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VIRTUAL QUALITY TOOLBOX AS AN INNOVATIVE SOLUTION SUPPORTING LIFELONG LEARNING

Abstract: *The article features the quality tools presentation and selection system for solving problems in production processes using the Virtual Reality (VR) technique. The main goal of the Authors' application is to facilitate the acquisition and assimilation of knowledge related to the use of quality tools in SMEs' everyday industrial practice. The solution is dedicated to production workers - including unskilled workers and those who resume education after a long break. The study carried out as part of the project has shown that one of the barriers in employee training is an inaccessible form of knowledge (text descriptions written in a language incomprehensible to production workers, no visual examples, complicated instructions and no practical guidelines for selecting a problem-solving tool). This obstacle was overcome by using in the developed prototype system immersive virtual reality techniques and the three-dimensional visualization of selected quality tools.*

Keywords: *Quality tools, Virtual Reality, Production processes, SMEs, Social innovation, Design Thinking*

1. Introduction

Quality tools are one of the many instruments of quality management in manufacturing enterprises (a set of the remaining ones is made up of, among others, techniques, methods or methodologies).

Quality management tools are well-established in the management of organizations "through quality". They are used to collect and process quantitative and qualitative data into useful decision-making information. Due to their universalism and impact in short periods of time, they are associated in a practical way with various phases of the product manufacturing process. With regard to quality objectives set in enterprises, they serve the implementation of partial objectives of an operational nature; they are also distinguished by their ease of use. They are not complicated compared to other quality management instruments. Most often, they can be described with a simple algorithm, program or instructions for use. As such, they are often used as educational material in the training of manufacturing enterprise employees.

However, the use of these instruments in the practice of manufacturing enterprises is limited due to their richness and diversity resulting, among others, from the mutual permeability of modern management concepts and, as a consequence, continuous expansion of the range of available instruments. This is a favourable phenomenon. Yet, it is difficult to accept in demanding production conditions.

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The importance of the problem of an accurate selection of quality tools was indicated, among others, by (Tari & Sabater, 2004), (Fotopoulos & Psomas, 2009) and (Castello et al., 2019). The authors emphasize that failures in the use of quality tools (including quality techniques - QT&T) do not result from their ineffectiveness "but rather because of a lack of clear understanding about when, where and how to apply them". In (Starzyńska, 2014), it was also noted that "while solving problems and improving enterprise processes and products, there is often a significant problem connected with fast, easy and flexible choice of appropriate tools for solution activities". A well-thought-out and systematic use of properly selected tools can be a source of continuous improvement of processes and products that stem from them.

Of course, one needs to be aware of who will be the user of quality tools in practice. Their spectrum includes people who are just becoming acquainted with these tools and those who are experienced in using them; production employees and quality staff in an enterprise; "self-taught people" and people using traditional training in this area; people making decisions on how to solve a problem (thus pointing to tools) and people using a specific quality tool in operational activities.

In manufacturing enterprises' daily practice, training related to basic quality tools is usually addressed at production specialists, shift foremen and machine operators.

Recent years have shown that the process of instructing and training operators has made a successful use of virtual or augmented reality techniques. Virtual reality is the use of a computer (digital technique) to achieve the effect of "transferring" users (or rather their consciousness) to a place other than where they really are. VR users must therefore be somehow placed in the so-called virtual environment (VE), created with the use of three-dimensional computer graphics, and must be provided with the ability to interact with the elements of this environment. Therefore, the most important elements that constitute VR are immersion (separation from the real world in favour of the virtual world) and interaction (responsive and reactive virtual world). The task of VR systems is to realistically simulate a specific section of reality that exists or could theoretically occur with the effect of human immersion in simulation. Assuming such an assumption, VR can be applied in practically every aspect of humans' professional activity and everyday life. However, there are certain groups of virtual reality applications where its advantages allow to obtain a particularly significant increase in the efficiency of certain processes. They are:

- generally-understood engineering: mechanical, electrical, construction, energy, etc.,
- education and training - both of school and professional character (e.g. in combination with engineering),
- medicine and medical education - for physicians and patients (rehabilitation, therapy),
- military - military engineering, instruction and training, military medicine,
- entertainment - computer games, interactive animations and non-game experiences.

The use of VR in production instruction and training is associated with the positive impact of immersion on the absorption of new content by users, which is evidenced in the source literature.

The article presents a solution based on the use of virtual reality techniques to conduct training related to quality tools. The developed virtual quality box was created as a social innovation project in the area of adult lifelong learning. The solution is dedicated to production workers - including unskilled workers and those who resume education after a long break.

The main goal of the Authors' application is to facilitate the acquisition and assimilation of knowledge related to the use of quality tools in SMEs' everyday industrial practice.

2. Literature Review

Quality tools have their well-established place in the management of organizations, regardless of a quality management concept adopted in them. The concept of Total Quality Management (TQM) emphasizes universal involvement; the Six Sigma concept is based primarily on measuring the effectiveness and efficiency of activities; on the other hand, the normative approach in quality management is oriented towards the observance of recognized standards in enterprise operations (Hamrol et al., 2013). Each of the above-mentioned concepts uses many quality tools, simultaneously emphasizing the selected ones. It should be mentioned that in some industries reaching for quality management tools (and methods) is, among others, a response to indications or recommendations for their use contained in quality standards.

In J. Oakland's TQM model, quality tools - in addition to teams and systems - create a "material" infrastructure for process management focused on meeting customer requirements and favourable cooperation with partners. The intangible sphere of an organization's functioning, in turn, is created by the previously emphasized involvement of employees, organizational culture and communication in a company (Oakland, 1993). As part of this concept, quality tools used for teamwork are, among other things, an instrument for building employee involvement.

According to (Castello et al., 2019), TQM elements can be grouped into two dimensions: "soft" elements (e.g. leadership, employee involvement, supplier management, customer focus, process management, continuous improvement, knowledge and education), and "hard" elements. For the effective deployment of these "soft" elements, they must be supported by the "hard" elements (Fotopoulos & Psomas, 2009), which consist of a set of quality tools and techniques Qt&T.

Six Sigma is a concept of continuous improvement of an organization, consisting in monitoring and continuous control in order to eliminate and prevent the emergence of nonconformities in processes and products that result from them. It represents a quantitative approach in management. As part of the Six Sigma concept, quality tools are primarily used to measure the effectiveness and efficiency of processes, which translates into the usefulness of quantitative tools, including a group of statistical tools. Improvement projects, carried out according to the DMAIC methodology, indicate a necessity to use a wide range of tools (Breyfogle, 2003).

The necessity of knowing and being able to practically use a wide range of tools is emphasized, among others, by the work of the European and American quality associations, aimed at developing unified criteria for obtaining qualifications by trainees at various belt levels (Thia et al., 2005). The scope of the obligatory body of knowledge is determined by a wide spectrum of quality tools and management methods, the knowledge and application of which translates into measurable benefits.

Quality management tools can also be treated as a source of new knowledge - also in a manufacturing enterprise. This is because they enable to process data (often obtained automatically from processes) into information which, placed by employees in various contexts, is a source of new organizational knowledge. In turn, reaching for quality tools is most often associated with obtaining or, directly, participation of employees whose experience and knowledge are the necessary support in the use of a given tool, the acquisition of which makes it a really useful tool.

According to (McMahon & Lane, 2002), quality management tools and techniques also found "separate" applications in the area of project management.

In turn, the work by (Levesque & Walker, 2007) highlights the importance of quality tools in the context of creating innovation. According to the authors, a skillful use of quality tools from the group of the so-called new quality management tools can shorten the time of the innovation cycle.

In enterprises' practice, the areas for the application of quality tools are industrial processes and non-industrial processes. In the first case, a clear division of the use of quality tools according to the stages can be observed: design and development of new products (they complement engineering design tools and systems) and the production process, with the production activity covering a wide range of product classes

(McQuater et al., 1996); (Adams 7 Dale, 2001); (Sousa et al., 2005); (Alsaleh, 2007); (Khanna et al., 2006); (Yeh et al., 2010). In the second group, quality tools are used in the processes of industries other than manufacturing and in services (Sousa et al., 2005), (Herbert et al., 2003), (Kujawińska et al., 2017), (Kujawińska et al., 2018), (Bożek et al., 2017), (Sukwadi & Hendry, 2018), (Moin, 2018).

The importance of quality tools results from the fact that without having reliable and complete information, it is difficult to talk about taking effective actions in the area of systematic quality improvement at the level of executive process implementation. Therefore, it is so important to propose new forms of instructions and training to support the consolidation of knowledge and skills of employees in this area.

The possibilities of using virtual reality in the transfer of knowledge have been well known and indicated by many authors in the literature for over two decades (Kozak et al., 1993; Bell & Fogler, 1995; Martín-Gutiérrez et al., 2017). The feeling of immersion and natural interaction augment the educational effect, improve concentration and multiply new knowledge acquired in a given unit of time. The latest VR solutions are interactive environments which provide conditions for, among others, teaching pupils and students (e.g. immersive educational applications for history, biology, medicine, architecture, machine construction (Martín-Gutiérrez et al., 2017; Nanu et al., 2014) or medical training (physiology presentations, anatomy atlases, procedure methodology presentations, instruction manuals for the use of medical equipment, etc. (Hamrol et al., 2013; Buń et al., 2018; Zhang et al., 2012).

The use of VR in industrial training is one of the most important applications of this technology, as it is indicated in cross-sectional publications (Abulrub et al., 2011; Choi et al., 2015). The use of VR techniques enables employees to develop and practise correct behaviour in hazardous situations in controlled and safe conditions. Visual and auditory stimuli in a virtual environment allow to maintain interest in training and facilitate remembering information and consolidating skills related to work performed. Effective industrial training with the use of VR is one of the methods of increasing production efficiency in industrial enterprises which are implementing the concept of Industry 4.0 (Romero et al., 2016; Schroeder et al., 2017).

According to industry reports, training in an enterprise with more than 100 employees costs an average of $1,200 per employee [td.org]. Therefore, using VR techniques to reduce this cost is reasonable. As mentioned earlier, industrial training was indicated by the pioneers of VR technology as a potential application as early as in the 1960s. The biggest advantages of VR as a tool for training production company employees include:

- effectiveness in acquiring new knowledge and skills in relation to traditional methods (Bell & Fogler, 1995; Colombo et al., 2013),
- improving the efficiency of manufacturing processes, especially assembly (Langley et al., 2016),

- safety of training, possible multiple repetitions of events which are dangerous to the health and life of training participants or which may lead to expensive equipment being damaged (Lin et al., 2002),
- lower cost of training compared to traditional one - no need to hire an instructor for the entire duration of training, the cost of VR equipment is lower than the depreciation of equipment and materials used during traditional training (Górski et al., 2018),
- possible optimization of workplaces in terms of ergonomics, safety or job satisfaction (Feldman, 2016; Budziszewski et al., 2016).

The use of VR technology should also be related to the planning of processes in a manufacturing enterprise. Training applications are often the result of work on optimizing the ergonomics of workplaces. In such a case, virtual design and training solutions permeate each other and training results can be used for iterative design. Industrial training in VR should be treated as a way to improve the production resource, which is humans. The implementation of training in VR allows to increase the efficiency of assembly or manufacturing processes (Langley et al., 2016), and simultaneously shorten the training time, often several times (Kishore, 2017). This allows to avoid interruptions and downtime.

As mentioned above, the preparation of virtual environments for industrial training is justified in situations where the implementation of traditional training may endanger the health and life of trainees or when conducting training under normal working conditions requires large financial outlays and time. An example of commercial solutions for industrial training are advanced haptic systems which are used to train future operators of mining machines. Trainees interact with the virtual scene according to strictly defined work scenarios which aim to provide the best possible training in machine operation and emergency situations (eg. equipment failures, hazards resulting from work environment) (Foster & Burton, 2004).

The need to use virtual simulation becomes particularly justified when it is not possible to organize training at a real position in the company (e.g. no physical equivalent of a position available only for training) or such a possibility is very limited (only during downtime). The analysis of VR solutions used for industrial training focused on activities performed at a workplace shows that they can support training in the implementation of the so-called procedural tasks (Rodriguez et al., 2012).

In this context, the system of presentation and selection of quality tools developed by the authors is unique, and not only because of the connection of quality engineering issues with VR technology. It should also be emphasized that the system is not oriented towards activity training, but helps in the assimilation of abstract concepts.

The innovation presented in the article in the form of a "virtual quality toolbox" focuses on how to educate employees in the area of quality tools, as well as to help employees who already know the above methods to choose appropriate tools for the specific problem they are struggling with at a given moment (Górski et al., 2018); (Starzyńska et al., 2018). The recipients of the social innovation are SMEs' employees. The innovation provides the main value, i.e. it educates about methods of solving quality problems and improving work in production, thanks to the transfer of knowledge from the "book" form to the form of interactive 3D visualization. Nowadays, Virtual Reality (VR) techniques are widely used - also in education. However, in the case of training conducted with the use of this technology, what is most often developed are trainees' manual skills (e.g. machine operation, assembly, etc.) (Martín-Gutiérrez et al., 2017).

3. Materials and methodology

The design and prototype of the application for learning and selecting quality tools in a virtual environment was made in accordance with the Design Thinking (DT) methodology. The DT approach is based on the assumption and understanding of users' problems and needs by designers. This assumption was realized through 3 main activities: (1) user focus - thorough understanding of their conscious and unconscious needs; (2) creative team cooperation - looking at the problem from many perspectives, looking for new solutions, going beyond usual patterns; (3) experimenting and testing subsequent product designs - building prototypes and collecting feedback from users testing prototypes. The next stages of the Design Thinking methodology were carried out linearly and cyclically (for selected ones). The first action was to build an interdisciplinary team composed of specialists who looked at the problem of learning using quality management tools from different perspectives. Among them were engineers, technologists and market analysts. An expert team was established consisting of specialists in the field of: quality management, virtual reality, augmented reality, statistics and industry representatives. The team carried out the activities in seven steps:

Step-1: Defining the group of recipients and empathizing - After defining the group of recipients, who were production workers and quality engineers in the project, the Design Thinking process began with the so-called empathy. The basis of a good solution is a thorough understanding of the user needs and problems. For this purpose, the Team used such tools as interviews, user observations, reconnaissance surveys along with a detailed analysis of the working environment and needs in the context of solution functionality.

Step-2: Synthesis of the information gathered in Step 1. At this stage, the Team analyzed the information in order to define what is the right problem for the user in the learning process and the use of quality management tools.

Step-3: Development of the application design. At this stage, the Team focused on generating as many possible solutions to the defined problem and selecting one to prepare the application design. The development of the project assumed the preparation of event scenarios, functionality and look of the application.

Step-4: Development of the solution prototype. At this stage, a physical prototype of the application was created for the selected lesson scenario - software in the VR environment.

Step-5: Testing prototype No. 1. At this stage, the selected solution was tested in the user environment by users from the so-called tester trial. The result of the testing was the collection of feedback allowing to identify problems and inconveniences in using the developed solution.

Step-6: Improving the prototype. At this stage, after analyzing the testers' suggestions, changes were made to improve the prototype - the creation of prototype No. 2.

Step-7: Testing prototype No. 2.

4. Results

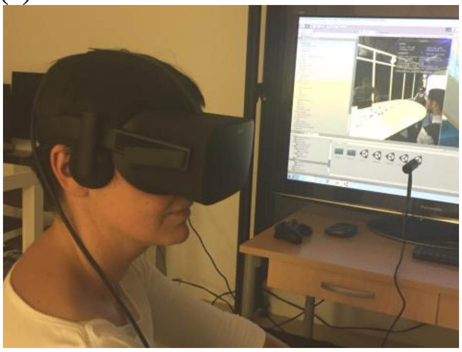
After the implementation of steps 1-6 of the presented methodology, the Team developed the final version of the prototype of the application for learning and selecting quality tools in a virtual environment (the so-called prototype No. 2). It was created in the Unity 3D environment. According to the learning scenario and interface design, the application contains various types of content, including audio, 2D, text and 3D content.

Interaction in the application takes place by pointing to objects with the sight and pressing an appropriate button. The basic way to operate the application is to use a VR helmet. The recommended helmet for the stationary version is the Oculus Rift (Figure 1a).

After starting the application, one should log in to the user account by entering the login and password or register in the case of a new user. There is also an option for password reminder, i.e. to have it sent to the e-mail address provided during registration.

The application in the Unity environment includes two basic types of scenes (levels) in prototype 1: main menu scene (Figure 1b), learning scene for the selected tool.

(a)



(b)

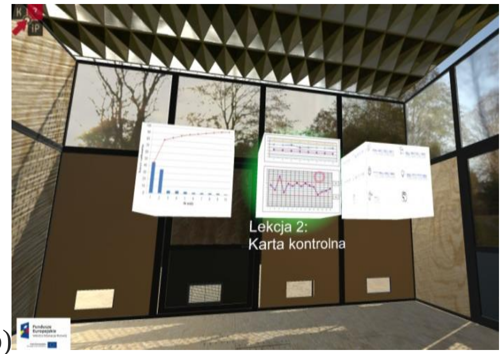


Figure 1. (a) Helmet visualization (b) Main menu scene - lesson (tool) selection

Each of the scenes contains a certain number of basic 2D and 3D objects, i.e. those that are assumed to be constant for most of the quality tools taught. These include, among others, a flipchart with 2D data, a production master, marking (2D interface - the logo of the authors' institution and the project) or a door that allows to exit the application to return to the main menu, as well as a predefined production environment, i.e. a production hall with machines, shelves for storing semi-finished products, employee workstations, etc., including, among others, a quality corner (QC), i.e. a desk, display, etc. and a meeting room containing a table, board, etc. (Figure 2).

Each quality tool is a separate scene - adding a new tool to the application requires duplicating the base scene containing elements common to all tools (i.e. a hall, machines, workers, a master, etc.) and adding appropriate logic by preparing a set of 3D objects characteristic for the selected tool (e.g. for Pareto analysis - measuring cups for sorting products, absent in the scenes for learning other tools) and programming appropriate logic, usually using a set of ready-made scripts initially prepared by the authors, or by adding new scripts.

Figure 2. Basic environment - production hall, production master, 2D content (text messages)

Learning the selected quality tool consists in performing appropriate activities by the user in the production hall. The entire process is broken down into a number of steps appropriate for a given tool. Moving to the next step is possible after performing an action (or sequence of actions), which may include, among others:

- listening to and reading information from the master (e.g. introduction to the problem),
- watching a predefined animation (e.g. behaviour of employees at the machine),
- taking the object from one place in the hall and transferring it to another (e.g. changing a tool in the machine),
- user interaction with a stationary object (e.g. changing machine settings),
- object-object interaction (e.g. lifting a caliper and measuring products on the production line).

Each step is assigned information content (text, 2D graphics, sometimes audio - text read by a presenter) and an appropriate set of interactive 3D models which appear after activating a given step. The user is informed by the master what he/she has to do at a given moment in order to proceed. After completing all the steps, the user is rewarded and can play the lesson once again or return to the menu and select another lesson.

Tasks that can be set to the user during the lesson are e.g .:

- picking up an object and using it in a suitable place (e.g. installing a tool in the machine, using a caliper to take measurements),
- listening to the master,
- observation of virtual employees,
- becoming acquainted with the board/flipchart/object and approving or making a choice by clicking on it.

Lessons can take place directly in the virtual production hall, next to the machines or in their vicinity, or in the virtual meeting room (Figure 3).

After completing all the lessons and exercises, one should take the exam. The exam consists of close-ended questions. One should choose an answer by marking the cube with an appropriate letter (A, B, C or D).

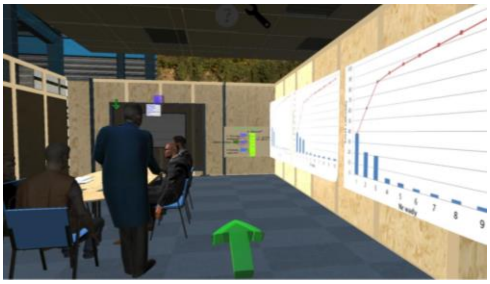


Figure 3. View of the virtual meeting room

One can proceed to any question at any time. After selecting all the answers, one should click the button "check the result", then the results and correct answers can be viewed. The result of the last test is also visible on the glass board in the main menu.

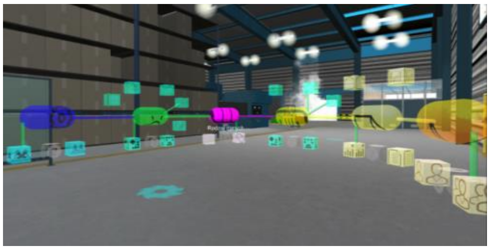


Figure 4. Tool selection view

For advanced users of quality tools, a tool selection mode is available, in which the criteria should be defined one by one, and the system will suggest which tool should be appropriate for us. The most important elements of the mode: - virtual advisor - information board displaying current recommendations - three-dimensional solids representing subsequent categories and criteria within the category - "go further" and "undo" balls and the "show current recommendations" cube - red and green information cube, showing respectively - lack of tools for a given set of criteria and achieving a single recommendation before completing the selection of criteria (Figure 4).

5. Evaluation of prototypes No. 1 and No. 2

The application evaluation process was carried out twice for prototypes 1 and 2 (presented above).

Application prototype No. 2 was tested both on executors and employees not directly related to the project, in accordance with the adopted methodology. During the tests, the users were to evaluate the comfort of using the application, assess the improvements introduced since the previous prototype and the modes of working with the application, i.e. the exam and tool selection modes.

Not all people participating in the research have daily contact with virtual reality technology. However, in most cases it was not their first contact with the proposed solutions. As already mentioned during the tests of the first prototype, when using VR applications that require user movement, symptoms of the so-called cyber sickness may occur. However, the introduction of changes suggested in the first prototype (a different arrangement of the elements used to go further) partially limited the unpleasant sensations - simple manipulations such as moving a three-dimensional button from the corner of the room to the worktable prevented the user from having to make quick head movements in a wide angular range, which reduces level of discomfort when using the application.

The unwanted symptoms most often occurred during a longer (> 30 min) use of the application in the immersive mode. At the same time, it was found that the average user will not be able to complete the full course at one go. It is related to the scope of the presented material. Regular, short use of the system is recommended (max. 30 minutes without removing the helmet).

The introduction of gesture support in the application additionally complicates the operation. The user focuses more on the need to operate additional controllers and the correct execution of gestures than on the conveyed content. Therefore, it was decided not to implement them in the second version of the prototype, especially since the users of the first prototype did not report such a need.

Increasing the virtual space in which staff meetings are held allows for more freedom of movement, and there is no feeling of "tight space" which can cause discomfort, especially for people with a tendency for claustrophobia. At the same time, more frequent movement may cause symptoms of cyber sickness.

The presented content (selected quality tools in the total number of 7) from the layman's perspective is very similar to each other, which may mislead the user. In many of the adopted scenarios, the schematic nature and overlapping of certain stages are noticeable - it is worth considering factors which distinguish a given tool from the others and display them in the final prototype so that it is clear to the student which tool he/she is learning at a given moment.

The exam mode and the tool selection mode will be expanded with a database of models enabling interactive illustration of test questions or questions in the tool selection mode.

Assessment of the effectiveness of learning in the "standalone" and mobile versions of the software: Another element of testing the virtual reality application for learning quality tools was to check the effectiveness of the applied solution in the process of teaching trainees. It was assumed that each of the training participants, after becoming acquainted with all the thematic lessons, would obtain a certain scope of new knowledge. In order to check the level of knowledge obtained in this way, a measurement instrument in the form of a knowledge test was developed. Since the subject of knowledge testing was the same educational content found in two versions of the software (the "standalone" and mobile versions of the application), the course of testing was properly organized. Each of the target groups was divided into halves (5 people in each target group). The difference in acquiring the substantive content was that a subgroup of production workers started by learning the lessons in the stationary version and then switched to testing the mobile version of the application. The remaining five people in this group of respondents tested the application versions in reverse order. In this way, it is possible to assess progress in acquiring knowledge, and also to evaluate the possible impact of the order of the tested versions of the software on the acquisition of substantive knowledge.

As mentioned above, 70 test questions (10 questions for each of the seven tools) were developed for the purpose of implementing the exam mode (checking the knowledge of the learner in the system), from which exam questions are randomly selected. Having gone through the complete set of lessons, the user answered 10 of them. In this way, it is possible to assess the level of new knowledge acquired by the user. In the implemented knowledge test, the user could score a maximum of 10 points. In the graphic (Figure 5), the number of points obtained after going through the learning process in the standard application is marked in green; the brown colour indicates the number of points obtained by users in the working mode with the mobile application.

In the case of 6 test participants (a group of production employees), there was progress in terms of specialized knowledge, with the seventh and tenth cases indicating that it happened regardless of the order of the tested versions of the application. In the case of one person, the level of knowledge after both tests was assessed the same. In the case of 4 people, it was not possible to conduct the test - this relates to three cases of testing the mobile version of the application and one case of testing the application in the "standalone" version.

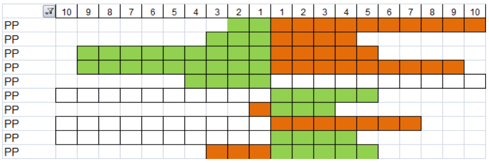


Figure 5. The results of the knowledge test in the group of production workers

The lack of data in the presented list results from the fact that during testing the application, symptoms of "cyber sickness" appeared in the testers. Testing the application was discontinued. Some testers experienced general discomfort, difficulty concentrating, nausea, blurred vision, imbalance, and other unpleasant sensations. In such cases, it was not possible to become acquainted with all the content of the application. In these cases, people gave up the knowledge test.

In the target group of "quality staff", the scores from the knowledge test are much higher. The maximum number of points (i.e. 10) was obtained in five knowledge tests. In the case of a group of people with experience in the area of quality management, it turns out that the order of the tested software versions does not affect the acquired level of knowledge (any "fluctuations" in the assessment are one point) (Figure 6). In six cases, it was not possible to conduct the knowledge test - this relates to four cases of testing the mobile version of the application and two cases of testing the application in the "standalone" version.

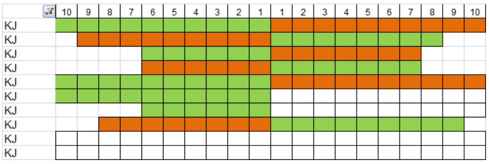


Figure 6. The results of the knowledge test in the group of quality staff

The lack of data in the presented list results from the fact (similarly as explained above) that during testing the application, symptoms of "cyber sickness" appeared in the testers from the "quality staff" group. Some testers experienced headaches, a "heavy head", general discomfort, difficulty concentrating, nausea, problems with focusing eyesight, blurred vision, imbalance, and other unpleasant sensations. Also in these cases, testers asked to discontinue testing the application. Consequently, it was not possible to become acquainted with all the content of the applications. In these cases, people also gave up the knowledge test.

6. Conclusions

The proposed VR system for learning quality tools meets the basic principle of getting more from less for more, i.e. using smaller resources (cheap VR systems, also possible on the Android mobile platform - reaching a wide audience) and limiting the need to hire a trainer, within 30-60 minutes a week, a large group of people - SME employees - will be able to learn about quality tools in a scope never seen before. Until now, the barrier has always been the inaccessibility and unattractiveness of knowledge about quality tools for average employees (and often also for SME owners), so they were not aware of the need to learn them at all, i.e. they were not aware that there are methods that could improve their work. The authors propose a system which at a low cost will make SME employees aware that they can work "smarter" and recognize and eliminate production problems faster using common-sense methods that are easy to learn and carry into effect thanks to an attractive visual form - presentation in a virtual reality environment.

Due to the fact that the sense of the proposed innovation is a new, cheap and more effective method of educating adults - SME production employees (in order to improve their work), the project can be entirely considered as a social innovation in the area of adult lifelong learning.

The proposed social innovation concerns a problem that is very common in small and medium-sized manufacturing enterprises - issues connected with the organization of work in production, waste and maintaining the required product quality level. In large enterprises, there is quality staff and appropriate standards are introduced. Small businesses, however, do not have the time and money to do this. Thus, social innovation in the proposed form (a system of learning about quality tools, i.e. methods of solving quality problems and improving the work of production employees using cheap VR systems to improve and make training more attractive) has a chance to be adopted in many SME enterprises.

The authors of the system presented in the article have so far conducted research in the area of knowledge, degree of use and evaluation of the effectiveness of the use of quality tools in Polish manufacturing enterprises. The results of these studies show that micro, small and medium-sized enterprises need special support in the choice and use of selected quality tools.

The use of quality tools in practice increases the competitiveness of companies. However, access to knowledge about them and the degree of their use in practice requires educational activities. This relates in particular to employees of small and medium-sized enterprises. Such enterprises, however, do not have funds for continuous training of their employees and for investments connected with the implementation of IT solutions. At the same time, the proposed solution may contribute to increasing the labour market chances for people taking part in training or looking for a job.

Education in the field of these quality tools (along with other instruments of the broadly understood quality management in enterprises and organizations) currently covers mainly education provided by technical institutions of higher education, which is caused by the low absorption of material presented in the current form by people with lower-level education. As part of the presented innovation, a system was developed to allow people at different levels of education to acquire knowledge in a given area. It should be emphasized that the target group (production employees) includes a large group of employees/people in the process of being hired with vocational education; they are also often trained for the profession. As shown in the examination of the system prototypes, the form of material presentation and the way of using it is attractive and accessible to a wide spectrum of people testing the solution (including elderly people who will want to supplement and expand their knowledge in a "user-friendly" system).

As mentioned before, education in the field of these quality tools (along with other instruments of the broadly understood quality management in enterprises and organizations) currently covers mainly education provided by technical institutions of higher education. The way of presenting knowledge from this area in the proposed system, as well as the method of publishing applications on generally available platforms (Google Play, App Store), may create a chance of learning it by people who have not had an opportunity to come across issues related to quality during their previous education. The designed solution is also addressed at people who have had contact with these issues, but who completed their education quite a long time ago - the substantive content recorded in the system and an innovative way of learning with the system will allow to acquire new and current knowledge without frustration resulting from a long break in studying.

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