *et al.* [48] observe that the use of educational technologies can both improve and, conversely, worsen the stress levels of future educators. This is associated with a variety of factors, including the specifics of the technology itself, the characteristics of the sample, institutional conditions, and university policies. Thus, such an approach suggests the need for deeper research, such as the current study, to assess the impact in a more layered and objective manner. It is also crucial to consider the potential reverse effects of using virtual tools on stress resilience. Vehteva *et al.* [49] point out possible issues that may arise during the implementation of the model. Major negative effects include virtual exhaustion during training, disorientation, and even increased stress from using new technologies during learning.

Additionally, other negative impacts include dependence on digital tools during the learning process and disorientation between real and virtual time, which complicates distinguishing between native content and gamified elements. In this aspect, balancing digitalization in educational processes with interactive components is essential [50], [51]. In response to this principle, the current intervention incorporates physical stress-relief measures such as yoga and meditation. The model demonstrated effectiveness without negative effects under stratified conditions; however, further research is potentially required to analyze deeper impacts. It would be beneficial to explore additional psychological parameters, such as depression and burnout, under the influence of VR.

## 5. CONCLUSION

The study results affirm the efficacy of utilizing a virtual model to enhance students' stress resilience and attentiveness. The innovative implementation of virtual technologies enhances integration and has the potential to exert a positive influence on other significant variables. In this regard, it is also essential to highlight the validation context of stratification, which confirms the absence of significant differences related to various external variables, indicating their lack of impact. The study has demonstrated the effectiveness of a combination of globally significant, technical, and cognitive techniques, which contribute to a consistent improvement in stress resilience and attentiveness across various student groups. The practical component of the study underscores the presence of an effective model, as evidenced by the experimental results. The study addressed not only experiential risks but also variations in social, demographic, and other statuses, thereby eliminating concerns regarding the diverse morphology of stress and inattentiveness. This, in turn, broadens the potential for application across different sample types.

Future researchers may explore a more in-depth analysis of this model through parallel effects on other cognitive barriers or by examining their combined impact. For instance, it would be valuable to investigate whether improvements in stress resilience might affect academic performance in specific subjects. It is also crucial to consider the program's influence on sustainable development, which may involve more specialized and productive interactions aimed not only at overcoming cognitive barriers but also at addressing academic performance, productivity, and students' professional perspectives on global challenges. An additional area of interest lies in the closer examination of VR as a tool for overcoming cognitive barriers. It is crucial to determine whether it can provide a long-term effect (e.g., over several years) comparable to its short- and medium-term impact. Given that the development of stress resilience and attentiveness requires systematic engagement, such an experiment would be of significant importance.

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C : **C**onceptualization
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## CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

## INFORMED CONSENT

Students provided informed consent for their participation in the experiment and data processing.

## ETHICAL APPROVAL

It was approved by the ethics committees of both universities where the research was carried out. Data regarding personal characteristics and medical conditions were kept confidential.

## DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article.

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