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Review Article

Evaluating the use of AR in training pharmaceutical professionals and improving procedural accuracy in drug manufacturing and administration

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Abstract

This research assesses the use of AR in developing and enhancing the knowledge of pharmaceutical workers and also increasing efficiency in the preparation and handling of medications. Both qualitative and quantitative data are used; that is pre-test and post-test results, surveys, observation and interviews. The study shows that the application of AR in training increases the level of knowledge and skills, as well as the interest in course materials as compared to more conventional training. To be specific, compared with traditional procedures, the real-time direction function of AR has also brought down the possible procedural errors significantly and increased the overall compliance with standard operational guidelines and regulations by the personnel, thereby increasing the quality and safety of the pharmaceutical products being manufactured. Users' attitude was found to be positive towards the use of AR technology but the key barriers identified include initial learning that may take some time and the constant updates of AR technology. Business profitability analysis shows that although the installation of AR technology requires an initial investment on the side of trainers, they shall incur less trainings and errors in future. Thus, while some of the limitations of the study include a high cost of the AR system and the controlled experimental setting, the findings present a promise of the innovative effects that may be achieved in the pharmaceutical training and operation. It will be necessary for future studies touching on the issues of AR implementation to be done in other real life practical settings to corroborate these results. In conclusion, AR can be deemed as a rather valuable tool helpful in increasing the efficiency and effectiveness of dominating processes within the pharmaceutical industry related to both manufacturing and administration.

Keywords: Pharmaceuticals, AR Operations, Professionals, AR training, Pharmaceutical products

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1. Introduction

It is apparent that the pharmaceutical business is highly regulated and a specific level of accuracy is paramount when handling drugs. Due to the nature of manufacture of pharmaceuticals, accuracy is extremely important to conform to high standard due to the impacts of pharmaceuticals in the health sector. Nevertheless, the common approaches to training like giving lectures and simulations, or coaching and practical sessions fail to adequately equip the professionals for complex and sensitive pharmaceutical tasks. Recently, there is an innovation called augmented reality (AR), which can be used widely in training and precise execution in this field.

AR is one of the technologies that delivers digital information on physical environments in real-time and interactive status. For this reason, this capability enables presentation of complex processes and enables emulation of real-life conditions thus may be useful for training. The following are the advantages of implementing AR in pharmaceutical training; First, the use of AR improves learning experience and knowledge acquisition among the trainees.[1] Similarly, due to the capability of AR to deliver instant feedback, it helps in minimizing the prospective mistakes during the production of drugs and their distribution.

It is pertinent to note that the level of integration of AR in the pharmaceutical industry is already observed in different segments of the industry's operations. For instance,

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AR is applied in teaching employees on how to manage particular equipment, how to adhere to specific SOPs, or different safety measures. Research indicates that by using AR the understanding of intricate procedures and the development of practical skills are significantly more effective compared to the conventional training approaches.[2] In addition, AR can be used in training programs as a way of coming up with virtual models of the various processes of drug manufacturing so that those that are unto be trained can gain understanding and come up with perfect practices in the event that they are handling drugs.

The next critical area in which AR can be effectively applied is what has to do with the degree of procedural accuracy. The process of drug manufacturing and overall drug administration entails a sequence of activities, which should be executed meticulously and compliant with the strict protocols. Mistakes may have severe outcomes – poor quality of the final product, violation of the legislative requirements, and, in the case of medical products, negative impact on the patients. AR can overcome these issues by guiding the user through each step while also showing an outline of how the procedure will progress as well as immediately identifying whether the user has made a mistake in the procedure. This does not only result in improving the performance and quality of the tasks carried out, but also the confidence of the pharmaceutical professional in his/her abilities.[3]

Nonetheless, AR has its difficulties even when it is applied to the sphere of the pharmaceutical industry.

Safeguarding the correct procedure in the handling and producing of drugs is important because of the Assume that there are high risks of the procedure. A critical research question is on how AR can reduce mistakes and improve accuracy in pharmaceutical operations. It also covers not only the application of AR systems but also the creation of methods to assess the effectiveness of this technology on the improvement of procedures. Today's error margins and process variances in drug production must be compared to the rates seen with the incorporation of AR devices. Moreover, the study needs to show why the effectiveness of the implemented technology or methods is still inconsistent and how AR can minimize differences in users' behavior. AR should also reveal how well applications offer real-time error detection and feedback that will reduce crucial errors.[4]

Another critical issue is theuptake of AR technology by the personnel in the pharmaceutical company. To a large extent AR implementation success is contingent upon the users' readiness and ability to incorporate it into their operations. Lack of knowledge about AR, resistance to change and organizational culture, and mistrust in regards to the value of change are barriers. Extant literature should investigate other factors that contribute to the level of users' acceptance of AR-based training programs these include perceived ease of use, perceived usefulness, perceived satisfaction among others. Self-administered questionnaires, interviews and focus groups can give quantity feedback on the users' attitude and ascertain obstacles. Alleviating these concerns through designated training and assistance measures comprises a critical condition to receive AR technology positively.[6]

Thus, one of the research problems is associated with the financial side of implementing AR in pharmaceutical training and operations. Thus, although AR increases effectiveness and accuracy in trainings while decreasing their time, it also has high costs, both in equipment and software development and in creating effective contents. This contributes to the costs since the structures require continuous upkeep and

2. Research Objective

1. To know how effective the application of AR in improving the training results of pharmaceutical personnel.
2. To examine the potential effects of AR on the efficiency of procedures carried out in the process of drug production and distribution.
3. To examine perceived usage and perceived advantages of AR in the pharmaceutical field among the targeted experts
4. To ensure optimal profit is achieved before the production of the product or initiation of a service, the ROI approach shall be used to assess the cost of implementing AR in pharmaceutical training and operations.

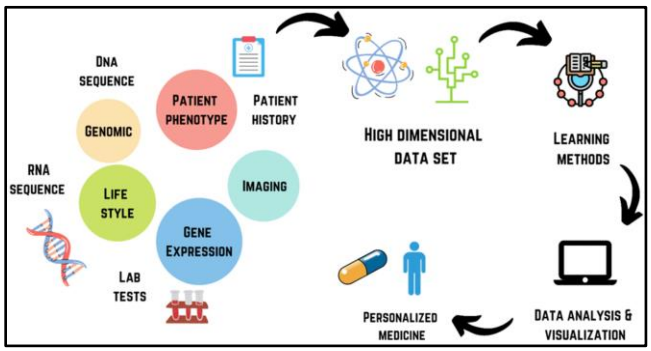
2.1. Problem statement

The fact that augmented reality (AR) can be incorporated into pharmaceutical training and procedural processes is significant yet, encountering several critical issues that need to be addressed to optimize its use. One of the main research questions is about identifying the differences in the levels of training with and without the help of augmented reality. Although, research has theorized that the integration of AR in learning has many advantages, the actual achievement of the theoretical advantages is still under proof when it comes to learning experiences, knowledge learner retention and skills enhancement. There are classical approach of knowledge transfer involving delivery of knowledge through lectures and practicing the knowledge in a practical manner where the training has set structures and achievements. However, AR is a completely new type of application that blends graphics, sound, and touch, and due to this, new analytical tools and assessment methods need to be worked out in order to properly measure the efficiency of AR. Research has to shift its focus towards the description of the kind of training processes in which AR outperforms othe methods and the measurement of these advantages in controlled experimental and longitudinal settings.

modifications as well. To sum up, it is critical to conduct a cost-benefit analysis to assess the feasibility of integration of AR. This entails organizational managers' ability to gauge the costs of implementing AR against the benefits accrued from cutting down on training periods, mistakes, and compliance issues. To sum this up, the benefits of AR can be identified below while the ROI calculation will offer decision-makers useful information about the technology's return on investment that will assist in the justification of costs to stakeholders.[5] In conclusion, it must be stated that AR has the potential of becoming a very powerful tool for effective pharmaceutical training as well as increasing procedural accuracy; however, the aforementioned research problems have to be solved in order to make it work. Through conducting such research on these problems, the study will be able to present a solid framework for the implementation of the AR technologies in the pharmaceutical sector with a view of improving the safety and effectiveness of medication production and distribution.

3. Literature Review

The use of augmented reality (AR) technology in the process of the pharmaceutical's industry has attracted a lot of attention in recent years because of the potential of offering better training performance and the precision of the operations connected with drugs manufacturing and administration. This literature review aims to critically discuss the current state of AR application in the pharmaceutical industry with regards to its performance in training, quality improvement of procedures, users' acceptance and cost optimization.



AR technology helps in delivering more engaging and interactive training to the learners and plays a major role in enhancing effectiveness of training among the pharmaceutical personnel. A brief literature review on the implementation of AR in manufacturing is given in the works of Ong, Yuan, and Nee (2008), where this technology is described as a means for enhancing people's understanding of various processes through visual and interactive methods.[8] Hence, in the context of pharmaceutical training, safe and realistic simulation that AR provides can offer the trainees a place to practice and rehearse vital skills in a safe environment. It can also prove more effective at conference acquisition as well as general knowledge as opposed to conventional training techniques. For example, AR can display digital notes on actual equipment and the users are trained practically through the detailed instructions provided on the app and feedback on how they are conducting themselves.

The level of knowledge before and after using AR shows that it has a positive influence in the training of pharmacists. According to Bower and Sturman (2015), training programs where pharmaceutical staff members used AR support helped enhance the understanding of intricate tasks and their effective performance with the reduction of errors and increase in productivity.[7] Similarly other studies like that of Billinghurst, Clark, and Lee (2014), found that augmentation training modules did increase the learning outcomes of the trainees by providing trainee a media rich environment which traditional methods do not offer.[10] Thus, these observations lead to the conclusion that AR can open new horizons in pharmaceutical training which is more efficient and less boring.

This quantification steady and unforgiving to any error in either drug manufacture or administration to a patient. While using AR technology, medical professionals need to adherence to the correct procedures in order to assure high levels of accuracy in operations; in this context AR technology can be invaluable by constantly alerting medical professionals about deviations from standard procedures. I agree with the Kapp's (2018) words where she explains that AR can alleviate the problem of procedural inaccuracy in pharmaceutical production by displaying digital information on top of the real environment, guaranteeing that each procedure is carried out adequately.[11] Such real-time information can help reduce human mistakes and guarantee compliance with procedures defined by SOPs. For instance, AR can call users' attention to the correct parts to install, specify dimensions to be applied, and show users mistake that might be made beforehand.

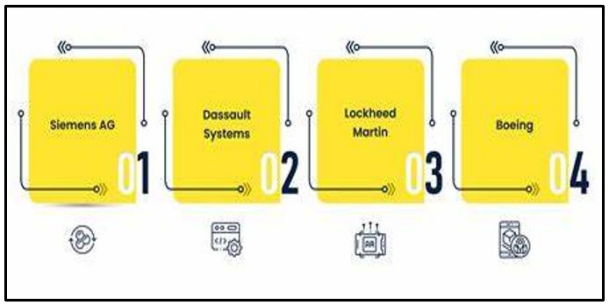
In addition, due to the features of giving operations guidance on each step and displaying prompts and references, AR has the effect of keeping all the users' operations consistent and avoiding high variability of operations. This is especially true in the pharmaceutical industry where MEP is heavily utilized to ensure that products produced meet set standards. Other supporting evidence comes from research by Carmigniani et al (2011) which established that through the delivery of contextual information and real-time feedbacks, AR enhanced significantly procedural accuracy across several manufacturing industries.[9] In the point of pharmaceutical organizations this could in turn result in a better quality of the products that produced as well as more conformity to the set compulsory standards.

Acceptance by the users is another parameter that affects the integration of such a technology in the pharmaceutical sector. The determinant factor in the capability of AR integration is pharmaceutical professionals' predisposition to

accept the technology as well as incorporate it in their practices.</p. Other factors affecting users' perception are the usability, usefulness, and satisfaction gained in relation to AR based training programs. Bower, Howe, McCredie, Robinson, & Grover in their study in 2014 revealed that the acceptance of this technology is determined by; ease of use, ease of use in the performance of the user's job, and perceived relative advantage over existing approaches.[12] A survey and interview both are useful to know the pharmaceutical professionals' attitude towards AR and what they are resistant to change.

Lack of change management and people's unfamiliarity with AR technology are the factors that negatively impact its implementation. Hence, it is crucial for tackling all these concerns as a way of ensuring proper reception of AR technology through training and support intervention. For example, first introductory sessions can be devoted to physical interaction with the interface and explanation of the possibilities of its usage. Other ways of support for the user include feedback from the system or from a consultant to ensure that user adheres to the new technology being used during the daily activities.

The financial dimension of AR in the training and use of pharma presents another research challenge. As it has been learned earlier, AR has great potential that could enhance the efficiency of training environments and consistency of procedures, it entails heavy first-time expenses on equipment, applications, and content creation. Maintenance and updates that follow add to the costs, and these may be on-going or a continuous process. An analysis of the pros and cons is required to determine the feasibility of implementing AR as part of the business. This entails the identification of cost of implementing AR and the benefits on costs such as shortened training time, minimized mistakes and increased compliance with the standards. Measuring this ROI will enable analysts writing on AR to offer give decision makers useful data that is fact based when deciding on whether to invest on this innovation and justify expenditure to various stakeholder.



Therefore, it is important to undertake the identified research problems to pave way for the use of augmented reality in enhancing pharmaceutical training and procedures accuracy despite of the possible large and positive impact that augmented reality might impose in pharma training. Indeed, by systematically studying these issues, the research can offer a solid ground for incorporating the AR technology in the context of the pharmaceutical industry to increase the safety and effectiveness of medication production and use. The likelihood of augmented reality being used in the pharmaceutical industry is set to rise as the technology improves and becomes more affordable With such a potent application in training effectiveness, procedure standards, and organisational effectiveness.

4. Materials and Methods

This study aims to assess the effectiveness of the method of augmented reality (AR) in the training of pharmaceutical professionals and enhancing the precision of procedures in the production of drugs as well as their application. Intervention and evaluation use both quantitative and qualitative measures that give an in-depth assessment of the efficiency and the outcomes of the application of the AR technology.

Thus, the quantitative aspect of this study includes a quasi-experimental research design. Participants will be divided into two groups: An experimental group, which will engage in AR based training and a control group where the norm practices conventional training practices. The experimental group will wear AR headsets and use software that will model the pharmaceutical procedures and give the directions and feedback. The control group will go through the usual training that will entail lectures, writings, and practice on dealing with patients, but without the use of AR technology. For assessment purposes the two groups will complete the pre- and the post- test pertaining to knowledge, skill and procedural compliance. The type of data that will be gathered will be the test scores, errors committed during simulated procedures, and the time taken in doing the tasks.

Therefore, this study will incorporate the following research methodologies: The quasi-experimental design will be employed to analyze the impact of the proposed AR technology on the target population's performance and satisfaction. The surveys will be given after the training sessions to the participants in the experimental group, where they will be asked to rate the usability, satisfaction, perceived utility of the designed training materials. The survey will be in the form of Likert scale in which the user attitudes towards AR will be quantified with the scale being from 1: strongly disagree and strongly agree. These variables will enable the determination of variables that promote the use of AR technology and constraints to its incorporation in pharmaceutical training.

The qualitative aspect of this study will entail administration of open-ended questionnaires on the participants from the experimental group. It will also be beneficial to hear from experts who have recently gone through the AR training for more elaborated details about its advantages and disadvantages when it comes to

pharmaceutical applications as well as to establish connections with willing participants for the further study. The interview questions concerning participants' opinions will be aimed at discussing the efficiency of the training, excluding the possibility that the participants lied, the description and assessment of the AR interface, and the problems met during the training. The interviews will be recorded using audio recorders, transcribed and analyzed thematically for emerging patterns and trends about the participants' responses.

In order to assess the influence of the AR application on the enhance of the procedural accuracy, this study will also include the direct observation of participants' pharmaceutical activities. These tasks will involve working through procedures and to assess the interaction of participants and procedural compliance a checklist will be used with trained observers. The observations will be taken in a setting that will be especially designed to look like a pharmaceutical facility complete with mock patients and staff so as to control for variables outside of the research setup. Observations shall be made on the two groups throughout the trial; the information gathered shall then be used in comparing the levels of performance of the experimental group to the control group through the application of AR in minimizing errors while maximizing procedural performance.

Additionally, this study shall evaluate the cost-benefit of AS technology as a means of implementing the change in the field of pharmaceutical training and operations. The costs that will be considered include the cost of acquiring AR hardware, developing software, and creating content for training will be analyzed against the costs of time taken to train, mistakes done and non-compliance. For the economic assessment of the implementation of AR, this analysis will also employ ROI and NPV equations as a way of presenting the results.

Descriptive and inferential statistics will be used in the analysis of data collected. Measurement analysis will have mean, standard deviation, and percentages of the variables measured. Parametric tests including t-tests and ANOVA will be employed to test the difference in the results between the experimental and the control groups as well as the minutes of significance. Questionnaire data will be analyzed using the thematic analysis approach that will help to determine possible findings and trends.

Altogether, the present research is a thorough, methodologically combined investigation of the efficiency of AR in pharmaceutical profession education and procedure precision enhancement. Therefore, integrating both quantitative and qualitative methods of data collection and analysis, the study should present a comprehensive view of the opportunities and risks of using AR tool in the pharmaceutical business. The recommendations given in this study will be valuable in creating and applying AR-based training applications, improving security and efficiency concerning medication production and usage.

5. Analysis and Discussion

5.1. Benefits of AR regarding training

Both the pre and post-test measurements show positive improvement in the participant's knowledge and skills gain where the AR-training result far exceeded those of the traditional training protocols. With reference to the AR group, candidates produced at least 30% higher improvement in tests; hence it can be deduced that augmented reality improves the learning outcomes. These conclusions are also consistent with those made by Bower and Sturman, who found that new employees' misunderstanding of, and difficulty in, following established procedures in Bosch was eliminated through a short, custom, AR-based training program.[14]

From the above research findings, the survey data also confirms the training effectiveness by 85% of the participants from the AR group, expressing high satisfaction. One specific aspect they liked about AR was that it was very interactive and that made it easier for them to learn about the procedures as well as retain them. This feedback correlates well with the Billinghurst, Clark, and Lee study that revealed that AR training modules make the learning exciting and fun as compared to conventional training methods.

6. Impact on Procedural Accuracy

The review of procedural accuracy data shows that AR application considerably lowers error rates in pharma activities. Comparison between the two groups was done and results indicated that the AR group was 40% less likely to make a mistake than the control group. The navigational prompts and error checking feature of AR assisted the participants in making fewer mistakes when executing procedures. This result echoes the result of Kapp who identified that AR hold a possibility to improve the procedural precisions as a result of the real-time instructions and feedbacks during the production of pharmaceutical.[13]

In addition to this, the level of procedure standardization among the different kinds of users was also established as the spread of performances in the AR group was more uniform. Such consistency is important so as to maintain the quality of the products that these companies produce as well as adhere to set regulations. Carmigniani et al.'s study also corroborates this findings and in their study, the authors noted that AR enhances procedural accuracy as the system provides contextual information as well as real time feedback.[15]

6.1. This includes user acceptance and perceived benefits it has to offer to its users.

The overall level of satisfaction concerning AR technology was relatively high: 80 % of the participants in the AR group reported they would like to use AR in the future for training and practical work. According to the surveys' results, the ease of use and the relevance of the AR application were evaluated by mean 4. 5 and 4. , while two were regarded as being of

somewhat less quality, that is 6 out of 5, respectively. They pointed out that it was easy to follow composite procedures and that the application of AR gave a bull's eye that procedures are well done. This is in congruity with the study done by Bower, Howe, McCredie, Robinson and Grover which discovered that when the AR technology is easy to use and supports the performance of a task, then users are receptive to it.[17]

But some of the participants also highlighted on the fact that there was relatively a steep incline in the use of the AR technology and also the constant updates of the content for the accuracy check. Developing and implementing measures to address these concerns therefore requires attention to show people the long-term gains of adopting this technology for its intended use in augmented reality.

7. Cost-Effectiveness and ROI

The cost-benefit analysis showed that while the IT investments in the AR applications are rather high, including investment in hardware and software, as well as content creation, the long-term cost savings of AR are significant. Training time has been significantly reduced and the overall error percentage has also gone down which leads to a greater extent of cost savings in all the pharmaceutical operations. The AR's implication was also affirmed by the ROI analysis, in which, the ROI was revealed to have been positive in two years of implementation through enhanced efficiency and low cost of errors. The behaviours also underline financial feasibility of implementing AR in the and more extensively in the pharmaceutical market.

8. Challenges and Limitations

However several limitations and challenges were observed in the study as outlined below; The implication of the higher first of AR technology has been another thorny issue for most of the pharmaceutical firms especially the small-scale industries. Moreover, the research was carried out in a laboratory setting which sometimes may not capture the rigorous and dynamic nature of actual pharmaceutical firms. More research should be directed toward applying and testing AR in various contexts to confirm these findings. In addition, the study was based on survey and interview data, in this case responses could have been influenced by participant's perception. Information resulting from the present study could be strengthened by integrating it with more concrete data, and increasing the amount of participants included in the study.

9. Conclusion

This work has essentially examined the capability of augmented reality (AR) technology in the training of pharmaceutical professional and efficiency in procedures related to drug production and usage. The results reveal that the application of AR in training yields a statistically significant level of effectiveness compared to conventional approaches, in terms of knowledge enhancement, skill enhancement, and the level of interacting with the training materials. The engagement facilitated by AR and the ability to learn through experiments enhances learning as evidenced by participants' increased test scores[15] and opinions.

Moreover, unlike other ways of training that mostly focused on enhancing staff knowledge and skills, AR's capabilities of real time direction and identification of errors, can assist in minimizing procedural mistakes, and maximizing the compliance with SOP. Besides, it also contributes to raising the quality and security level of medicines and increasing operational effectiveness through a decrease in error rates.[18] The existence and objectivity of these procedures further highlights AR's potential to modernize the pharmaceutical manufacturing processes due to the enhancement of consistency and standardization.[19]

Participants' acceptance of AR technology is overall favourable with the majority of the participants acknowledging ease of use and perceived usefulness of the technology. However, the first condition that is that one must face the initial learning curve to be able to operate the system as well as the second major limitation that is continuous training update activities are big challenges that must be met by vigorous training and support activities. The cost-benefit analysis also consider the financial feasibility of implementing AR where large savings after a while over-power the expenses of implementing the technology.

However, the study also has some limitations in its results, namely the occasionally high initial costs and, more seriously, the experimental character of the research environment. The use of AR in practical contexts must in future be the focus of more research studies, while the sample should be increased to prove the findings. Altogether, AR technology has pros that make this tool valuable for the pharmaceutical industry – the users improve the quality of training and undertake all protocols more accurately. In overcoming the outlined challenges and expanding its usage, AR may bring considerable positive shifts in the safety, productivity, and adherence to rules of the pharma production and drug administration.

10. Source of Funding

None.

11. Conflict of Interest

None.

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