A GAMIFIED AUGMENTED REALITY APPLICATION FOR HUMAN-MACHINE INTERACTION IN CNC MILLING MACHINE

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

July 2022

FK 2022 113

Abstract of thesis presented to the Senate Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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Chairman: Assoc. Prof. Ir. Ts. Faieza Binti Abdul Aziz, PhD
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The 4th industrial revolution and the digital transformation are prevailing factors in the manufacturing industry and augmented reality (AR) currently plays an important role to undertake the challenges in integrating technologies to expedite the march towards the revolution. The manufacturing evolution provided more efficient techniques to extend the humans capabilities and cost reduction in various areas. Computer Numerical Control (CNC) milling machine was the most difficult machine as it takes several procedures with different processes. It requires skilled users and knowledge in programming, 3-D model design, and understanding machine language. Therefore, machining competencies in CNC machines practices are highly demanded. Tool length offsets are one of the most widely misunderstood aspects of CNC milling operation and these procedures rely on human-input parameters. Human-machine interaction (HMI) is an interaction and communication between human and a machine, a dynamic technical system and it is the methodology for evaluation of user interface techniques. The objectives of this research are to measure the ability of beginners, and empowering the CNC milling machine operation. A gamified AR application is to be developed, called CNC Milling Interaction Learning (CMiL), to assist user understanding in performing the machining task. Then, the AR application effectiveness is being evaluated for user acceptance of this technology. This research also developed a conceptual framework on HMI with cybergogy learning concept for human engagement and heutagogy learning. The items difficulties in handling CNC milling machine were identified through and experiment which involved 31 participants. Numbers of softwares have been used for the AR application development. The hardware used was Boxford VMCi300 CNC milling machine and, tablet or mobile as the device to run the CMiL application. CMiL effectiveness evaluation, involved 20 CNC milling machine users and experts. A conceptual framework was developed and validated by the CNC milling machine expertise and curriculum developer. As a result, 14 items were identified as difficulties to empower CNC milling machines for beginners. An immersive 3D gamified AR application was developed to

enhance the user experiece and user interface for better understanding with video, images, tasks, simulation in the AR environment. The CMiL application contents was 100% function, pertinent with the real-scene machine procedures, validated by CNC machines experts. Therefore, 90.5% of CMiL users have accepted that CMiL can be act as the learning platform for the CNC Milling machine, 76.1% agreed that the apps enhanced their knowledge and 85.7% agreed that the CMiL apps enhanced their skills. The newly developed conceptual framework on humanistic theory guided by technology-based learning design shows the relationships and connectivity of the gamified AR application. 90% experts concurred that the conceptual framework of cybergogy and heutagogy learning concept by CMiL application leads to assist user interface and user experience of the HMI elements. This can be concluded that using AR via gamification and digital content offers a rich experience, assist and support the enhancement of psychomotor phase in human skills development. It is a tool for learning motivation and enhances cognitive, persistence, and competencies in human performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

APLIKASI REALITI BERPERANTARA SECARA GAMIFIKASI UNTUK INTERAKSI MANUSIA-MESIN BAGI PEMESINAN CNC KISAR

Oleh

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Revolusi industri ke-4 dan transformasi digital adalah faktor yang mempengaruhi industri pembuatan dan aplikasi realiti berperantara, *augmented reality (AR)* memainkan peranan penting untuk menghadapi cabaran dalam mengintegrasikan teknologi ke arah pencapaian revolusi yang lebih pantas. Evolusi pembuatan menyediakan teknik yang lebih cekap untuk memperluas kemampuan manusia dan pengurangan kos dari pelbagai bidang. Mesin *Computer Numerical Contro*l (CNC) adalah mesin yang paling sukar kerana memerlukan beberapa prosedur dengan proses yang berbeza. Ia memerlukan pengguna dan pengetahuan yang mahir dalam pengaturcaraan, reka bentuk model 3-dimensi, dan memahami pengaturcaraan. Oleh itu, kemahiran yang tinggi dan pekerja yang berpengalaman ada amat diperlukan bagi mengendalikan mesin CNC. Pengukuran dan penentuan ketinggian mata alat, ofset adalah salah satu aspek yang paling banyak disalah tafsirkan dan dilakukan dalam pelbagai cara sebelum menjalankan operasi mesin CNC dan prosedur ini bergantung pada maklumat parameter oleh manusia. Interaksi manusia-mesin, *human-machine interaction* adalah proses komunikasi antara manusia dan mesin, sistem teknikal yang dinamik dan ini adalah metodologi untuk penilaian teknik ke atas antara muka, *user interface* pengguna. Oleh yang demikian, objektif penyelidikan ini adalah untuk mengukur kemampuan pengguna yang baru untuk mengendalikan mesin CNC kisar. aplikasi realiti berperantara (AR) yang dibangunkan dan dikenali sebagai, CNC Milling Interaction Learning (CMiL), adalah untuk membantu pemahaman pengguna dalam melaksanakan proses pemesinan secara asas. Kemudian, keberkesanan aplikasi realiti berperantara (AR) ini dinilai penerimaannya untuk digunapakai oleh pengguna dan penggunaan terhadap teknologi ini. Penyelidikan ini juga membangunkan kerangka konsep mengenai interaksi manusia-mesin dengan konsep pembelajaran cybergogy untuk meningkatkan penglibatan manusia dan pendekatan konsep pembelajaran heutagogy. Bagi mengenal pasti kesukaran item mengendalikan Mesin CNC Kisar, 31 sampel telah terlibat di dalam eksperimen yang dilaksanakan. Oleh yang demikian, dalam proses

membangunkan aplikasi interaktif perantara (AR) ini, beberapa perisian telah digunakan. Perkakasan pula yang digunakan adalah mesin kisar CNC Boxford VMCi300 dan, tablet atau telefon sebagai peranti untuk menjalankan aplikasi CMiL. 20 pengguna dan juga pakar dalam mesin CNC kisar telah terlibat dalam penilaian keberkesanan CMiL. Kerangka konsep dibangunkan dan disahkan oleh pakar mesin CNC kisar yang juga sebagai pembangun kurikulum TVET. Hasilnya, 14 item dikenal pasti sebagai kesukaran untuk mengendalikan mesin CNC kisar kepada pengguna yang baru. Aplikasi realiti berperantara AR secara gamifikasi 3D yang dibangunkan adalah untuk meningkatkan persepsi manusia dan antara-muka pengguna untuk pemahaman secara praktis yang lebih baik berpandukan video, gambar, tugasan, simulasi di dalam persekitaran aplikasi ini. Kandungan aplikasi CMiL ini telah disahkan oleh pakar dalam bidang pemesinan CNC. Keberfungsian aplikasi ini adalah 100% sebagaimana prosedur pemesinan secara sebenar. Oleh itu, 90.5% telah menerima aplikasi CMiL untuk digunapakai sebagai landsan pembelajaran bagi pemesinan CNC kisar, 76.1% bersetuju bahawa aplikasi ini dapat meningkatkan pengetahuan mereka dan 85.7% bersetuju bahawa aplikasi CMiL meningkatkan kemahiran mereka. Rangka kerja teori humanistik yang baru telah dibangunkan berpandukan reka bentuk pembelajaran yang berasaskan teknologi gamifikasi AR. 90% pakar dalam bidang pemesinan CNC, penggerak industri, aplikasi maya dan para akademik dalam sistem TVET telah bersetuju bahawa rangka kerja teori humanistik yang dibangunkan menunjukkan hubungan domain pembelajaran cybergogy dan pembelajaran kendiri, heutagogy melalui aplikasi CMiL. Ianya memberi kesan terhadap antara-muka pengguna pada sesebuah mesin dan persepsi manusia melalui emosi dan keyakinan. Ini dapat disimpulkan bahawa menggunakan AR melalui gamifikasi dan kandungan digital memberi pengalaman, membantu dan menyokong peningkatan fasa psikomotor dalam proses peningkatan kemahiran manusia. Ini adalah sebuah alat dan kaedah bagi memotivasikan pembelajaran dan meningkatkan kognitif, keupayaan, dan kecekapan dalam prestasi manusia.

ACKNOWLEDGEMENTS

First and foremost, I would like to praise Allah the Almighty, the Most Gracious, and the Most Merciful for His blessing given to me during my study and in completing this thesis. May Allah's blessing goes to His final Prophet Muhammad (peace be up on him), his family and his companion.

I would like to express my sincere thank you to my beloved supervisor, Assoc. Prof. Ir. Ts. Dr Faieza Binti Abdul Aziz, who educate me with her patience, courage, and support all the way throughout my PhD journey. She is very understanding and always consistently shared her knowledge and experiences, motivating and encouraging me till the end of this research. My gratitude also goes to my committee supervisors, Ts. Dr Rahman bin Hemdi, Assoc. Prof Siti Azfanizam Bt Ahmad and Assoc. Prof. Dr Aziz Bin Hairuddin for their knowledge, time and support along this wonderful educational journey in my life. My very thankful to Mr Mohanadhas a/l Kanagaraj and Mr Salahuddin Bin Yusof from Community College, Kepala Batas, for sharing and giving their time, experience and especially their valuable knowledge upon this research.

Lastly, my deepest loves and appreciation goes to my soulmate, Shamsul Khamar bin Abdullah, my children; Aleya Syafiah, Akeef Nuqman and Aasif Nadeem, my mother Hajah Che Nin Bt Hj Said, my late father Hj Abdul Rani bin Abd Kadir, my family, my friends and, my colleges for their loves and encouragement in supporting me thru this beautiful and adventurous journey in life.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
APK	Android Application Package
AR	Augmented reality
BI	Behavioral Intention
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CC	Community College
CMiL	CNC Milling Interactive Learning
CNC	Computer Numerical Control
COVID-19	Coronavirus Disease
HCI	Human-Computer Interaction
HMI	Human-Machine Interaction
INFIT	Inlier-sensitive or information-weighted fit
IR	Industrial Revolution
MCO	Movement Control Order
MR	Mixed Reality
MNSQ	Mean-Square
OUTFIT	Outlier-sensitive or information-weighted fit
PEOU	Perceived Ease of Use
PIDM	Person Item Distribution Map
PMC	Point Measure Correlation
PU	Perceived Usefulness
TAM	Technology Acceptance Model

TVET	Technical Vocational Education Training
UDL	Universal Design for Learning
UI	User Interface
UX	User Experience
VM	Virtual Manufacturing
VR	Virtual Reality

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CHAPTER 1

INTRODUCTION

1.1 Overview

Precision manufacturing of machine tools is very evolutionary. Incremental experience-based improvements are steadily achieved and as the machinery itself advances in precision, the components that make up the next generation of machines also improve. Dornfeld (2008) stated that together with the value-added by skilled craftsmen results in ever-increasing accuracy of machine tools could increase. Nekrasov et al. (2018) defined that the quality of the part is characterized by the precision of its processing where a good fit of the product parts depends on how accurately the size and shape of the part are maintained during machining. In metalworking operations, the quality of cutting-tool performance is one of the most significant issues that need to be addressed (Grigoriev et al., 2019).

Machine equipment equipped with Computer Numerical Control (CNC) an abbreviation for Computer Numerical Control systems has a high discreteness of movements, functions of adjusting the movement of the tool, accounting for wear of the cutting edge, etc. CNC is and such machines are electro-mechanical contrivances that handle machine shop tools using computer programming inputs. Machine tool errors have been mainly categorized by Chatterjee (1996) in two classes namely, quasi-static and dynamic errors. It is often difficult to achieve desired accuracies due to the complexity and the interactions of the various factors. The quasi-static error is related to the relative positioning error between the tool and the workpiece.

Martinov et al. (2017) had developed a generic platform underlying the design of custom CNC systems for hi-tech production complexes. Sima et al. (2020) identified the influences of the Industry Revolution 4.0, IR 4.0 on human capital development and consumer behavior which are shifting the work environment and the drivers for human capital development and consumer behavior. AR currently plays an important role to undertake the challenges in integrating technologies to expedite the march towards IR 4.0 (Rani et al., 2020). Machine tools developed by Czerniak et al. (2017) aided with advanced technology controllers, ergonomic requirements focused on the communication, cooperation, and interaction between humans and machines to reduce human error. Ali (2012) investigated the higher age group of CNC machine operators, using motor action time and applied force as response variables to evaluate the CNC machine operator's performance.

AR can be combined with human abilities to provide efficient and complementary tools to assist manufacturing tasks comparatively, fewer AR applications can be found in CNC machining (Nee et al., 2013). An AR interface has been applied by Yew et al. (2016) to improve the information perception of the different types of workers in a manufacturing facility and to make interaction with manufacturing software, CADCAM. Fischer et al. (2016) used AR as an aid for workforce training and the study showed better interaction between humans and machines. Qeshmy et al. (2019) implemented AR as automation to alleviate the workload of an operator with augmented system performance to reduce human errors in the assembly area. A virtual CNC milling simulation process to assist the generation of G-codes with AR application was applied by Yap et al. (2016).

Ulmer et al. (2020) has developed a concept on evaluation system combining gamification and VR practice for flexible assembly tasks and compared it to existing works. Paravizo et al. (2018) used game elements to support manufacturing education tackling sustainability awareness issues. Gamification can generate valuable feedback for improving employees' engagement and performance, (Ulmer et al., 2020). Paliokas et al. (2020) used an AR application game-based with a quiz, to foster motivation and enhance learning experiences. Gamification can be integrated effectively into manufacturing education to motivate students and enhance their learning effectiveness, (Zhiqiang et al., 2020). Reddy et al. (2020), has compared time of machining completion using virtual CNC turning machine and determined that the virtual learning gived faster completion of 62 minutes of time compared to conventional learning 75 minute.

Digital design and manufacturing technologies provide great support for product realization from design conception and engineering to manufacturing, sales, and services of a product. Chen et al. (2015) used cyber-physical system (CPS) models, for intelligent-machining applications, such as the optimization of NC processing parameters and the health assurance of CNC machine tools. Dong (2004) defined that the more machines used in manufacturing, HMI has changed from the adaption of humans to machines gradually to the adaption of machines to humans. Damiani et al. (2018) determined that virtual application such as VR and AR could be adapted for workforce training as the applications could interact human workforce in efficient way. This was the way by improvised the cooperation between humans and machine as well teach workers complex tasks in a safer manner to increase their productivity.

1.2 Problem Statement

The advanced technology in machines tools involved computers, automation, coding, etc. Many machining processes continue to require immediate human input for years to come, (Ma et al., 2019). The human input involved machine set-up procedure, programming and workpiece installation before the CNC machining operation. Therefore, human skills are still needed even an advanced technology and robotics took the place for fast and smart manufactured. Lynch (2019) stated that handling CNC machines is very difficult because it requires skilled users and knowledge in programming, 3D model design, and understanding machine language. Karuguzel et al. (2015) has described one of the most important and unique cutting parameters which is the tool axis offset and determined its effects on process outputs such as cutting force, surface quality, and tool wear.

Tool length offsets are one of the most widely misunderstood aspects of CNC mill operation, (Lamngeun, 2019). This is at least partly because there are many different ways to manage length offsets, shown in Figure 1.1

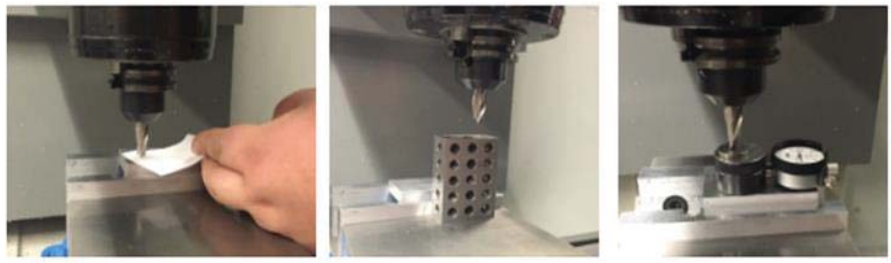

Figure 1.1: Methods of tool length offset in CNC milling machine
(Source: Lamngeun, 2019)

The geometric errors are greatly affected by the error modeling and error measurement methods, which could require significant machine downtime to implement, (Gu et al., 2015). Nazir (2016) in his article pointed out improper setting, improper maintenance, and improper programming lead to the failure of CNC machines. Zhang (2010) determined that an important aspect of human-machine interaction is the methodology for the evaluation of user interface techniques. The use of metrics beyond precision and recall include,

- time required to learn the system
- time required to achieve goals on benchmark tasks
- error rates
- retention of the way to use the interface over time.

Berlin & Adam (2017) developed a framework as Figure 1.2, to understand the relationship between factors affecting the mental workload, and how this affected the attention of the workers and their performance which then leads to produce errors.

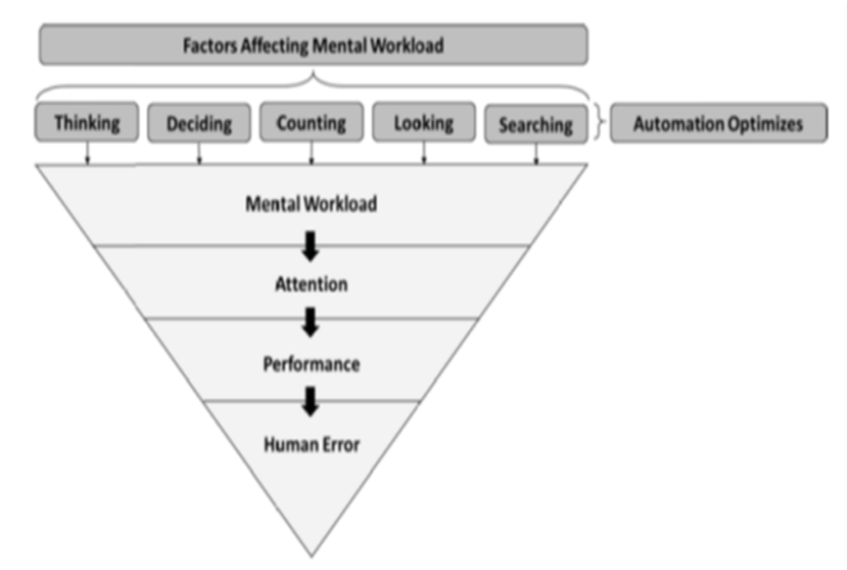

Figure 1.2: Mental Workload framework
(Source: Berlin and Adam, 2017)

As related to CNC machining operation, mental resources required to perform a set of concurrent tasks related to thinking and deciding method of machining, counting for programming, looking and searching for controller button and machine components for machine set-up and etc. Gregori et al. (2017) considered the social aspects to promote social sustainability while developing new production systems, together with more traditional environmental aspects by ensuring the crucial aspect of human growth and wellbeing. Monika et al. (2020) emphasized AR as a supporting tool for a direct visualization solution, as well as an enriched information graphics environment to track the machining process in real-time.

Dudley et al. (2018) further described that for machine learning, it is essential that the implementation of new and exciting artificial intelligence for such applications is followed by careful design of user interfaces. Bacca et al. (2015) applied mobile AR for educational purposes from a collaborative creation process (Co-Creation) and based on the universal design for learning (UDL) for a vocational program of car maintenance. Based on Quintana et al. (2020) case study, AR has been acknowledged as a suitable sustainable technology that may foster social and cognitive justice and inclusive education, and train students that are equally prepared for the dynamic future.

Figure 1.3 indicates the traditional human-machine interaction only incorporates human perception from system output (1). An improved model suggested, have to include personal capabilities, individuality, and actual condition (2) as well as physiological processes involved in interpersonal communication (3), (Riener, 2017).

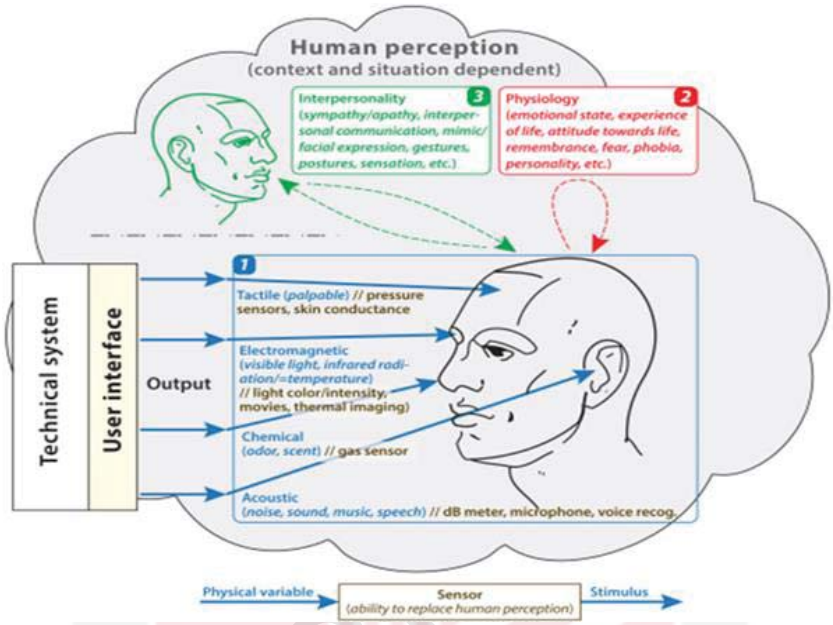

Figure 1.3: The traditional and improved model of human-machine interaction
(Source: Riener, 2017)

Based on the various studies, the human input requires multiple methods of approaching due to the mobility of the CNC machines to users. Critically issued by Lotti et al. (2019), CNC milling machine interfaces from the point of view of human-machine interaction and summarized 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. Chardonnet et al. (2017) justified that CNC machines are high complexity machines with low ergonomics. The operator has to move continuously between the machine window and a control screen to ensure smooth operations. 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 understanding and learning outcome for adjustment and improvement (Lin et al., 2017).

Previous studies had indicated numbers of issues regarding human-input parameters in CNC machines operation which are regarding to:

- workpiece installation
- G code and M code programming
- machine parameters
- machine set-up procedures

Therefore, the affected of mental workload to handle the CNC machine effects the human perception. The context and situation perception affected physiology condition based on human experience and emotional state which include phobia, fear and remembrance. The human perception involves physiology is being improvise by using digital learning platform to enhance user interface (UI) and user experience (UX) to empower handling CNC milling machine. The AR is a trending technology that has been used as a supporting tool to reduce and assist the occurrence of human errors which affected product precision generally and to embrace the (IR 4.0) specifically. Devedzic et al. (2016) indicated that AR as a key technology of concept Industry 4.0 to support learning activities becomes a trend in education and AR-based methods are proven to be effective teaching aids for engineering courses.

Therefore, in this study, the process of machine setting procedures for model Boxford VMCi300 CNC milling machine will be developed using AR application with interactive element embedded with game-based to gives motivation and enhance learning engagement, with enjoyment and playfulness along with the machine set-up tasks given. This application will use mobile or table as a device to enhance the learning practice of handling CNC milling machines by adopting AR technology, fusing the virtual 3D models or animations in real-life scenes. The time of machine set-up completion could be compared between two learning environment, conventional and virtual application to evaluate the effectivenss of the AR application. Throughout the needs in the industry and education, especially in the TVET education, skills training now becomes a requirement for job prospects, especially in the manufacturing sectors. This cybergogy and heutagogy learning concept approach will enhance the psychomotor values and confidence level for the effective skilled outcome.

The research questions of this study are:

I. What are the obstacles restricted empowering the CNC machine operation?
II. How to sustain information between users and machine (human-machine interaction) and mobilize users' experience of the CNC machine operation
III. Why the gamified AR application learning platform better than the conventional machine learning for CNC machine set-up procedure
IV. How to show that the AR application act as Cybergogy and Heutagogy learning concept that beneficial for handling CNC machine

1.3 Research Objectives

Objectives that to be achieved in the research are:

I. To measure the abilities of beginners in empowering handling CNC Milling machines.
II. To develop a gamified augmented reality (AR) model for machine set-up for CNC milling operation.
III. To evaluate the effectiveness of augmented reality (AR) application in handling CNC milling machines.
IV. To develop a conceptual framework for cybergogy and heutagogy learning concept through augmented reality (AR) application.

1.4 Hypothesis

Based from the above objectives, several hypotheses had been drawn as below:

- Using the AR application in cybergogy learning platform will enhance emotive, social and cognitive presence that engaged learners to learn CNC milling machine
- Extended AR platform to gamification will improve self-determination which influence users' skill performance (solving tasks and improve score)
- Conceptual framework with cybergogy and heutagogy learning platform can be developed that beneficial in human-machine interaction (HMI) CNC milling machine.

1.5 Significance of the Study

Manufacturing evolution provided more efficient techniques to extend the humans capabilities and cost reduction in various areas. 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 case study interest is more on enhancing the innovation and creativity of human-machine interaction through training, teaching, and learning for upskilling and reskilling activities with interactive technology. Through the AR apps via gamification the machining handling procedures and interfacing with Boxford VMCi300 CNC milling machine, could be used in various TVET institutions for CNC machining courses and other manufacturing programs. Eventhough the AR application massively demanded in the IR 4.0 implementation, the safety aspect highly required. When using the AR application, the user should aware the physical safety risks. Augmented reality applications can be immensely distracting and may lead to physical injuries. It is

to be awared as well that visually induced motion sickness (VIMS) can occur in augmented reality (AR) optical see-through applications, (Kaufeld et al., 2022)

1.6 Scope of Work

The gamified augmented reality (AR) application developed is based on the model Boxford VMCi300 CNC milling machine, with control panel and CADCAM software. Manual procedures of the machine and CNC milling machining course syllabus including rubrics were used as part of the application contents. The detection collision between tools and workpiece were assumpted. 31 respondents, only students as beginners of CNC machine users are being observed for identifying obstacles to empower CNC machining course. In the evaluation of the AR application usability, only 20 respondents are being selected base on the knowledge and experience using the BOXFORD VMCi300 CNC milling machine and CADCAM software. The respondant group was from students, lecturers, instructors, and graduated students of Community College, Department of Polytechnic, and Community College Malaysia.

1.7 Thesis Layout

This thesis is structured into five (5) chapters as listed:

Chapter 1 contains an introduction and overview of the research, problem statements, research objectives, significance of the study, scope of work, and, thesis outline.

Chapter 2 reviews previous works on virtual application, human-machine interaction, CNC machines, gamification, and theoretical framework studied by researchers. This includes design development in AR application, gamification in machining as well cybergogy and heutagogy learning concepts.

Chapter 3 describes and explains the methodology used to achieve all the research objectives respectively. This includes hardware and software used in the design and development of the gamified AR application. The effectiveness of usability was being evaluated with a theoretical model and measurements items were validated.

Chapter 4 analyze and discuss the finding results with data and tabulated graph and develop a conceptual framework according to variables of UI and UX for assisting interaction between human and machine.

Chapter 5 concludes the results and discussion with novelty from the research in implementing the virtual application in the machining industry and future recommendations to sustainability in quality education

REFERENCES

Abd. Aziz, A., Mohamed, A., Arshad, N.H., Zakaria, S., Zaharim, A., Ghulman, H.A. & Masodi, M.S. (2008). Application of Rasch Model in Validating the Construct of Measurement Instrument. International Journal of Education and Information Technologies, Issue 2, Volume 2 (Pp. 105-112).

Abdul Aziz, F., Alsaeed, A.S.M.A., Sulaiman, S., Ariffin, M.K.A.M., Al-Arhabi, A.R.Y., Virtual Reality Training Platform in Onshore Pipeline, (2020), Lecture Notes in Mechanical Engineering, pp. 207-216

Abdul Rahman, M. H., Ismail Yusuf Panessai, I., Mohd Noor, N. A. Z., & Mat Salleh, N. S. (2018). Gamification Elements and Their Impacts on Teaching and Learning – a Review. The International Journal of Multimedia & Its Applications, 10(06), 37–46.

Adom, D., Hussain, E. K., & Joe, A. A. (2018). Theoretical and Conceptual Framework: Mandatory Ingredients Theoretical And Conceptual Framework: Mandatory Ingredients Engineering Dickson Adom * Emad Kamil Hussein. International Journal of Scientific Research, 7(1), 93–98.

Afeti, G. (2006) Strategy to revitalize technical and vocational education and training (TVET) in Africa. Background document for the African Union's TVET Experts' meeting, 13-14 December 2006, Addis Ababa.

Aiken, S. (2003). Estimation of Item Parameters. In F. G. H. W. & M. I. (Eds.), Rasch Models, Foudations, Recent Developments and Applications. (p. 39–52.). New-York: Springer-Verlag.

Ajzen, I. From Intentions to Actions: A theory of Planned Behavior. In Action-Control: From Cognition to Behavior; Kuhl, J., Beckman, J., Eds.; Springer Science & Business Media: Berlin, Germany, 1985; pp. 11–39.

Akintoye, A. (2015). Developing Theoretical and Conceptual Frameworks.

Aleksandrov, A. A., Kapyrin, P. A., Meshkov, N. A., Neusypin, K. A., Popovich, A. E., & Proletarsky, A. V. (2018). Gamification in the advanced higher professional education: Fundamentals of theory and experience of use. International Journal of Civil Engineering and Technology, 9(11), 1800-1808

Ali, I. (2012). Ergonomic Design of Human-CNC Machine Interface. In Human Machine Interaction - Getting Closer (Issue October).

Ali, S. M., & Mohsin, H. (2021). Design and Fabrication of 3-Axes Mini CNC Milling Machine. IOP Conference Series: Materials Science and Engineering, 1094(1), 012005.

Alptekin M., Temmen K. (2020) Gamification in an Augmented reality Based Virtual Preparation Laboratory Training. In: Auer M., Tsiatsos T. (eds) The Challenges of the Digital Transformation in Education. ICL 2018. Advances in Intelligent Systems and Computing, vol 916. Springer, Cham.

Alsawaier, R. S. (2018). The effect of gamification on motivation and engagement. The International Journal of Information and Learning Technology, 35(1), 56-79.

Ananga, P. (2020). Pedagogical Considerations of E-Learning in Education for Development in the Face of COVID-19. International Journal of Technology in Education and Science, 4(4), 310–321.

Andreas Riener, Chapter 19 - Subliminal Perception or “Can We Perceive and Be Influenced by Stimuli That Do Not Reach Us on a Conscious Level?”, Emotions and Affect in Human Factors and Human-Computer Interaction, Academic Press, 2017, Pages 503-538,ISBN 9780128018514,

Andrei O. J. Kwok & Sharon G. M. Koh (2021) COVID-19 and Extended Reality (XR), Current Issues in Tourism, 24:14, 1935-1940

Anna Brolin, Peter Thorvald & Keith Case (2017) Experimental study of cognitive aspects affecting human performance in manual assembly, Production & ManufacturingResearch, 5:1, 141-163

Aqil Burney, S., Asim Ali, S., Afshan Ejaz, P., & Ahmed Siddiqui, F. (2017). Discovering the Correlation between Technology Acceptance Model and Usability. IJCSNS International Journal of Computer Science and Network Security, 17(11), 53.

Aristovnik, A., Keržič, D., Tomaževič, N., & Umek, L. (2016). Determining factors of students’ perceived usefulness of e-learning in higher education. Proceedings of the International Conference on E-Learning, EL 2016 - Part of the Multi Conference on Computer Science and Information Systems 2016, 3–10.

Artino, A. R. (2012). Emotions in online learning environments: Introduction to the special issue. The Internet and Higher Education 15(3), 137-140.

Asha Kanwar, K. Balasubramanian & Alexis Carr (2019) Changing the TVET paradigm: new models for lifelong learning, International Journal of Training Research, 17:sup1, 54-68,

Ayeh, J., Au, N., & Law, R. (2013). Towards an Understanding of Online Travllers' Acceptance of Consumer -Generated Media for Travel Planning: Integrating Technology Acceptance and Source Credibility Factors. In L. Cantoni & Z. Xiang (Eds.), Information and Communication Technologies in Tourism 2013 (pp. 254- 267). Heidelberg: Springer

Aziz, F.A. & Abdullah, Farooq & Win, L.L. (2018). Using marker based augmented reality for training in automotive industry. International Journal of Recent Technology and Engineering. 7. 118-121.

Azrilah, A. A., Azlinah, M., Noorhabibah, A., Sohaimi, Z., Azami, Z., Hamza, A. G., & Mohd. Saidfudin, M. (2008). Application of Rasch Model in validating the construct of measurement instrument. International Journal of Education and Information Technologies, 2(2), 105–112.

Babuli Chandra Kar, Amlana Panda, Ramanuj Kumar, Ashok Kumar Sahoo, Rasmi Ranjan Mishra,Research trends in high speed milling of metal alloys: A short review,Materials Today: Proceedings,Volume 26, Part 2,2020,Pages 2657-2662,ISSN 2214-7853

Bacca, J., Baldiris, S., Fabregat, R., Kinshuk, & Graf, S. (2015). Mobile Augmented reality in Vocational Education and Training. Procedia Computer Science, 75(Vare), 49–58.

Badilla-Quintana, M. G., Sepulveda-Valenzuela, E., & Arias, M. S. (2020). Augmented reality as a sustainable technology to improve academic achievement in students with and without special educational needs. Sustainability (Switzerland), 12(19).

Ballav, A., & Ghosh, M. (2017). Human factors of human machine interaction: analyzing future trends through the past and the present. International Journal of Research, 4(7), 138–144.

Balog, A., & Pribeanu, C. (2010). The role of perceived enjoyment in the students' acceptance of an augmented reality teaching platform: A structural equation modelling approach. Studies in Informatics and Control, 19(3), 319–330.

Bangse K, Wibolo A and Wiryanta I K. (2020). Design and Fabrication of a CNC Router Machine for Wood Engraving (Journal of Physics: Conference Series) vol 1450 pp 1–7

Berg, L. P., & Vance, J. M. (2017). Industry use of virtual reality in product design and manufacturing: a survey. Virtual Reality, 21(1), 1–17.

Berlin, C., & Adams, C. (2017). Production Ergonomics: Designing Work Systems to Support.

Bernstein, B. (2000). Pedagogy, symbolic control, and identity: Theory, research, critique (Vol. 5). Rowman & Littlefield

Bharath, V. G., & Rajashekar, P. (2015). Virtual manufacturing: a review. National Conference Emerging Research Areas Mechanical Engineering Confrence Proceedings, 3(March 2015), 355–364.

Bhoyrub, J., Hurley, J., Neilson, R., Ramsay, M., & Smith, M. (2010). Heutagogy: An alternative practice based learning approach. Nurse Education in Practice, 10, 322–326

Blaschke L.M., Hase S. (2016) Heutagogy: A Holistic Framework for Creating Twenty-First-Century Self-determined Learners. In: Gros B., Kinshuk, Maina M. (eds) The Future of Ubiquitous Learning. Lecture Notes in Educational Technology. Springer, Berlin, Heidelberg.

Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. International Review of Research in Open and Distance Learning, 13(1), 56–71.

Bond T.G and Fox C.M, (2007). Applying The Rasch Model: Fundamental Measurement in Human Science. London: Lawrence Erlbaum Associates.

Boral, P. (2019). The design of the CNC milling machine. MATEC Web of Conferences, 254, 01003.

Brecher, C., Wiesch, M., & Wellmann, F. (2019). Productivity Increase - Model-based optimisation of NC-controlled milling processes to reduce machining time and improve process quality. IFAC-PapersOnLine, 52(13), 1803–1807.

Bröhl, C., Nelles, J., Brandl, C., Mertens, A., & Schlick, C. M. (2016). TAM reloaded: A technology acceptance model for human-robot cooperation in production systems. Communications in Computer and Information Science, 617(July), 97–103.

Burrus, B. D. (2012). Gamification: A trend to accelerate learning. Toledo Business Journal, December I (567), 6–9.

Buzko, I., Dyachenko, Y., Petrova, M., Nenkov, N., Tuleninova, D., & Koeva, K. (2016). Artificial Intelligence technologies in human resource development Artificial Intelligence technologies in human resource development. July.).

Canning, N. & Callan, S. (2010). Heutagogy: Spirals of reflection to empower learners in higher education. Reflective Practice, 11(1), 71-82.

Carrier, S. I., & Moulds, L. D. (November 2003). Pedagogy, andragogy, and cybergogy: exploring best-practice paradigm for online teaching and learning. Paper presented at the the 9th Annual Sloan-C/ALN (Asynchronous Learning Networks) Conference, Orlando, Florida.

Caupin. (2006). ICB – IPMA Competence Baseline. International Project Management Association.

Chardonnet, J., Fromentin, G., Outeiro, J., Chardonnet, J., Fromentin, G., Outeiro, J., Chardonnet, J., Fromentin, G., & Outeiro, J. (2017). Augmented reality as an aid for the use of machine tools. February.

Chase, S. C., & Scopes, L. (2012). Cybergogy as a framework for teaching design students in virtual worlds. Digital Physicality - Proceedings of the

30th ECAADe Conference, Prague, 12-14 September 2012, 1(September 2012), 125–133.

Chatterjee, “Spindle deflections in high-speed machine tolos: modelling and simulation,” International Journal of Advanced Manufacturing Technology., vol. 11, no. 4, pp.232-239, 1996.

Chavan, S. R. (2016). Augmented reality vs. Virtual Reality: Differences and Similarities. In International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) (Vol. 5).

Chen, J., Yang, J., Zhou, H., Xiang, H., Zhu, Z., Li, Y., Lee, C. H., & Xu, G. (2015). CPS Modeling of CNC Machine Tool Work Processes Using an Instruction-Domain Based Approach. Engineering.

Chen, S., Chen, M., & Lyu, J. (2019). Design of Intelligent Medicine Box for Elderly People Based on Context Awareness and FAST Theory. IOP Conference Series: Materials Science and Engineering, 573(1).

Chen, Y., Wang, Q., Chen, H., Song, X., Tang, H., & Tian, M. (2019). An overview of augmented reality technology. Journal of Physics: Conference Series, 1237(2).

Christensen and Raynor. The Innovator’s Solution: Creating and Sustaining Successful Growth, Harvard University Press, Cambridge, MA. ISBN: 978-1578518524, 2003

Chryssolouris, G., Mavrikios, D., Rentzos L., The Teaching Factory: A Manufacturing Education Paradigm. Procedia CIRP Keynote paper of the 49th CIRP Conference on Manufacturing Systems, (2016) 44-48.

Chung, R., & Wu, C. (2011). The Identification of Personnel Director’ S Competency Profile Through The Use of the Job Competence Assessment Method. African Journal of Business Management, 5(2), 405–415

Couldry, N. and Hepp, A. 2017. The Mediated Construction of Reality. Cambridge: Polity Press

Czerniak, J. N., Brandl, C., & Mertens, A. (2017). Designing human-machine interaction concepts for machine tool controls regarding ergonomic requirements. IFAC-PapersOnLine, 50(1), 1378–1383.

D. A. Dornfeld, The Path of Precision: Machine Tools and the Products They Create, First. Mori Seiki Co., Ltd., 2008

D. A. Syah and A. Nuryanto, “Pencapaian Kompetensi Siswa pada Pembelajaran Praktik Beragam Kompetensi Teknik Pemesinan,” J. Pendidik. Vokasional Tek. Mesin, vol. 7, no. 3, pp. 169–178, 2019.

Damiani, L., Demartini, M., Guizzi, G., Revetria, R., & Tonelli, F. (2018). Augmented and virtual reality applications in industrial systems: A

qualitative review towards the industry 4.0 era. IFAC-PapersOnLine, 51(11), 624–630.

Davis, F.D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Q. 1989, 13, 319–340. [CrossRef]

De Wit, P. A. J. M., & Moraes Cruz, R. (2019). Learning from AF447: Human-machine interaction. Safety Science, 112(October 2018), 48–56.

Deans M. 2021, CNC Milling Coordinate System Made Easy, Autodesk.com

Deterding, S., Dixon, D., Khaled, R., &Nacke, L. (2011). "From game design elements to gamefulness: defining gamification". In Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments (pp. 9-15). ACM.

Devedzic, G., Ghionea, I. G., Fiorentino, M., Di Bari, P., Cukovic, S., Ghionea, I., & Subburaj, K. (2016). Engineering Design Education for Industry 4.0: Implementation of Augmented reality Concept in Teaching CAD Courses.

Di Serio, Á, Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. Computers & Education, 68, 586–596.

Dillon, A. (2006). User Interface Design. Encyclopedia of Cognitive Science,

Dilshad E, Ashfaq U, Ashick, Shaheem M V, Alfaz P and Sarbas M M. (2018). Fabrication of Three Axis CNC Milling Machine (International Journal of Innovative Science and Research Technology) vol 3 no 5 pp 548–551

Dong S. Progress and challenge of human-computer interaction. Journal of Computer-Aided Design and Computer Graphics; 2004, 16(1):1-13.

E. Alostad, & Aziz, F. A. (2018). Augmented reality Application in Maintenance Process and Inspection for Automotive Industry, Journal of fundamental and applied sciences. In Journal of Fundamental and Applied Sciences (Vol. 10, Issue 5S).

Elisa D. Mekler, Florian Brühlmann, Alexandre N. Tuch, Klaus Opwis, Towards understanding the effects of individual gamification elements on intrinsic motivation and performance,Computers in Human Behavior,Volume 71,2017,Pages 525-534,ISSN 0747-5632

Elshafey, A., Saar, C. C., Aminudin, E. B., Gheisari, M., & Usmani, A. (2020). Technology acceptance model for augmented reality and building information modeling integration in the construction industry. Journal of Information Technology in Construction, 25(August 2018), 161–172.

Faieza Abdul Aziz, Adel S.M.A Alsaeed, Shamsuddin Sulaiman, Mohd Khairol Anuar Mohd Ariffin & Muhammad Faris Al-Hakim, Mixed Reality Improves

Education and Training in Assembly Processes, J. Eng. Technol. Sci., Vol. 52, No. 4, 2020, 598-607

Fast-Berglund, Å, Gong, L., & Li, D. (2018). Testing and validating Extended Reality (xR) technologies in manufacturing. Procedia Manufacturing, 25, 31–38.

Ferrer, V., Perdomo, A., Rashed-Ali, H., Fies, C., & Quarles, J. (2013). How does usability impact motivation in augmented reality serious games for education? In 2013
164 5th International Conference on Games and Virtual Worlds for Serious Applications, VS-GAMES 2013. doi:10.1109/VS-GAMES.2013.6624233

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.

Fishbein, M.; Ajzen, I. Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research; Addison-Wesley: Reading, MA, USA, 1975.

Fisher, C. (2007). Researching and Writing a Dissertation: A Guidebook for Business Students. Financial Times Prentice Hall: Intervarsity Press.

Froyd JE, Wankat PC, Smith KA. Five Major Shifts in 100 Years of Engineering Education. Proceedings of the IEEE 2012; 1344-1360.

Gardecki, A., Podpora, M., & Kawala-Janik, A. (2018). Innovative Internet of Things-reinforced Human Recognition for Human-Machine Interaction Purposes. IFAC-PapersOnLine, 51(6), 138–143.

Gartner Inc (2011). Gartner's 2011 Hype Cycle Special Report Evaluates the Maturity of 1,900 Technologies.
https://www.businesswire.com/news/home/20110810005551/en/Gartners-2011-Hype-Cycle-Special-Report-Evaluates-the-Maturity-of-1900-Technologies

Gautham, G.R., Suresh, M., &Ranganathan, R. (2018). Factors affecting human performance in lathe machine shop operations. International Journal of Engineering and Technology (UAE), 7, 882–885.

Grajewski, D., Górski, F., Zawadzki, P., & Hamrol, A. (2013). Application of virtual reality techniques in design of ergonomic manufacturing workplaces. In Procedia Computer Science

Grant, C. & Osanloo, A. (2014). Understanding, Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for 'House'. Administrative Issues Journal: Connecting Education, Practice and Research, Pp. 12-22

Grech, A. and Camilleri, A. F. 2017. Blockchain in Education. https://ec.europa.eu/jrc/en/publication/eurscientific-and-technical-research-reports/blockchain-education

Greenbaum, N. R., Jernite, Y., Halpern, Y., Calder, S., Nathanson, L. A., Sontag, D. A., & Horng, S. (2019). Improving documentation of presenting problems in the emergency department using a domain-specific ontology and machine learning-driven user interfaces. International Journal of Medical Informatics, 132(July), 103981.

Gregori, F., Papetti, A., Pandolfi, M., Peruzzini, M., & Germani, M. (2017). Digital Manufacturing Systems: A Framework to Improve Social Sustainability of a Production Site. Procedia CIRP, 63, 436–442

Grigoriev, S. N., Fedorov, S. V., & Hamdy, K. (2019). Materials, properties, manufacturing methods and cutting performance of innovative ceramic cutting tools - A review. Manufacturing Review, 6.

Gu, J., Agapiou, J. S., & Kurgin, S. (2015). CNC machine tool work offset error compensation method. Journal of Manufacturing Systems, 37, 576–585.

Ha J, Cho K, Rojas FA, Yang HS (2011) Real-Time Scalable Recognition and Tracking based on the Server–Client Model for Mobile Augmented reality. Proceedings IEEE 1st International Symposium on Virtual Reality Innovation 2011 (ISVRI 2011), 2011 March 19–20, Singapore, 267–272.

Habibi, H., Jumadi, J., & Mundilarto, M. (2019). The rasch-rating scale model to identify learning difficulties of physics students based on self-regulation skills. International Journal of Evaluation and Research in Education, 8(4), 659–665.

Haider, S. (2006). Milling Machine. Validation Standard Operating Procedures, 345–347.

Halamek, L. P., Cady, R. A. H., & Sterling, M. R. (2019). Using briefing, simulation and debriefing to improve human and system performance. Seminars in Perinatology, 43(8), 151178.

Hanafi, N.M., Rahman, A.A., Mukhtar, M.I., Ahmad, J., & Warman, S. (2014). Validity and Reliability of Competency Assessment Implementation (CAI) Instrument Using Rasch Model. World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 8, 162-167.

He, Y., Chen, Q., & Kitkuakul, S. (2018). Regulatory focus and technology acceptance: Perceived ease of use and usefulness as efficacy. Cogent Business and Management, 5(1).

Heen Chen, Kaiping Feng, Chunliu Mo, Siyuan Cheng, Zhongning Guo and Yizhu Huang, "Application of Augmented reality in Engineering Graphics

Education," 2011 IEEE International Symposium on IT in Medicine and Education, 2011, pp. 362-365.

Hentati, A., Forsell, E., Ljótsson, B., Kaldo, V., Lindefors, N., & Kraepelien, M. (2021). The effect of user interface on treatment engagement in a self-guided digital problem-solving intervention: A randomized controlled trial. Internet Interventions, 26(May).

Ho, P.-C., Chung, S.-M., & Lin, Y.-H. (2012). Influences on children's visual cognition capabilities through playing "intelligent matrix" developed by the augmented virtual reality technology. International Journal of Humanities and Arts Computing, 6(1-2), 160–171.

Holden, H., & Rada, R. (2011). Understanding the influence of perceived usability and technology self-efficacy on teachers' technology acceptance. Journal of Research on Technology in Education, 43(4), 343–367.

https://technologystudent.com/cam/cnc1.htm

https://www.boxford.co.uk/cnc-vertical-milling-machines

https://www.cnc1.com/hubfs/fanuc-library/Fanuc_Series_16i_18i_21i_Model_B.pdf

Hubert, M., Blut, M., Brock, C., Zhang, R. W., Koch, V., & Riedl, R. (2019). The influence of acceptance and adoption drivers on smart home usage. European Journal of Marketing, 53(6), 1073–1098.

Hwa Jen Yap, Yun Suen Pai, S.-W. C. & K. S. Y. (2016). Development of an Augmented reality-Based G-Code Generator in a Virtual CNC Milling Simulation. International Journal of Computer Science and Engineering (IJCSE), 5(2), 63–72.

Iftene, A., & Trandabăt, D. (2018). Enhancing the Attractiveness of Learning through Augmented reality. Procedia Computer Science, 126, 166–175.

ILO, & UNESCO. (2020).The digitization of TVET and skills systems. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_752213.pdf

Imenda, S. (2014). Is there a conceptual difference between theoretical and conceptual frameworks? Journal of Social Sciences, 38(2):185-195.

International Organization for Standardization (ISO), Standard 6893.

ISO 9241-11:2018, Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts, I. 159/SC 4 E. of human-system interaction.

ISO 9241-210. Ergonomics of human-system interaction — Part 210: Humancentred design for interactive systems. International Organization for Standardization, 2010

J. S. Ha, and P. H. Seong, “A human-machine interface evaluation method: a difficulty evaluation method in information searching (demis),” Reliability Engineering & System Safety, vol. 94, no.10, pp. 1557-1567, 2009

Jacob, E. R., Duffield, C., & Jacob, A. M. (2019). Validation of data using RASCH analysis in a tool measuring changes in critical thinking in nursing students. Nurse Education Today, 76, 196–199.

Jakob, M., & Geyer, M. (2006). The Influence of Machine Speed on Human Performance for Simple and Highly Repetitive Work Processes: A pilot study. Agricultural Engineering International: CIGR Ejournal, January.

John J. Dudley and Per Ola Kristensson. 2018. A Review of User Interface Design for Interactive MachineLearning.ACM Trans. Interact. Intell. Syst.8, 2, Article 8 (June 2018)

Juraschek, M., Büth, L., Posselt, G., & Herrmann, C. (2018). Mixed Reality in Learning Factories. Procedia Manufacturing, 23(2017), 153–158.

Kaindl, H. (2020). Human-machine interaction. Advances in Intelligent Systems and Computing, 1018(04), 428–433.

Kang, H. J., Chung, K. W., & Nam, K. Y. (2015). A competence model for design managers: A case study of middle managers in Korea. International Journal of Design, 9(2), 109–127.

Karagiannis, P., Togias, T., Michalos, G., & Makris, S. (2020). Operators Training Using Simulation and VR Technology. Procedia CIRP, 96, 290–294.

Karaguzel, U., Uysal, E., Budak, E., & Bakkal, M. (2016). Effects of tool axis offset in turn-milling process. Journal of Materials Processing Technology, 231, 239–247.

Ke, Q., Liu, J., Bennamoun, M., An, S., Sohel, F., & Boussaid, F. (2018). Computer Vision for Human–Machine Interaction. Computer Vision for Assistive Healthcare, 127–145.

Khalifa, F. A., Semary, N. A., El-Sayed, H. M., & Hadhoud, M. M. (2016). Markerless tracking for augmented reality using different classifiers. Advances in Intelligent Systems and Computing, 407(November), 25–35.

Khan L A, Mehtab U, Hasan E U and Hussain Z. (2014). Design and Fabrication of a CNC Machine for Engraving and Drilling (International Interdisciplinary Journal of Scientific Research) vol 1, no 3, pp 1–7

Khan, I. A. (2014). Multi-Response Ergonomic Evaluation of Higher Age Group CNC Machine Operators. In Journal of Engineering Research and Applications www.ijera.com (Vol. 4, Issue 8).

Khatib, M., Al Khudir, K., & De Luca, A. (2021). Human-robot contactless collaboration with mixed reality interface. Robotics and Computer-Integrated Manufacturing, 67(August 2020), 102030.

Kimberlin, C.L., & Winterstein, A.G. (2008). Validity and reliability of measurement instruments used in research. American journal of health-system pharmacy: AJHP: official journal of the American Society of Health-System Pharmacists, 65 23, 2276-84.

Klimova, A., Bilyatdinova, A., & Karsakov, A. (2018). Existing Teaching Practices in Augmented reality. Procedia Computer Science, 136, 5–15.

Koivisto, J., & Hamari, J. (2019). The rise of motivational information systems: A review of gamification research. International Journal of Information Management, 45, 191–210.)

Kuric, I., Cisar, M., Zajacko, I., & Gal, T. (2018, April). Diagnostics of the wire coating production line by implementation of computation methods. In 2018 5th International Conference on Industrial Engineering and Applications (ICIEA) (pp. 463-467). IEEE.

Lamngeun, V. (2004). Lathe Machines. Manufacturing Processes, 49–91

Latham, J. (2017). Conceptual Framework. http://johnlatham.me/frameworks/ research- methods-framework/conceptual-framework/

Lathan, C. (2017) Enabling Ability: The Future of Human-Machine Interaction, https://www.smithsonianmag.com/videos/enabling-ability-the-future-of-human-machine

Legaki, N. Z., Xi, N., Hamari, J., Karpouzis, K., & Assimakopoulos, V. (2020). The effect of challenge-based gamification on learning: An experiment in the context of statistics education. International Journal of Human Computer Studies, 144(November 2019).

Lemay, D.J., Morin, M.M., Bazelais, P., & Doleck, T. (2018). Modeling Students' Perceptions of Simulation-Based Learning Using the Technology Acceptance Model. Clinical Simulation in Nursing, 20, 28-37.

Lemon, C., Huckvale, K., Carswell, K., & Torous, J. (2020). A Narrative Review of Methods for Applying User Experience in the Design and Assessment of Mental Health Smartphone Interventions. International Journal of Technology Assessment in Health Care, 36(1), 64-70.

Leopardi, A., Ceccacci, S., Mengoni, M., Naspetti, S., Gambelli, D., Ozturk, E., & Zanoli, R. (2021). X-reality technologies for museums: a comparative evaluation based on presence and visitors experience through user studies. Journal of Cultural Heritage, 47, 188–198.

Li, Y., Hedlind, M., & Kjellberg, T. (2015). Usability evaluation of CADCAM: State of the art. Procedia CIRP.

Lin, C. (2013). Exploring the relationship between technology acceptance model and usability test. Information Technology and Management, 14, 243-255.

Lin, M. H., Chen, H. C., & Liu, K. S. (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.

Lin, P. W. (2018). Design and Fabrication of a Small-Scale CNC Milling Machine. International Journal of Scientific & Engineering Research, 9(8), 1204–1209.

Lindberg, T., Nasanen, R. and Muller, K. (2006). How age affects the speed of perception of computer icons. Journal of Displays, 27(4-5), 170-177

Liu, C., & Xu, X. (2017). Cyber-physical Machine Tool – The Era of Machine Tool 4.0. Procedia CIRP, 63, 70–75.

Liu, M., Huang, Y., & Zhang, D. (2018). Gamification's impact on manufacturing: Enhancing job motivation, satisfaction and operational performance with smartphone-based gamified job design. Human Factors and Ergonomics in Manufacturing, 28(1), 38–51.

Liu, P., Lu, L., Liu, S., Xie, M., Zhang, J., Huo, T., Xie, Y., Wang, H., Duan, Y., Hu, Y., & Ye, Z. (2021). Mixed reality assists the fight against COVID-19. Intelligent Medicine, 1(1), 16–18.

Lotti, G., Villani, V., Battilani, N., & Fantuzzi, C. (2019). Peer review under responsibility of International Federation of Automatic Control.

Lupton, D. (2016). "The Quantified Self". John Wiley &Sons.

Luse, A., Mennecke, B., & Townsend, A. (2012). Selecting a Research Topic: A Framework for Doctoral Students. International Journal of Doctoral Studies, 7, 143-152.

Lynch Mike (2019), https://www.cncci.com/post/the-basics-of-computer-numerical-control

Lyu, Y. (2019). Using Gamification and Augmented reality to Encourage Japanese Second Language Students to Speak English.

M. Sailer, J. Hense, H. Mandl, and M. Klevers, "Fostering development of work competencies and motivation via gamification". In Competence-based vocational and Professional Education pp. 795-818. Springer, Cham, 2017.

Ma, X., Tao, F., Zhang, M., Wang, T., & Zuo, Y. (2019). Digital twin enhanced human-machine interaction in product lifecycle. Procedia CIRP, 83, 789–793.

Ma, Z. Y., Chen, Y. P., Yuan, C. M., & Zhou, Z. D. (2006). An Efficient 3D Registration Method Using Markerless Image in AR-Based CNC Machining Simulation.

Manjunatha C J, Manjunath K and Suresha P. (2015). Design and Development of Portable Milling Machine (International Journal of Innovation in Engineering, Research and Technolog, 15, Conference Proceedings) pp 1–6

Mara Kaufeld, Martin Mundt, Sarah Forst, Heiko Hecht. (2022),Optical see-through augmented reality can induce severe motion sickness,Displays,Volume 74,2022,102283,ISSN 0141-9382,

Marache-Francisco, C., & Brangier, E. (2015). Gamification and human-machine interaction: A synthesis. Travail Humain, 78(2), 165–189.

Marc, J. R. (2002). Book review: e-learning strategies for delivering knowledge in the digital age. Internet and Higher Education, 5, 185-188.

Marope, P., Chakroun, B., & Holmes, K. (2015). Unleashing the potential: Transforming technical and vocational education and training. Paris, France: UNESCO

Martinetti, A., Rajabalinejad, M., & van Dongen, L. (2017). Shaping the Future Maintenance Operations: Reflections on the Adoptions of Augmented reality through Problems and Opportunities. Procedia CIRP, 59, 14–17.

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual technologies trends in education. Eurasia Journal of Mathematics, Science and Technology Education, 13(2), 469–486.

Martinov, G. M., Kozak, N. V, Nezhmetdinov, R. A., Grigoriev, A. S., Obukhov, A. I., & Martinova, L. I. (2017). Method of decomposition and synthesis of the custom CNC systems. Automation and Remote Control, 78(3), 525–536.

McFarlane D, Sarma S, Chirn JL, Wong CY, Ashton K. Auto ID systems and intelli-gent Manufacturing control. EngAppl. Artif Intel 2003; 16(4):365–76.

Mekni, M., & Lemieux, A. (2014). Augmented reality: Applications, Challenges and Future Trends.

Mikhail, M., Mithani, K., & Ibrahim, G. M. (2019). Presurgical and Intraoperative Augmented reality in Neuro-Oncologic Surgery: Clinical Experiences and Limitations. World Neurosurgery, 128, 268–276.

Miles, M. B., & Huberman, A. M. (1994). Qualitative Data Analysis: An Expanded Source Book (2nd ed.). Newbury Park, CA: Sage.

Milgram, P. & Kishino, F. (1994). 'A taxonomy of mixed reality visual displays'. IEICE Transactions on Information Systems, Vol. E77-D, No.12 Dec. 1994.

Ministry of Higher Education. (2017). Technical Vocational Education & training (TVET) in Malaysia: Selected Works. In Ministry of Higher Education (Issue January). http://mycc.my/document/files/PDF Dokumen/Technical Vocational Education Training (TVET) in Malaysia Selected Works.pdf

Minoufekr, M., Schug, P., Zenker, P., & Plapper, P.W. (2019). Modelling of CNC Machine Tools for Augmented reality Assistance Applications using Microsoft Hololens. ICINCO.

Mohamed Noor, N., Yusoff, F. H., Lob Yussof, R., & Ismail, M. (2015). The Potential Use of Augmented reality in Gamification. Proceeding of International Conference on Computing and Informatics, 048, 159–167.

Monika, T., Pollák, M., Jozef, T., Marek, K., & Jakub, K. (2020). Augmented reality as a support tool in machining process. TEM Journal, 9(1), 407–411.

Mora, A., Riera, D., González, C., & Arnedo-Moreno, J. (2017). Gamification: a systematic review of design frameworks. Journal of Computing in Higher Education, 29(3), 516–548.

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.

Muhammad Saleem, Suzilawati Kamarudin, Haneen Mohammad Shoaib & Asim Nasar (2021) Retail Consumers' Behavioral Intention to Use Augmented reality Mobile Apps in Pakistan, Journal of Internet Commerce.

Munadi, S., Choiron, Z., Harjanto, C. T., & Ardhantano, R. (2020). The achievement of competency standards for machining graduates. Journal of Physics: Conference Series, 1700(1).

Mur-Artal, R.; Montiel, J.M.M.; Tardos, J.D. ORB-SLAM: A Versatile and Accurate Monocular SLAM System. IEEE Trans. Robot. 2015, 31, 1147–1163. [CrossRef]

Muresan, M. (2014). Using Cybergogy and Andragogy Paradigms in Lifelong Learning. Procedia-Social and Behavioral Sciences, 116, 4722–4726.

Natanson E. (2021), https://www.forbes.com/sites/eladnatanson/2021/06/01/play-to-pay-gamification-is-the-future-of-retail-apps/?sh=600039732092

Nazir B. Tamboli (2016), http://www.tambolieng g.com/cnc-turned-components/most-commonly-facedcnc-machine-problems

Nee, A. Y. C., & Ong, S. K. (2013). Virtual and Augmented reality Applications in Manufacturing. IFAC Proceedings Volumes, 46, 15–26.

Nekrasov, R., Putilova, U., & Tempel, Y. (2018). Precision CNC machining and ways to achieve it. MATEC Web of Conferences, 224.

Neugebauer, R., Klimant, P. and Witt M. 2012. Realistic Machine Simulation with Virtual Reality. Procedia CIRP, 2012. 3(0), 103-108.

Nghiep, T. N., Sarhan, A. A. D., & Aoyama, H. (2018). Analysis of tool deflection errors in precision CNC end milling of aerospace Aluminum 6061-T6 alloy.

Nguyen, D., & Meixner, G. (2019). Gamified augmented reality training for an assembly task: A study about user engagement. Proceedings of the 2019 Federated Conference on Computer Science and Information Systems, FedCSIS 2019, 18, 901–904.

Novak-Marcincin. (2013). Application of Augmented reality Technologies in Virtual Manufacturing in Scientific Papers Academic Journal of Manufacturing Engineering (Vol. 11).

Olszewski, R., Gnat, M., Trojanowska, H., Turek, A., & Wieladek, A. (2018). Towards social fuzzy geoparticipation stimulated by gamification and augmented reality. ICNC-FSKD 2017 - 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery, 1363–1370.

Omran, A., & Suleiman, A. S. H. (2017). Identifying the Competence Components of theConstruction Project Managers in the Palestinian Construction Industry. The Engineering Project Organization Journal, 7(2)

Onirix (2019), https://www.onirix.com/learn-about-ar/the-best-augmented-reality-hardware-in-2019/

Osman, S. A., Naam, S. I., Omar, M. Z., Jamaluddin, N., Kofli, N. T., Ayob, A., & Johar, S. (2013). Employer Perceptions of Student Ability during Industrial Training as Assessed by the Rasch Model. Procedia - Social and Behavioral Sciences, 102, 134–140.

Paliokas, I., Patenidis, A. T., Mitsopoulou, E. E., Tsita, C., Pehlivanides, G., Karyati, E., Tsafaras, S., Stathopoulos, E. A., Kokkalas, A., Diplaris, S., Meditskos, G., Vrochidis, S., Tasiopoulou, E., Riggas, C., Votis, K., Kompatsiaris, I., & Tzovaras, D. (2020). A gamified augmented reality application for digital heritage and tourism. Applied Sciences (Switzerland), 10(21), 1–18.

Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2021). Measuring user experience, usability and interactivity of a personalized mobile augmented reality training system. Sensors, 21(11).

Papakostas, C.; Troussas, C.; Krouska, A.; Sgouropoulou, C. User acceptance of augmented reality welding simulator in engineering training. Educ. Inf. Technol. 2021.

Pappalardo, L., Cintia, P., Pedreschi, D., Giannotti, F., & Barabasi, A.-L. (2017). Human Perception of Performance. December. http://arxiv.org/abs/1712.02224

Paravizo, E., Chaim, O., Braatz, D., Muschard, B., & Rozenfeld, H. (2018). Exploring gamification to support manufacturing education on industry 4.0 as an enabler for innovation and sustainability. Procedia Manufacturing, 21, 438-445.

Paryanto, F. Hidayat, and C. T. Harjanto, “Implementation of problem-based learning to improve student learning achievement in turning machining lesson,” J. Phys. Conf. Ser., vol. 1446, no. 1, 2020,

Pease, W. (1952). An Automatic Machine Tool. Scientific American, 187(3), 101–112.

Ping, L., & Liu, K. (2020). Using the Technology Acceptance Model to Analyze K-12 Students’ Behavioral Intention to Use Augmented reality in Learning. Texas Education Review, 8(2), 37–51.

Planinic, M., Boone, W. J., Susac, A., & Ivanjek, L. (2019). Rasch analysis in physics education research: Why measurement matters. Physical Review Physics Education Research, 15(2), 20111.

Prashil, M., Patel, N., Shreyas, M., Pavagadhi, D., & Acharya, S. G. (2019). Design and Development of Portable 3-Axis CNC Router Machine. International Research Journal of Engineering and Technology, 1452–1455.

Pürzel, F., Klimant, P., Wittstock, V., & Kuhl, M. (2013). Real NC control unit and virtual machine to improve operator training. Procedia Computer Science.

Qeshmy, D. E., Makdisi, J., Ribeiro da Silva, E. H. D., & Angelis, J. (2019). Managing Human Errors: Augmented reality systems as a tool in the quality journey. Procedia Manufacturing, 28, 24–30.

Ragni, M., Perini, M., Setti, A., & Bosetti, P. (2018). ARTool Zero: Programming trajectory of touching probes using augmented reality.

Rajput, R., & Sarathe, A. K. (2016). Comparative Study of CNC Controllers used in CNC Milling Machine American Journal of Engineering Research (AJER). 62(4), 54–62.

Rapp, A., Hopfgartner, F., Hamari, J., Linehan, C., & Cena, F. (2019). Strengthening gamification studies: Current trends and future opportunities of gamification research. International Journal of Human Computer Studies, 127(July), 1–6.

Rauschnabel, P. A., Brem, A., & Ro, Y. K. (2015). Augmented reality Smart Glasses: Definition, Conceptual Insights, and Managerial Importance. -, 313, 1–21.

Ravinder Reddy, N., Satyanarayana, V. V., Jagadesh Kumar, J., & Sreeram Reddy, G. (2020). Gamification technique in engineering education to

improve learnability. Journal of Engineering Education Transformations, 33(Special Issue), 147–149.

Ravitch, S. M. & Carl, N. M. (2016). Qualitative Research: Bridging the Conceptual, Theoretical and Methodological. Los Angeles, U.S.A.: SAGE Publications, Inc.

Razak, I. H. A., Kamaruddin, S., & Azid, I. A. (2011). Towards human performance measurement from the maintenance perspective: a review. International Journal of Engineering Management and Economics, 2(1), 60.

Rebbani, Z. (2021). Definitions and Applications of Augmented/Virtual Reality: A Survey. International Journal of Emerging Trends in Engineering Research, 9(3), 279–285.

Reintjes J. F., 1991, Numerical control: Making a new Technology," Oxford University Press, New York, USA

Reis, A. C. B., Júnior, E. S., Gewehr, B. B., & Torres, M. H. (2020). Prospects for using gamification in industry 4.0. Production, 30.

Riener, A. (2017). Chapter 19 - Subliminal Perception or "Can We Perceive and Be Influenced by Stimuli That Do Not Reach Us on a Conscious Level?" (M. B. T.-E. and A. in H. F. and H.-C. I. Jeon (ed.); pp. 503–538). Academic Press.

Rienties, B., & Rivers, B. A. (2014). Measuring and Understanding Learner Emotions: Evidence and Prospects. In: LACE review papers. Milton Keynes: LAC

Riley C. (2020) Manufacturing Skills Training Builds Pipeline for In-Demand Trades, Mstercam Education

Rohidatun, M. W., Faieza, A. A., Rosnah, M. Y., & Hayati, S. N. (2017). Develop a Virtual and Augmented reality System to Enhance Learning and Training Assembly. Journal of Computational and Theoretical Nanoscience, 14(11), 5617–5620.

Ronald T. Azuma; A Survey of Augmented reality. Presence: Teleoperators and Virtual Environments 1997; 6 (4): 355–385.

Ronquillo. R (2021), https://www.thomasnet.com/articles/custom-manufacturing-fabricating/understanding-cnc-milling

Rubin J. & Chisnell D. (2008) Handbook of usability testing: how to plan, design and conduct effective tests. (John Wiley & Sons, 2008).

Saifudin, M., Abd. Aziz, A., Rodzo'an, N. A., Omar, M.Z., Zaharim, A. & Basri, H. (2010). Easier Learning Outcomes Analysis using Rasch Model in Engineering Education Research. EDUCATION'10 Proceedings of the 7th WSEAS International Conference on Engineering Education (pp 442-447).

Salman, A., & Abd.aziz, A. (2015). Evaluating user Readiness towards Digital Society: A Rasch Measurement Model Analysis. Procedia Computer Science, 65(Iccmit), 1154–1159.

Santi, G. M., Ceruti, A., Liverani, A., & Osti, F. (2021). Augmented reality in Industry 4.0 and Future Innovation Programs. Technologies, 9(2), 33.

Schroeter, R., Oxtoby, J., & Johnson, D. (2014). AR and gamification concepts to reduce driver boredom and risk taking behaviours. In Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 1–8).

Segovia, D., Ramírez, H., Mendoza, M., Mendoza, M., Mendoza, E., & González, E. (2015). ScienceDirect Machining and Dimensional Validation Training using Augmented reality for a Lean Process. Procedia - Procedia Computer Science, 75, 195–204.

Sequeira, A. H. (2012). Introduction to Concepts of Teaching and Learning. SSRN Electronic Journal, September 2012.

Shikalepo, E. E. (2020). Defining a Conceptual Framework in Educational Research Defining a Conceptual Framework in Educational Research. Namibia University of Science and Technology, 1(2), 1–8. Shikalepo, E.E. (2018). The influence of financial incentive on teacher motivation and learner performance in rural Namibian schools.

Shoubashy, H. El, Hatem, P., El, A., & Khalifa, N. (2020). What is Gamification? Literature Review of Previous Studies on Gamification. Australian Journal of Basic and Applied Sciences, 14(8), 29–51.

Siapera, E. 2018. Understanding New Media, 2nd edition. Thousand Oaks, CA: Sage Publishing.

Siew, C. Y., Ong, S. K., & Nee, A. Y. C. (2019). A practical augmented reality-assisted maintenance system framework for adaptive user support. Robotics and Computer-Integrated Manufacturing, 59, 115–129.

Siltanen, S. Texture generation over the marker area. In Proceedings of the ISMAR 2006: Fifth IEEE and ACM International Symposium on Mixed and Augmented reality, Santa Barbara, CA, USA, 22–25 October 2006; pp. 253–254. [CrossRef]

Sima, V., Gheorghe, I. G., Subić, J., & Nancu, D. (2020). Influences of the industry 4.0 revolution on the human capital development and consumer behavior: A systematic review. Sustainability (Switzerland), 12(10).

Sobral, J. (2018). Understanding Human Error in Industry. 7th International Symposium on Industrial Engineering, September.

Softtek (2021), https://softtek.eu/en/tech-magazine-en/user-experience-en/what-are-the-different-types-of-augmented-reality/

Soori, M., Arezoo, B., & Habibi, M. (2013). Dimensional and geometrical errors of three-axis CNC milling machines in a virtual machining system. Computer-Aided Design, 45(11), 1306–1313.

Stephenson D, Agapiou JS. Metal cutting theory and practice. 2nd ed. Boca Raton, FL: Taylor and Francis; 2006

Stepputat, M., Jagusch, K., Jericho, D., Sender, J., & Flügge, W. (2020). Component-dependent extended reality for assembly assistance for batch size 1. Procedia CIRP, 97, 361–366.

Stiegler A., Zimmermann G. (2015) Gamification and Accessibility. In: Zhou J., Salvendy G. (eds) Human Aspects of IT for the Aged Population. Design for Aging. ITAP 2015. Lecture Notes in Computer Science, vol 9193. Springer, Cham.

Sumintono, B. (2018). Rasch Model Measurements as Tools in Assesment for Learning.

Sung Youl Park. (2009). An Analysis of the Technology Acceptance Model in Understanding University Students' Behavioral Intention to Use e-Learning. Journal of Educational Technology & Society, 12(3), 150–162.

Tahar, A., Riyadh, H. A., Sofyani, H., & Purnomo, W. E. (2020). Perceived Ease of Use, Perceived Usefulness, Perceived Security and Intention to Use E-Filing: The Role of Technology Readiness. The Journal of Asian Finance, Economics and Business, 7(9), 537–547.

Tan, J., Rönkkö, K., & Gencel, Ç. (2013). A Framework for Software Usability and User Experience Measurement in Mobile Industry. 2013 Joint Conference of the 23rd International Workshop on Software Measurement and the 8th International Conference on Software Process and Product Measurement, 156-164.

Tang, A., Owen, C., Biocca, F., & Mou, W. (2003). Comparative effectiveness of augmented reality in object assembly. Conference on Human Factors in Computing Systems - Proceedings, January, 73–80.

Tao, D., Shao, F., Wang, H., Yan, M., & Qu, X. (2020). Integrating usability and social cognitive theories with the technology acceptance model to understand young users' acceptance of a health information portal. Health Informatics Journal, 26(2), 1347–1362.

Tarhini, A., Hone, K., & Liu, X. (2013). Extending the TAM model to empirically investigate the students' behavioural intention to use e-learning in developing countries. Proceedings of 2013 Science and Information Conference, SAI 2013, September, 732–737.

Teo, T., Ursavas, O. F., & Bahcekapili, E. (2011). Efficiency of the technology acceptance model to explain pre-service teachers' intention to use technology: A Turkish study. Campus-Wide Information Systems, 28(2), 93-101.

Thomas, A.S. (2012). . Constructing conceptual frameworks: Building the route. In: Sharon, F.R. & Gretchen, B.R. The research journey: Introduction to inquiry (pp. 89). New York: Guilford Publications.

Thorndike, E. L., Bregman, E. O., Tilton, J. W., & Woodyard, E. (1928). Adult Learning. New York: Macmillan.

Tom & Mary Norton (2021), https://tvetjournal.com/tvet-tools/tvet-digital-education

Tzimas, E., Vosniakos, G.-C., & Matsas, · Elias. (2008). Machine tool setup instructions in the smart factory using augmented reality: a system construction perspective. International Journal on Interactive Design and Manufacturing (IJIDeM).

Ulmer, J., Braun, S., Cheng, C., Dowey, S., & Wollert, J.F. (2020). Gamified Virtual Reality Training Environment for the Manufacturing Industry. 2020 19th International Conference on Mechatronics - Mechatronika (ME), 1-6.

Ulmer, J., Braun, S., Cheng, C., Dowey, S., & Wollert, J.F. (2020). Human-Centered Gamification Framework for Manufacturing Systems. Procedia CIRP, 93, 670-675.

Van Dijk LA, Van Der Berg GC, Van Keulen H. Interactive lectures in engineering education. European Journal of Engineering Education 2001; 26(1): 15-28.

Van Roy, R., Zaman, B., 2018. Unravelling the ambivalent motivational power of gami fication: a basic psychological needs perspective. Int. J. Hum. Comput. Stud.

Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. Information Systems Research, 11(4), 342-365.

Venkatesh, V., & Bala, H. (2008). Technology Acceptance Model 3 and a Research Agenda on Interventions. Decision Sciences, 39(2), 273-315.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management science, 46(2), 186-204

Vigneshrao, S., Karthik, S., Yuvaraj, C., Sudhakaran, M., & Scholar, U. G. (2017). Design of 3-Axis Computer Numerical Control (Cnc) Router Using Stepper Motor. International Journal of Global Engineering, 1(3), 46–55.

Wang S, Wan J, Zhang D, Li D, Zhang C. Towards smart factory for Industry 4.0: A self-organized multi-agent system with big data based feedback and coordination. Comput Netw 2016;101:158–68

Wang, M., & Kang, M. (2006). Chapter 11 Cybergogy for Engaged Learning: A Framework for Creating Learner Engagement Through Information. Learning, 225–253.

Weng, F., Yang, R. J., Ho, H. J., & Su, H. M. (2018). A tam-based study of the attitude towards use intention of multimedia among school teachers. Applied System Innovation, 1(3), 1–9.

Werbach, K., & Hunter, D. (2012). For the Win: How game thinking can revolutionize your business. Wharton Digital Press.

Whitson, J.R. (2013). “Gaming the quantified self”. Surveill. Soc. 11, 163–176.

Wickens, C.D., Hollands, J.G., Banbury, S., & Parasuraman, R. (2013). Engineering Psychology and Human Performance (4th ed.). Psychology Press.

Wiederkehr, P., & Siebrecht, T. (2016). Virtual Machining: Capabilities and Challenges of Process Simulations in the Aerospace Industry. Procedia Manufacturing, 6, 80–87.

Wild, F., Klemke, R., Lefrere, P., Fominykh, M., & Kuula, T. (2017). Technology acceptance of augmented reality and wearable technologies. Communications in Computer and Information Science, 725, 129–141.

Wong, S.-C. (2020). Competency Definitions, Development and Assessment: A Brief Review. International Journal of Academic Research in Progressive Education and Development, 9(3).

Wu, L., Li, C., Tang, Y., & Yi, Q. (2017). Multi-objective Tool Sequence Optimization in 2.5D Pocket CNC Milling for Minimizing Energy Consumption and Machining Cost. Procedia CIRP, 61, 529–534.

Yang, H., Zhang, J., Wang, Y., & Jia, R. (2021). Exploring relationships between design features and system usability of intelligent car human–machine interface [Formula presented]. Robotics and Autonomous Systems, 143, 103829.

Yasin, R. M., Yunus, F. A. N., Rus, R. C., Ahmad, A., & Rahim, M. B. (2015). Validity and Reliability Learning Transfer Item Using Rasch Measurement Model. Procedia - Social and Behavioral Sciences, 204(November 2014), 212–217.

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

Yip, J., Wong, S. H., Yick, K. L., Chan, K., & Wong, K. H. (2019). Improving quality of teaching and learning in classes by using augmented reality video. Computers and Education, 128(April 2018), 88–101.

Young, M.J. (2003) ‘Human performance model validation: one size does not fit all’, SummerComputer Simulation Conference, pp.732–735.

Yousefian, O., Balabokhin, A., & Tarbutton, J. (2020). Point-by-point prediction of cutting force in 3-axis CNC milling machines through voxel framework in digital manufacturing. Journal of Intelligent Manufacturing, 31(1), 215-226

Yuyin, W., & Yuhang, C. (2021). Influence of virtual imaging technology based on html5 technology on digital painting. Microprocessors and Microsystems, 82(December 2020), 103855.

Zahra, F., Hussain, A., & Mohd, H. (2017). Usability evaluation of mobile applications; Where do we stand? AIP Conference Proceedings, 1891(October).

Zaineldeen, S., Hongbo, L., Koffi, A. L., & Hassan, B. M. A. (2020). Technology acceptance model' concepts, contribution, limitation, and adoption in education. Universal Journal of Educational Research, 8(11), 5061–5071.

Zanatto, D., Chattington, M., & Noyes, J. (2021). Human-machine sense of agency. International Journal of Human Computer Studies, 156(September), 102716.

Zhang, F., Zhou, B., Liu, L., Liu, Y., Fung, H. H., Lin, H., & Ratti, C. (2018). Measuring human perceptions of a large-scale urban region using machine learning. Landscape and Urban Planning, 180(August), 148–160.

Zhang, J., Ong, S.K. and Nee, A.Y.C. (2012). Design and Development of an in situ Machining Simulation System using augmented reality technology. Procedia CIRP, 2012. 3(0), 185-190

Zhang, P. (2010). Advanced industrial control technology. William Andrew/Elsevier

Zhang, Y. (2020). Promoting user experience with gamified AR travel guide system for city tourism. 1–39.

Zhang, Y., & Kwok, T.-H. (2018). Design and Interaction Interface using Augmented reality for Smart Manufacturing. Procedia Manufacturing, 26, 1278–1286.

Zhiqiang, Z., Jun, T. Da, Xiaoming, D., Chong, N. K., Choon, S. S., & Choe, W. Y. (2020). Immersive Gamification Platform for Manufacturing Shopfloor Training. May.

Zichermann, G., & Cunningham, C. (2011). "Gamification by design: Implementing game mechanics in web and mobile apps". O'Reilly Media, Inc