Gamified AR Application as A Learner Model for CNC Milling Machine during COVID 19 Pandemic

Salahuddin Yusoff[1,*], Mohanadhas Kanagaraj[1], and Nadia Abdul Rani[2]
[1]Kolej Komuniti Kepala Batas, No 87, Lorong Bertam Indah 11, Taman Bertam Indah, 13200 Kepala Batas, Pulau Pinang, Malaysia
[2]Universiti Putra Malaysia, Jalan Universiti 1 Serdang, 43400 Seri Kembangan, Selangor, Malaysia
*Corresponding author: salahuddin.kkbest@gmail.com

Abstract

The COVID-19 pandemic has forced many organizations around the world to make full use of a variety of emerging online communication platform technologies due to movement control order (MCO) enforcement. TVET system implementation is based on skill practices. Therefore, students were unable to accomplish the learning outcome (LO) which required hands-on activities. This paper shares the work in developing and implementing a gamified (AR) application, CNC Milling Interactive Learning (CMiL) for students and trainees to understand the Boxford VMCi 300 CNC Milling machine standard operation for tool set-up procedure. In this gamification learning platform, an immersive AR application has been developed to assist the understanding through visualization, interactive, simulation, and task completion. The assessment feature with immediate feedback was embedded within the gamification platform, which aims to help students assess their level of understanding and help instructors monitored the learning progress of the students. The students' scores obtained, shows the increment of percentage, where the lowest value was 25% of improvement and the highest value was 42.62% with several attempts of CMiL usability. The 3rd LO of the CNC Machining course (SMN2034) was measured by using this gamified AR application, CMiL. As a conclusion, the learner model guided by technology-based learning design, support and enhance the psychomotor phase in human skills development as well as a tool of cybergogy concept with virtual application technology.

Keywords: - augmented reality, gamification, CNC machining, psychomotor phase

1 Introduction

The growing need and initiative to reduce operating costs of production capacities, human resources and errors in component production have led to the growth of manufacturing automation and higher demand for the latest technology of CNC machines. CNC machines can perform multiple operations unlike conventional machine tools, which require changing of tools after every operation adding on to the cycle time. Chardonnet et al. (2017) justified that CNC machines are a high complexity machine, especially for beginners; with low ergonomics since the operator has to move continuously between the machine window and a control screen to ensure smooth operations.CNC machining is part of the Industrial Machining curriculum for any Vocational Education Training provider. A CNC machining course is a collaborative between programming numerical data and simulation the possibility of machining process which involves numbers, graphics, and machine controller that rise the complexity in handling the machine. As part of the Higher Education Institution, Community College under the Department of Polytechnic and Community College, Ministry of Higher Education had introduced skilled based education for school leavers before they entered the workforce by implementing Technical Education and Vocational Training (TVET). Raihan and Shamim (2013) stated that the role of TVET institutions continuously changing throughout the emergence of technology.

An outcomes-based approach for Manufacturing Technology Program in Community College, Malaysia faces the challenge to run the activities for CNC Machining Course (SMN 2034) which contained learning and hands-on in machining with CNC programming, machine set-up, machining procedures with datum, and tool offset. These are the assessment that will be measure as an outcome for students' understanding of handling CNC milling machines. This outcome-based approach used a constructive alignment teaching principle that combines constructivism, the idea that learners construct or create meaning out of learning activities what they learn, and alignment, a curriculum design concept that emphasizes the importance of defining and achieving intended learning outcomes. Biggs (1986)

stated that constructive alignment starts with the notion that the learner constructs his or her learning through relevant learning activities. The COVID-19 pandemic crisis faces by Malaysians currently, has impacted many economic, financial, and other sectors which included the education sectors as well. Due to the spread of this disease and the closure of physical classes, online learning through the uses of several devices like computers, laptops, tablets and mobile phones with internet access in synchronous and asynchronous environments become the alternative learning methods. The limitations of face-to-face learning methods and hands-on learning experience are affected which restricted students' understanding and limited tutors monitoring. Considering the constraints of insufficient instruction by online learning, students won't have any experience working with any types of equipment for several courses needed for skill practice. Selvanathan et al. (2020) have concluded that students are still coping with the new norms working from the home period, but they had dissatisfaction with certain elements that may need to be considered.

Many kinds of efforts have been established for learning sessions during the COVID-19 pandemic crisis. This includes videos, youtube, google meet, etc. The main problem will be, how a student can interact with the machine? It is the main factor which is needed to be analyzed to what extent students could handle the CNC Milling machine with Movement Control Order (MCO) implementation throughout many sectors and nations. Lotti et al. (2019) critically issued CNC interfaces, from the point of view of human-machine interaction and summarised as: not suitable support information, the alternation between panel and machine, non-homogeneity of presented information, and user's tasks not focusing on production functions. Many machining processes will continue to require immediate human input for years to come. Tools length offsets are one of the most widely misunderstood aspects of CNC mill operation. This is at least partly because there are many different ways to manage length offsets, as shown in Figure 1.

Figure 1: Methods of tool length offset in CNC milling machine

Align with the 4th industrial revolution, the Augmented Reality (AR) technology currently plays an important role to undertake the challenges in integrating technologies to expedite the march towards sustainability in education as well as confronted the pandemic issues. Therefore, this case study's interest is more on enhancing the innovation and creativity of human-machine interaction through teaching and learning activities with interactive technology. A gamified AR application has been developed as a learning platform to assist the understanding of the machining process which includes datum set-up and tool offset for Boxford VMCi300 CNC Milling machine.

2. Literature Review

Ability is talent, skill, or proficiency in a particular area of human or person to do things with passion and confidence in self. The impact of Industry 4.0 on workforce recruitment is expected to be significant since the requirements of the skill needs will be changed. AR has become one of the pillar elements to revolute the IR4.0 realization. The industry will demand skilled candidates to work in this new era of industrial 4.0. The human workforce was integrated into the manufacturing systems and must be flexible and adaptive (Yew et al., 2016). A good digital learning platform should be able to completely record learners' learning history so that instructors could understand learners' learning conditions and learners could realize the level of learning outcome for adjustment and improvement (Lin et al., 2017). Fischer et al (2016), have adopted augmented and virtual (A/V) realities as an aid for workforce training and it is much better interaction between human and machine. Rani et al. (2020) has reviewed and investigated the capabilities of AR as new emerging technologies that will improvise machining operation to embrace Industry 4.0 (I4.0) for product precision, cost, and maintenance.

2.1 Augmented Reality (AR) Application

AR has been used in several areas for better understanding and to reduce the error of any handling activity by a human. A mobile application was used by Mourtzis et al. (2018) for visualizing Computer-Aided Manufacturing (CAM) instructions. Ragni et al. (2018) developed ARTool Zero supports the operators in programming touching probe trajectories, generating and simulating on the fly the part-program that guides the probe in the identification of a geometrical feature. Paliokas et al. (2020) used an AR application with quiz game-based, enhanced users experience in museum settings. The immersive gamification environment should demonstrate the real-world contexts in a virtual gaming world to

foster motivation and enhance learning experiences regarding given teaching content. Zhao et al. (2020) found that gamification can be integrated effectively into manufacturing education to motivate students and enhance their learning effectiveness.

2.2 Gamification

Gamification is becoming more prevalent in education because of its perceived ability to motivate students and make their learning activities more active and participatory, (Christensen and Raynor, 2013). Gamification is a new trend where game elements are used in unlikely contexts, such as education, health or social areas, and marketing (Hakulinen et al., 2015; Hanus and Fox, 2015 and Koivisto and Hamari, 2014). Huotari and Hamari (2017) have referred that gamification as the transformation of systems, services, organizations, and activities to afford similar experiences, motivations, and skills as good games.

3. Methodology

The process of developing AR applications has two stages of development which are modelling the component and designing the scene in the application. The software used to generate 3D models and animation is Autodesk Inventor. In the second stage of developing the application, models designed in 2D and 3D are imported into Unity 3D for compiling in creating the gaming environment and augmented reality instructional scene. The user interface is designed based on acquired content obtained from the course content and rubric assessment. A marker-based on Figure 2, was used in this application for the AR projection setting and documents control of the course content. The finished scene is then rendered and the script is compiled and exported to be used on the Android platform. Figure 3 shows the workflow process to develop an AR application for handling CNC Milling machines.

Figure 2: Marker-based for AR projection

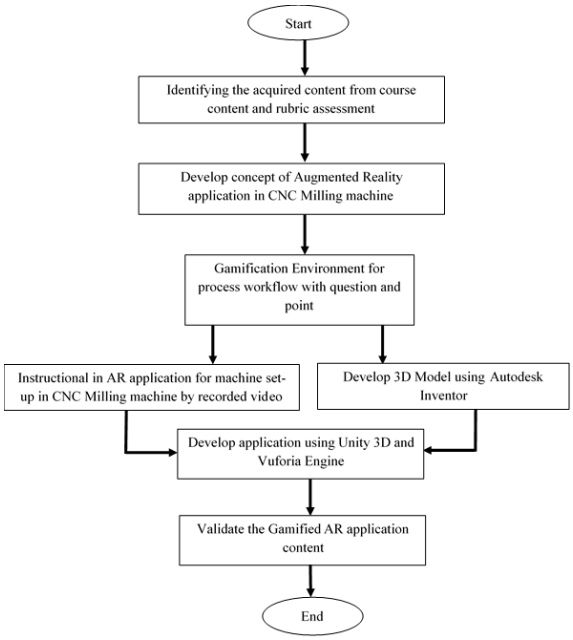


Figure 3: The workflow of AR application development

The application consists of two integrated aspects which are hardware and software equipment. The hardware used was the Boxford VMC300 CNC Milling machine and, tablet or mobile as the device to run the CMiL application. The software needed to be developed in a 3D parametric model in Autodesk Inventor with file extension exported to an .obj and converted to a .fbx extension file. These files then can be input in UNITY 3D model software. The 3D object of components in the CNC Milling machine consists of a worktable, jigs, clamp, collet, and tool were drawn by Autodesk Inventor. The 3D model has the same scale as the real parts and tools for a better user experience. Once the 3D models have been developed, Unity 3D and Vuforia Engine play the role of a cross-platform gaming engine that develops 2D and 3D gaming experience for computers, consoles, and mobile phones. This software features a drag and drops function and scripting using C++ with Microsoft Visual Studio. Each of these functions is important for the application for a better interface to ease the user in understanding the operation of the CNC Milling machine. Figure 4 shows the gamification AR application environment.

To ensure the content of the CMiL application fulfill the course content, three (3) instructors run the application with marker-based and compare the AR content with the real scene for machine set-up procedure by Boxford VMCi300 CNC Milling machine.

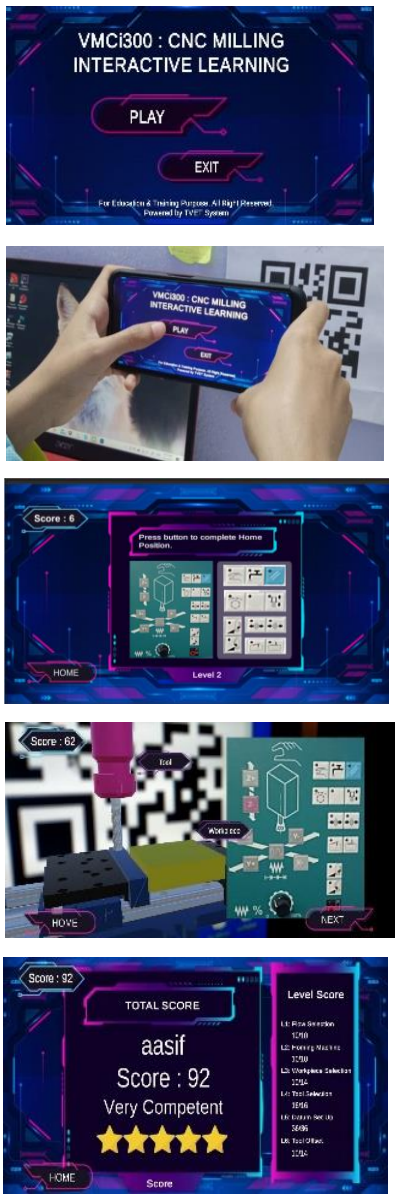


Figure 4: Gamified AR application environment

Then the application was run twice by students to compare the scoring marks and level of competency.

4. Finding and Analysis

The CMiL gamified AR application contained 6 levels of tasks which are:

i. Flow selection
ii. Homing machine
iii. Workpiece installation
iv. Tool selection
v. Tool Offset
vi. Datum set-up

The score of each level of the task follows the weightage of the rubric in the CNC machining course assessment. A storyboard was created, referred to course content and rubric assessment, had synchronized the gamification content and the process of learning flow accordingly. The recorded video as Figure 5 shows the method of handling the machine by process act as a visualization tool for references, cognitive support, and instruction for machine users.

Figure 5: Recorded videos of machining procedure

The 3D animation plays the role of simulating the machine components and feedback when the control panel buttons were pressed by the user. Figure 6 shows the 3D animation model.

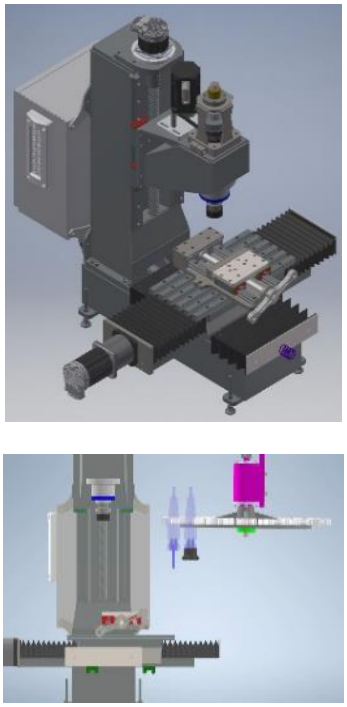
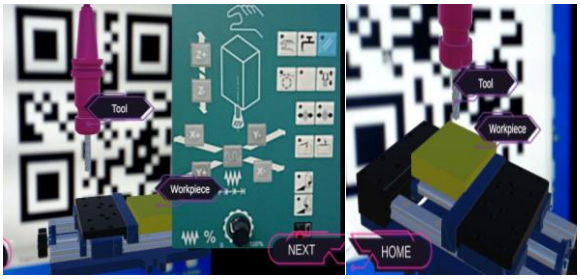


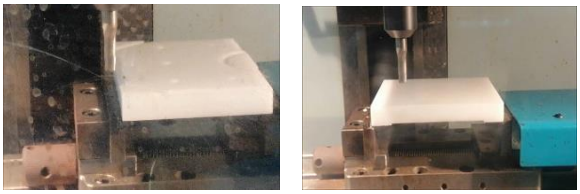
Figure 6: 3D assembly model for machine components

The AR environment as Figure 7 (a), interacts with the user to give the experience of handling a CNC Milling machine where the user can press the

control panel button and visualize the simulation. This will give motivation and engage the user to explore the machining process. Figure 7 (b) refers to the real scene in the datum and tool offset set-up procedure.



(a)



(b)

Figure 7: (a) AR environment for datum and tool offset set-up procedure and, (b) real scene for datum and tool offset set-up procedure

The task completion will be evaluated with a score in each level and the user competency measured was based on the percentage provided by the course assessment. Figure 8 shows the final stage of the level score and the user's competency.

Figure 8: User's Score and competency

The assessment feature with immediate feedback was embedded within the gamification platform, which aims to help students assess their level of understanding and help instructors monitored the learning progress of the students. The contents then were validated by the 3 instructors who are CNC machining subject matter experts, reviewed, and revised based on the Outcome Based Learning requirement. Then the CMiL application was run by 6 students, assisted individually who were affected during the MCO as Figure 9. The scoring level was itemized by learning sequence accordingly to Boxford Cad Cam Software process flow and Constructive Alignment Assessment. Table 1 indicates the score achieved by students.

Figure 9: CMiL Apps used by students via Google Meet

Table 1: Score marks and % of improvement of each student

Student	Pre Test	Post Test	% of improvement
01M	73	97	32.88
02M	80	100	25.00
03M	69	94	36.23
04M	65	90	38.46
05M	61	87	42.62
06M	70	93	32.86

5. Conclusion

The Gamified AR application CMiL, improvise the learning method in handling CNC Milling Machine for beginners. The score of each student has shown an improvement after using the application several times. The student understanding of the CNC Milling machine has increased, where the lowest value was 25% of improvement and the highest value was 42.62%. The 3rd LO of the CNC Machining course (SMN 2034) was measured and this application engaged students to learn and understand the Boxford VMCi300 CNC Milling operation even though was not in real practice. Therefore, the gamified AR application CMiL improved the understanding of students as beginners to handle the CNC Milling machine. The application assisted the machining procedures with interactive AR application, visualization with videos and simulation, and task completion for the level of achievement in handling CNC Milling machines. The learning process affected by the pandemic COVID 19 crisis could be overcome by using the CMiL application. Learning outcomes can be measured with this application and enhance psychomotor learning for human performance. This learner model guided by technology-based learning design could provide opportunities to learn and develop skills through cybergogy learning concept with virtual application technology for motivation and engagement in learning CNC Milling Machine.

Acknowledgment

The authors deeply acknowledge the management of the Manufacturing Technology Unit of Kepala Batas Community College and Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia for the facilities: Boxford VMCi300 CNC Milling machine and lab assistance to run the experiment for the AR development. Each of the members has provided extensive personal and professional guidance and taught a great deal about both scientific research and life in general, especially during the pandemic crisis.

References

Abdul Rani, N., Abdul Aziz, F., Hairuddin, A. A., Ahmad, S. A., & Hemdi, A. R. (2020). Augmented reality: capabilities and challenges in machining industry aligned with industry 4.0. *Advances in Materials and Processing Technologies*, 1-9.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher education*, *32*(3), 347-364.

Chardonnet, J. R., Fromentin, G., & Outeiro, J. (2017). Augmented reality as an aid for the use of machine tools. Retrieved September 2, 2021, from https://hal.archives-ouvertes.fr/hal-01598613.

Christensen, C., & Raynor, M. (2013). *The innovator's solution: Creating and sustaining successful growth*. Harvard Business Review Press.

Fischer, C., Lušić, M., Faltus, F., Hornfeck, R., & Franke, J. (2016). Enabling live data controlled manual assembly processes by worker information system and nearfield localization system. *Procedia CIRP*, *55*, 242-247.

Hakulinen, L., Auvinen, T., & Korhonen, A. (2015). The Effect of Achievement Badges on Students' Behavior: An Empirical Study in a University-Level Computer Science Course. *International Journal of Emerging Technologies in Learning*, *10*(1).

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & education*, *80*, 152-161.

Huotari, K., & Hamari, J. (2017). A definition for gamification: anchoring gamification in the service marketing literature. *Electronic Markets*, *27*(1), 21-31.

Koivisto, J., & Hamari, J. (2014). Demographic differences in perceived benefits from gamification. *Computers in Human Behavior*, *35*, 179-188.

Lin, M. H., & Chen, H. G. (2017). A study of the effects of digital learning on learning motivation and learning outcome. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3553-3564.

Lotti, G., Villani, V., Battilani, N., & Fantuzzi, C. (2019). New trends in the design of human-machine interaction for CNC machines. *IFAC-PapersOnLine*, *52*(19), 31-36.

Mourtzis, D., Zogopoulos, V., Katagis, I., & Lagios, P. (2018). Augmented Reality based Visualization of CAM Instructions towards Industry 4.0 paradigm: a CNC Bending Machine case study. *Procedia CIRP*, *70*, 368-373.

Ragni, M., Perini, M., Setti, A., & Bosetti, P. (2018). ARTool Zero: Programming trajectory of touching probes using augmented reality. *Computers & Industrial Engineering*, *124*, 462-473.

Raihan, M. A., & Shamim, M. R. (2013). Emerging Educational Technologiesfor TVET to Boost Learning: Issues, Trends, and Horizons. *International Journal If Innovative Research in Science, Engineering and Techology*, *2*(7), 3213-3222.

Selvanathan, M., Hussin, N. A. M., & Azazi, N. A. N. (2020). Students learning experiences during COVID-19: Work from home period in Malaysian Higher Learning Institutions. *Teaching Public Administration*, 0144739420977900.

Yew, A. W. W., Ong, S. K., & Nee, A. Y. (2016). Towards a griddable distributed manufacturing system with augmented reality interfaces. *Robotics and Computer-Integrated Manufacturing*, *39*, 43-55.

Zhao, Z., Toh, D. J., Ding, X., Ng, K. C., Sin, S. C., & Wong, Y. C. (2020). Immersive Gamification Platform for Manufacturing Shopfloor Training.