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VIRTUAL REALITY-BASED TRAINING FOR MINERS: AN ASSESSMENT FROM PARTICIPANTS' PERSPECTIVE

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Purpose: This scientific article presents the results of the survey in which the miners of Jastrzębska Spółka Węglowa evaluated modern training, which uses virtual reality, in which they participated. The objectives of the paper include: an assessment of the attractiveness of individual elements of the training process, an assessment of the individual components of the VR training application, an assessment of the gamification elements of the VR application, and finally, an examination of the need to expand the VR application scenario.
Design/methodology/approach: The article uses the survey method. The survey was completed by participants – workers of Jastrzębska Spółka Węglowa – taking part in a modern training using VR.
Findings: The results of the survey provide valuable insight into the assessment of training for miners that uses virtual reality. Based on the results, it can be concluded that training using virtual reality is rated very highly. Moreover, all elements of the training were rated very well, few participants indicated the need to expand the training application. The gamification elements used in the training application were also rated very well.
Research limitations/implications: The most important research limitation was the research sample – it is recommended to expand the research sample to include more employees in the future. In the future, it is also planned to use further VR applications for training at Jastrzębska Spółka Węglowa.
Practical implications: The research results show that the use of training based on virtual reality has a very positive reception among the participants. Participants showed a positive attitude towards all elements related to the VR application and the entire training process. The results show how virtual reality applications can be used in practice for training purposes in mining companies.
Originality/value: The article presents the results of survey research that evaluate the training program, originally developed in Jastrzębska Spółka Węglowa for research and training purposes.

Keywords: virtual reality, training, miners, JSW, VR.
Category of the paper: Research paper.

1. Introduction

From remote work and e-commerce to telemedicine and digital entertainment, the Internet has opened an age of opportunities and challenges that fundamentally alter the way we live, work, and interact with the world around us. With the development of Industry 4.0 new challenges and opportunities appear. They are strongly connected with Internet of Things (IoT), which is based on devices for undertaking functions from data sensing, computation to communication and IoT intelligence (Maddikunta et al., 2022). What is more, the development of technology has a strong impact on society and their lifestyle. More and more popular becomes the term of Society 5.0 (Mourtzis et al., 2022). It represents a vision of a highly advanced and interconnected society where technology serves as a catalyst for positive social and economic transformation. There is also a term that merges IoT and social aspects, namely Social Internet of Things (SIoT) (Wu et al., 2023). When it comes to Industry 4.0, one of them is immersive technologies (Agrawal et al., 2019) such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). In addition, these immersive technologies are also connected with the term Metaverse, which is a new developing trend that offers the potential to create virtual versions of physical objects, resulting in a digital twin (DT) of the physical world (Banaeian Far et al., 2023). These technologies have created opportunities for new applications in various areas, for example construction industry (Ghobadi, Sepasgozar, 2020), anatomy field (Izard et al., 2017), education (Radianti et al., 2020; Steculа, 2019), entertainment (Steculа, 2022) and even to overcoming traumas (Kovar, 2019). Another area of application of immersive technologies is training. Virtual reality and augmented reality can be used in production and service enterprises and different organizations for training of various types (Steculа, 2023). VR and AR training is a form that activates participants and provides them with many stimuli from visual, through auditory, to tactile. Training using immersive technologies is a modern form of approach to people in today's digitalized world. Modern people who use the achievements of technology, especially those related to communication and information technologies, also expect modern forms of training, study, and education that use innovative techniques and technologies. Virtual reality creates just such an opportunity.

This article discusses the topic of training conducted using virtual reality. It presents practical survey research, and its results, conducted on training participants. The trainees were employees of Jastrzębska Spółka Węglowa, working at positions of miners. The entire training process was developed as part of research, and its most challenging element was the design of a virtual reality application that served as a training tool. The paper consists of 5 chapters.

Chapter 2 includes a method applied in the research. Chapter 3 presents the results of the survey, and it includes answers for 6 questions form the survey. The last chapter of Conclusions summarizes the paper and the research.

2. Research methods

The results presented in this article come from one phase of a larger study on virtual reality. As part of this research, among others: a training program using virtual reality was developed, an appropriate VR application was created, the training process was implemented, and then the training process was assessed based on various criteria.

The training took place in the training room of Jastrzębska Spółka Węglowa at the Pniówek coal mine, equipped with the necessary virtual reality equipment – the research was also carried out there. The trainees used HTC VIVE Pro VR goggles, which provided images and sounds, and controllers that allowed them to use virtual hands. In total, 98 people who were employees of Jastrzębska Spółka Węglowa took part in the training.

The training was divided into 3 parts, which included:

- theoretical lecture,
- discussion with training participants,
- training part carried out using virtual reality goggles (VR application).

This article focuses on the research stage related to the evaluation of the developed training process by the training participants. The techniques used in this stage of the research were a survey questionnaire completed by the training participants after the training. 94 people took part in this study. This article presents the results of part of the survey research – the answers to six survey questions are thoroughly described and interpreted.

The following research goals (objectives) were set in the work:

O1: Assessment of the attractiveness of individual elements of the training process.

O2: Assessment of individual components of the VR training application.

O3: Assessment of gamification elements of VR applications.

A4: Explore the need to expand the VR application scenario.

As mentioned, for the study purpose the VR application was developed. Figure 1 shows a screenshot from an exemplary view of the developed application. It shows a virtual miner as a cooperator of the participant during virtual training.

Figure 1. The screenshot from an exemplary view of the developed VR application.

3. Results

3.1. Research group

Among the 94 people who participated in the training and who were the subject of research interest, there were 96.8% men and 3.2% women (Fig. 2). Half of the respondents were 25-44 years old (Fig. 3). The youngest respondents (under 25 years of age) were slightly less represented, and respondents aged 45 and over were the least likely to appear in the group of respondents. Most respondents were people with secondary education (64.9%), next in terms of number was the group of people with basic vocational education (31.9%), and the least numerous among the training participants were people with higher education (18 ,1%) (Fig. 4).

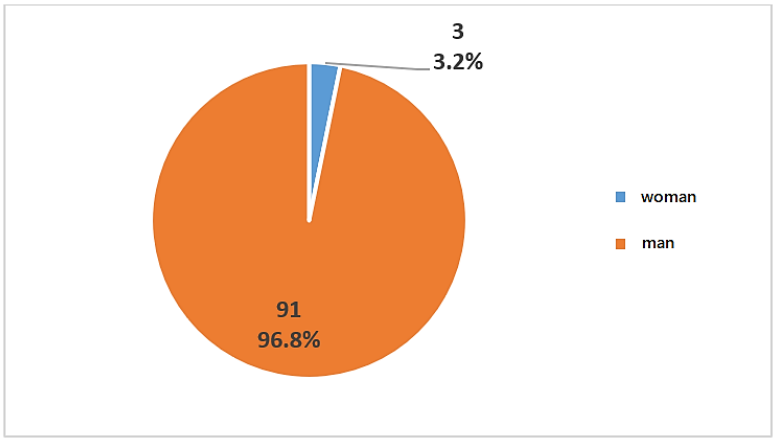

Figure 2. Gender of respondents (N = 94).

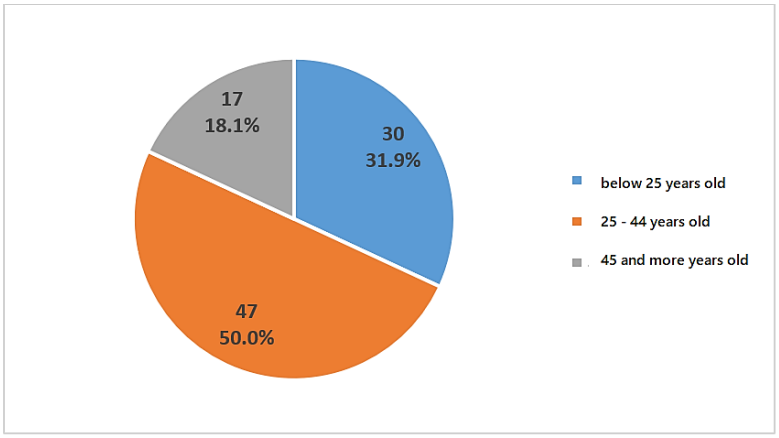

Figure 3. Age of respondents (N = 94).

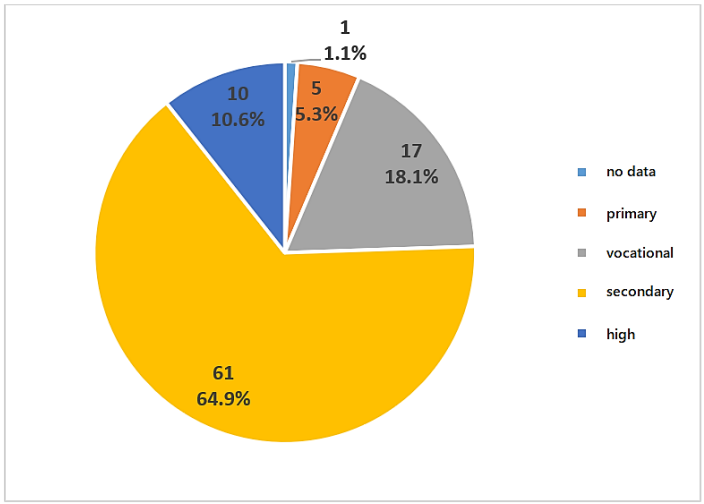

Figure 4. Education of respondents (N = 94).

In terms of work experience, the largest group were people who worked for 11 to 15 years in the company (35.1%), followed by people who worked less than 5 years (34%) (Fig. 5). As many people worked for 5 to 10 years as for 25 to 20 years (10.6% each). People who worked for more than 20 years constituted the smallest group among respondents (9.6%).

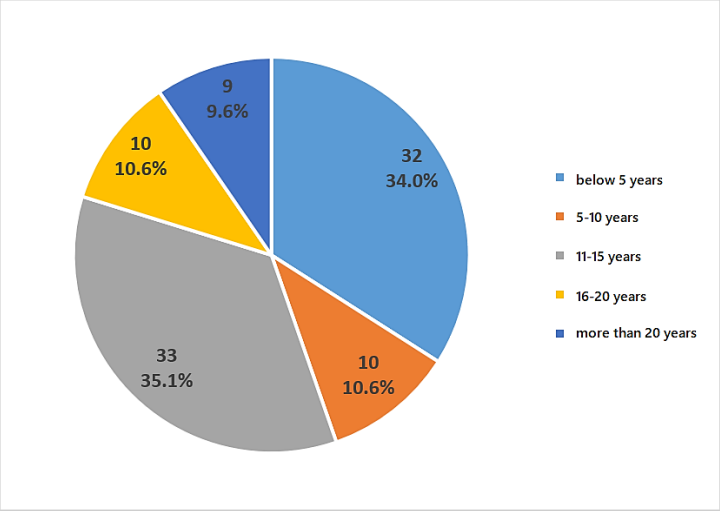

Figure 5. Work experience in JSW of respondents (N = 94).

For a group slightly smaller than one third of respondents (30.9%), the training was the first opportunity to contact virtual reality (Fig. 6). Most of the participants had already experienced VR before (69.1%).

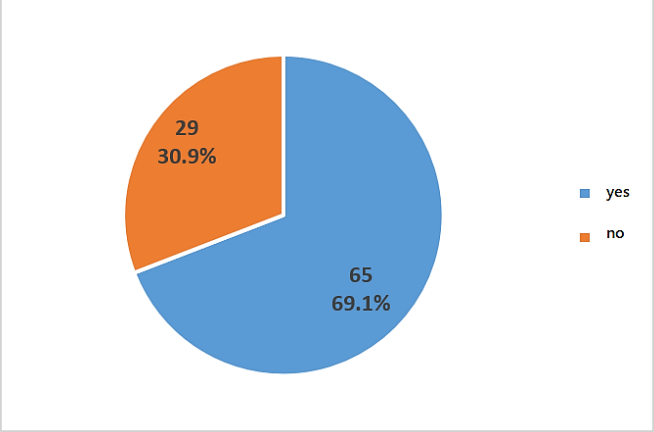

Figure 6. Experience in VR of respondents (N = 94).

Despite quite commonly declared prior contact with VR, more than half of the respondents declared that they did not play computer, console or smartphone games at all (52.1%) (Fig. 7). One quarter of the respondents spend up to 3 hours a week on such entertainment (25.5%), and approximately every seventh respondent declared that they play electronic games from 3 to 10 hours a week (14.9%). People who devote more than 10 hours a week to gaming constitute the smallest group (6.4% of all respondents).

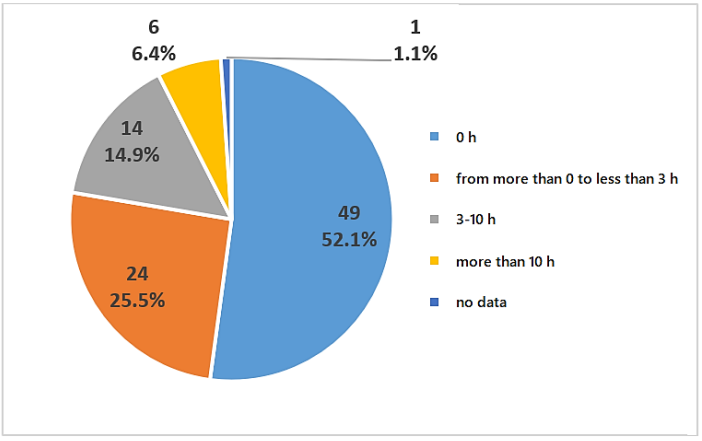

Figure 7. Time spent by respondents on computer games during the week (N = 94).

3.2. Assessment of the training process

The starting point for discussing issues related to opinions related to training completed using an application based on VR technology was the analysis of participants' assessments of the basic elements of the course, i.e. the lecture, discussion, and the VR application itself. The collected data, presented in Figure 8, indicate an unequivocally positive reception of the training in all highlighted aspects. None of the respondents had a definitely negative opinion about any component of the training (lecture, discussion, or application), and rather negative opinions were incidental. There were also few people who were unable to clearly evaluate the training. Among the respondents, voices indicating a definitely positive reception of all elements dominated (52.1% in relation to the lecture; 53.2% in relation to the discussion and 60.6% in relation to the application). Next in terms of number were respondents who assessed the training rather positively (38.3% in relation to the lecture; 37.2% in relation to the discussion and 33% in relation to the application). The presented distributions of responses indicate a high assessment of the attractiveness of the training. It is worth emphasizing that the lecture and discussion were considered attractive, while the VR application turned out to be its highest-rated element. This is an argument that demonstrates the validity of including innovative elements, such as advanced VR applications, in the training process.

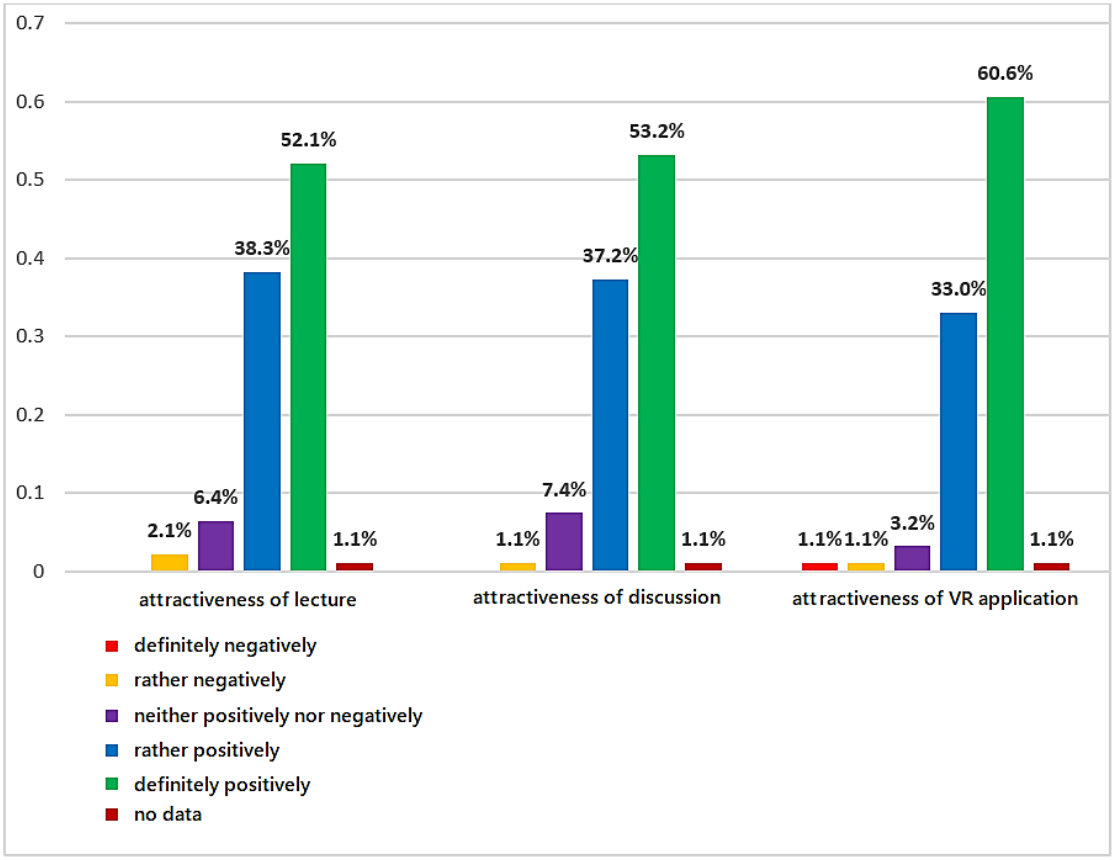

Figure 8. The assessment of attractiveness of the given element of training (N = 94).

In order to make a more accurate diagnosis of this training tool, respondents were asked to rate its individual components. Taking into account the most important aspects of the application's functioning, the following were distinguished:

- video materials,
- the reader's messages,
- operation of virtual devices,
- 'windows' with supporting texts,
- sound effects of objects/environment.

All of the components listed above were highly rated by respondents. In relation to each of them, more than 70% of participants expressed positive opinions, and negative opinions only in relation to the issue of sound effects were expressed by more than 10% of respondents. Neutral assessments were also not often indicated by respondents. Detailed data are presented in Figure 9.

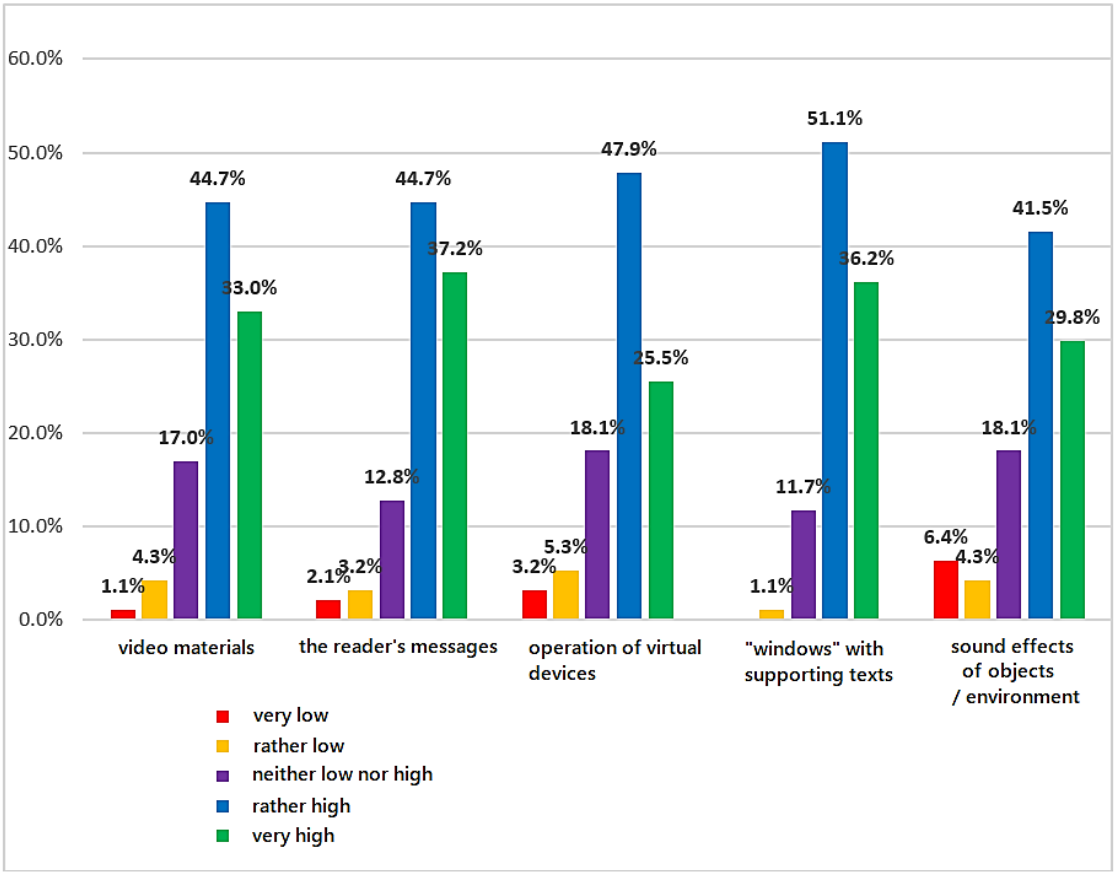

Figure 9. The assessment of components of VR application (N = 94).

The distribution of responses presented above contributes to a positive assessment of the application in all aspects of its functioning. However, it is worth noting some differences in opinions - the best rated by the participants were the supporting texts appearing in the "windows", while the lowest were the sounds of the environment and objects simulated by the application. This element should be refined so that the sounds reflect the real world as precisely as possible.

3.3. Assessment of gamification elements

The next question raised the issue of gamification. According to Gabe Zichermann and Christopher Cunningham (Zichermann, Cunningham, 2012), gamification may be considered a new term, but the mere use of game mechanics to solve problems and engage participants is not a new idea. Gamification is the conscious and purposeful use of mechanisms used in game design in order to activate and motivate a selected group of participants in the training process. Gamification is used as a support for solving real problems in the real world, by changing behaviors, habits, attitudes, moods, or objectifying processes. It allows the entity or person to use its solutions to effectively achieve its goal. According to Sobociński (Sobociński, 2014), mechanisms used in games, introduced into educational activities, can contribute to stimulating creativity and systematicity. Implementing gamification (or at least its elements) into the teaching process can stimulate internal motivation and readiness to make significant sacrifices,

which are observed among players on a daily basis, and which are often missing in the education system. In this context, it is worth noting that introducing gamification into training using VR applications can contribute to arousing curiosity among training participants, which helps to increase commitment and modify people's behaviors and habits.

The application used during the research included, among others: the following gamification elements:

- results table – indicating the number of attempts made and their effect in the form of a point (when the action was completed successfully). For training participants who have the greatest satisfaction during the game from awareness of the competition, the leaderboard is the driving mechanism. The leaderboard is a motivator to engage in the struggle for results. In a VR application, not only earning points and completing subsequent tasks provides the user with satisfaction. There is also gaining achievements, overcoming difficulties, and solving problems. These elements help maintain a high level of commitment among training participants.
- current feedback – shows the training participant where they are at a given moment. The ability to obtain immediate feedback is an advantage of the application over real experiences. During using the application, when the score increases, feedback (with information if the user has chosen the right way) is immediately provided. In this aspect, the developed application uses the following elements:
  - **a sound signal** – which is an approval for a given action or information about a poorly performed task,
  - **the color of the highlighted item** – orange indicates an incorrect item chosen, or green confirms the correct item chosen,
  - **to proceed to the next stage** – signaled by the displayed "good" message.

As part of the research, over 70% of respondents believed that the gamification factor had a positive impact on the effectiveness of the training (including 27.7% who rated this impact very high, and 46.8% rather high). Neutral answers were much less frequently formulated (18.1% of responses), and negative opinions were chosen sporadically (7.4% of the total; including only 2 people giving extremely negative opinions). Detailed data is presented in Figure 10.

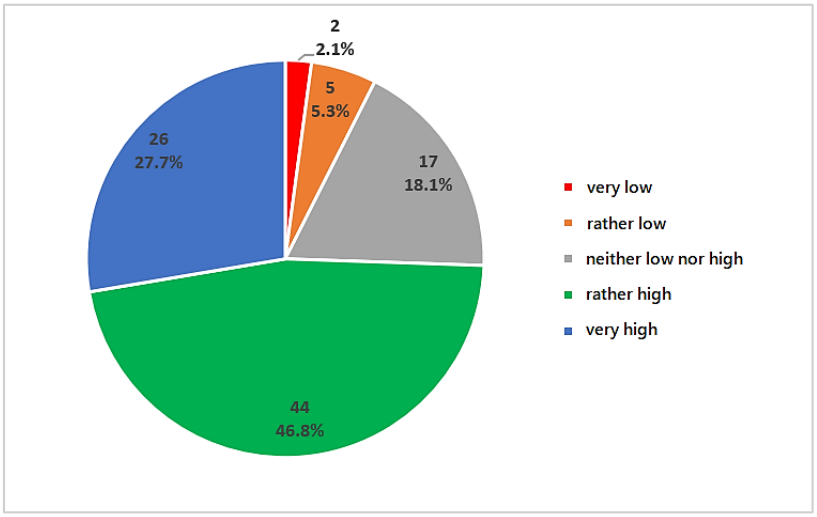

Figure 10. The assessment of the effectiveness of introduction gamification elements into training VR application (N = 94).

3.4. Suggestions for an extending the VR application

A summary of the research regarding the evaluation of the application by training participants may be the examination of suggestions regarding the possible expansion of the prepared tool. Figure 11 presents the distribution of answers to the question of the need for an extension of the VR application. It was concluded that almost three-quarters do not see such a need (71.3% of responses), but 28.7% of respondents believe that the implemented training instrument can be developed.

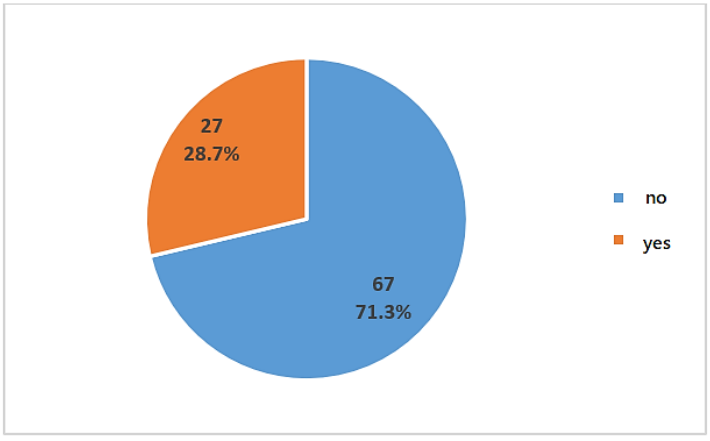

Figure 11. Answers to the question "*Should the VR application scenario be extended with additional elements?*" (N = 94).

4. Conclusions

The evaluation of the training process, carried out by the participants, showed a very positive reception of all its elements, including the lecture, discussion, and the VR-based application itself. None of the respondents rated a single element of the training strongly negatively, proving the high level of acceptance of this form of training. The VR application was rated by participants the highest, indicating the validity of including innovative elements, such as advanced VR applications, in training processes. Supportive texts and sound effects were particularly positively assessed but sounds in the application can be improved. Gamification, which is the use of game mechanics in the training process, was well-received by the participants. Gamification elements, such as a leaderboard and ongoing feedback, had a positive impact on training engagement and effectiveness, which suggests their value as a motivational tool in training processes. Despite the generally positive reception of the application, some participants indicated the possibility of expanding the training tool. However, more than 70% said that there is no need to make changes to the application scenario. This means that the app has been well received, but there is potential for further development and improvement.

Summing up, the results of the analysis suggest that training using applications based on virtual reality technology has been accepted in the mining environment. This is important considering the specific nature of miners' work, which is not only crucial for mining efficiency, but also carries great risk and danger. As a result, this article not only confirms the positive reception of VR training in mining, but also suggests the possibility of further improvement, which may contribute to improving the safety and efficiency of work in this industry.

The main limitation of the research was the research trial. However, this paper only shows the results of a part of the research while in reality this training was implemented in JSW and many workers participated and still participate in this new type of training. The whole research on the development of training using VR has practical, not only theoretical character. Naturally, the survey questions could be also more detailed when it comes to the evaluation of every element of the training program.

The research provides new knowledge on the general opinion and attitude toward training using VR. It proves that this immersive technology is not only accepted by the mining environment but also is evaluated very well. Hence, it shows that VR training can be used for training for miners and this direction of applied innovation in this industry is proper. Also, all interactive elements, included in the training, can be successfully used. This research shows that training that uses virtual reality has a future. They are attractive to participants and arouse involvement thanks to the use of gamification elements. Thanks to this research, it is possible to draw conclusions that all the elements used in the training worked well and were positively received.

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