International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 10, Issue 11, 2020

Development Design Augmented Reality-Based Jobsheet in CNC Programming Subjects

Febri Prasetya[a*], Bayu R. Fajri[b], Fadli Ranuharja[c], [a,b,c]Faculty of Engineering, Universitas Negeri Padang, Jl. Prof. Dr. Hamka, Air Tawar Bar., Kec. Padang Utara, Kota Padang, Sumatera Barat 25132, Indonesia, Email: [a*]febriprasetya@ft.unp.ac.id

Research and development of jobsheets based on augmented reality (AR) aims to support the implementation of student lectures on CNC programming subjects majoring in mechanical engineering at Universitas Negeri Padang. This research is a research & development (R & D) using the Four D development procedure with stages of define, design, develop and dissemination. The results showed that, at the Define stage, a needs analysis was carried out with the result that the development of AR-based jobsheets was appropriate as an effort and solution for the limited ability of students to learn about learning especially work drawings and machining processes on CNC machines. In the design phase, it shows that there are four contents contained in the jobsheet that is developed according to the needs of the AR jobsheet development. In the design phase, the AR jobsheet is designed by designing an application that can be installed on a smartphone. Whereas the develop phase showed that all aspects of the assessment met the validity standard, the AR jobsheet had high average practicality, and the AR jobsheet was considered effective in improving students' ability to understand work drawings and machining processes in CNC programming subject. Finally, at the dissemination stage, it is carried out through the implementation of the use of AR jobsheets in all CNC programming subject at Universitas Negeri Padang.

Key words: *Jobsheet, Augmented Reality, CNC Programming Subject.*

Introduction

History records that human civilisation is divided into periods. Each period has characteristics and differences with other periods. Nowadays, humans have entered the period of digitalisation, where the development of digital technology devices has been affiliated in all fields such as education, trade, law, culture, public service, art or better known as the era of the industrial revolution 4.0 (Kesici and Tunç 2018; Jalinus, Syahril and Nabawi, 2019). The industrial revolution 4.0 has brought a series of changes in human life (Roblek, Meško, and Krapež 2016; Rizal, et al. 2019). In the era of the industrial revolution, 4.0 requires a generation that is highly competitive, responsive and independent in various aspects. This era is marked by the existence of cyber-physical systems and has changed the way of human life in its scale, scope, and complexity, the transformation that is happening is different from what has been experienced by humans ever before (Suwardana 2018; Jalinus and Nabawi, 2018). At the same time, the presence of industrial revolution 4.0 not only opens up various opportunities for businesses, governments, and individuals to be more competitive but also brings challenges to the widening of the gap in the standard of living in community groups (Liao et al. 2017).

At present, Indonesia's competitiveness has only reached 45th out of 140 countries in the world (for 2018), with a value of 64.9, up 1.4 points from 2017. Indonesia's superiority is in the breadth of market share (rank 8th), culture entrepreneurship (rank 24th) and business dynamics (rank 30th). Even Indonesia is declared as "one of the most connected emerging economies", on a par with other developing countries. However, Indonesia's ability to innovate is still very low, research and development have not been much of the focus of Indonesia's development, and the quality of higher education is still far from expectations (D.Pembelajaran, Riset, and Tinggi 2019). This is due to the uneven enthusiasm and innovation skills possessed by the people of Indonesia so that universities can not yet play a role as a centre for scientific development and innovation to improve the nation's competitiveness.

Lecturers as practitioners in the smallest scope of tertiary education must have an appropriate innovation strategy to develop innovative and creative digital-based learning media so that students can have the skills as expected and be able to learn independently. The development of digital applications by utilising smartphones as digital devices is very important in supporting the learning process in the classroom. One form of digital application utilisation that is trending among the people today is Virtual Reality (VR) and Augmented Reality (AR).

In the world of education, Virtual Reality (VR) and Augmented Reality (AR) were introduced in the 1990s. At that time these technologies were applied to mathematics (Kebritchi, Hirumi, and Bai 2010), health (McCarthy and Uppot 2019), ar ((Di Serio, Ibáñez, and Kloos 2013) and several other science subjects. Augmented reality is an artificial technology that displaying real objects in the form of visual objects in 3D view by utilising a smartphone as a display media,

3D object visualisation in learning can improve learning engagement and learning qualification contests (Dalgarno and Lee 2010).

In the practice of learning the use of augmented reality, technology is still not widely used. The potential of augmented reality in supporting learning practices, specifically in manufacturing is enormous (Sorko and Brunnhofer 2019). Augmented reality technology can provide changes in the way people work, especially in the design process and work processes in manufacturing. Manufacturing work processes can be visualised in advance through the appearance of 3D objects so that the problem-solving ability that will arise when manufacturing work is carried out (Ong, Yuan, and Nee 2008) (Makris et al. 2016)

However, the reality is the use of AR for education in Indonesia is still low because educators both teachers and lecturers still survive using conventional methods, as well as in learning through the practical use of AR technology is still rare. Even though smartphone ownership has exceeded 50% of the total population of Indonesia, data from APJII (Association of Indonesian Internet Service Providers and Kominfo 2019). While science is increasingly developing, which means that the world of education must be able to adapt and be integrated with current developments in science and technology such as the use of AR or VR technology in learning.

Vocational education is one of the lines of education in Indonesia that prepares students to work in certain fields, professions. It develops students who have skills relevant to the world of work or industry an means that students must be able to apply their knowledge, skills and experience in solving problems in daily life days related to the field that he fielded.

Vocational education prepares students primarily to work in certain fields, as professional and being highly capable (UUPT No.12 of 2012). Vocational higher education has a role in producing competent graduates with qualifications that match the challenges faced by the Indonesian people so that the portion of practical courses is greater than theoretical courses. Specifically, in the mechanical engineering department for each practical course must be equipped with a worksheet that becomes a reference and guide in carrying out practicum in the workshop. Training / Technical Guidance of KTSP Ministry of National Education implies aspects that must be met for a good jobsheet in learning: 1) title, name of competency/sub competency, 2) equipment, machinery/tools needed to complete the learning competency, 3) material, type of material used to complete the competency, 4) the direction, the reason why the competency is taught, highlight the effectiveness of the jobsheet. In addition to learning in making jobsheets it should also pay attention to 1) the composition of the display, 2) easy to understand language, 3) able to test understanding, 4) provide stimulus, 5) readable (ease of reading), 6) learning material.

Study Literature

CNC Programming Subjects

Computer Numerical Control (CNC) programming is one of the compulsory subjects that must be mastered by students, especially mechanical engineering students. CNC programming is a follow-up course from the branch of machining which is the process of working on machine tools that were previously operated manually but are now operated on CNC machines and computers have assisted the operation with certain program languages.

In general, the construction of CNC machine tools and their working systems is synchronisation between computers, programmer and operator. If compared with conventional similar machine tools. CNC machine tools are superior, both in terms of their level of accuracy, precision, flexibility, and production capacity. (Candra et al. 2019).

CNC belongs to courses that emphasise mastery of theory and practice. Usually, the activities in lectures consist of activities (1). Activities inside the classroom, the activities carried out here are the delivery of material by the lecturer and the activities of preparing the CNC machine program by students, (2). In the CNC workshop, the activity here is the execution of programs that have been compiled by students on CNC machining and the manufacture of workpieces. However, what is emphasised in this course is the ability of students to be able to design and compile CNC programs precisely and correctly. The ability to make the right program and is supported by understanding the material correctly as well. CNC programming material in the form of knowledge about:

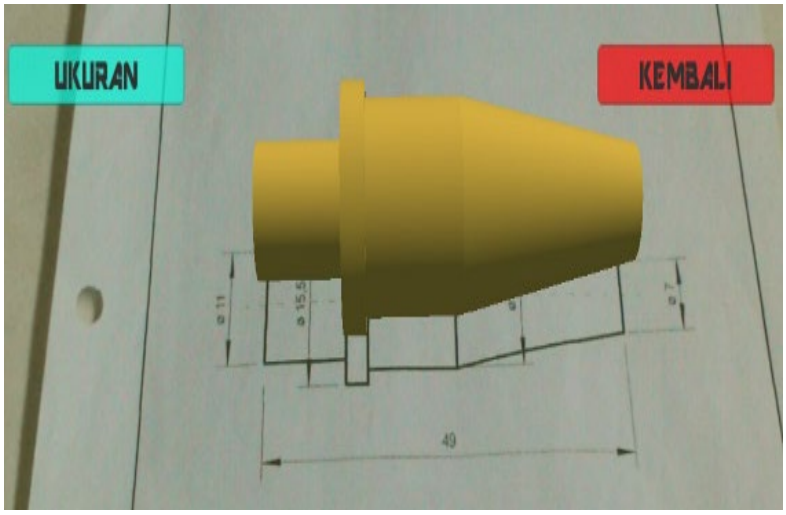
1. Read a working picture
2. Regarding the names and functions of engine components
3. Various kinds of tools (cutting tools) and tools and adjustments (settings) on CNC machines (TU2 & TU3A)
4. The working principle of TU2A or TU3A CNC machines
5. Numerical codes for machine commands and their functions and uses.
6. Program input and execution on CNC machines (TU2A & TU3A)
7. Health safety work K-3 (self, others, machines, tools, and the environment)

Augmented Reality

Augmented Reality (AR) is a new technology that involves overlaying digital graphics in the real world (Figure 1). Augmented reality (AR) refers to a broad spectrum of technology that projects computer-generated material, such as text, images, and videos, to the user's perception of the real world (Gershon 2001).). Initially, the researchers defined AR in terms of special facility devices, such as head-mounted displays (HMD). However, because the definition is too

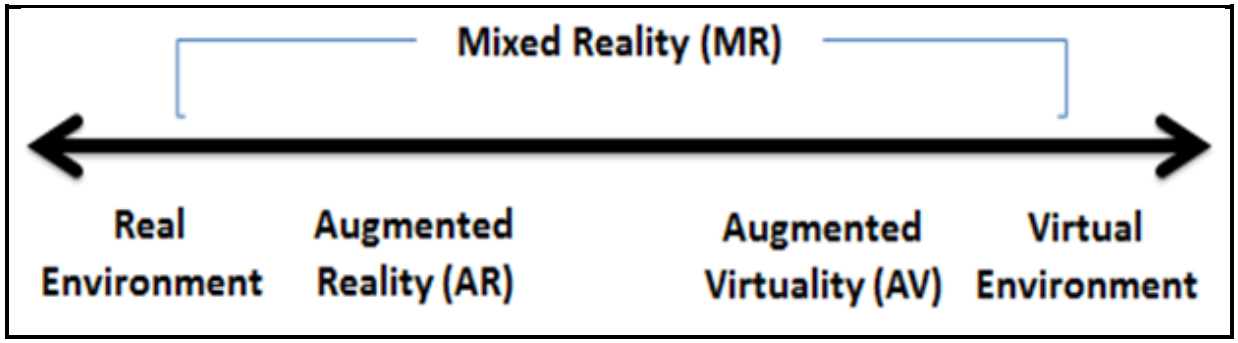
simple for developing and developing fields, and defines an AR implementation with three characteristics: (a) a combination of real and virtual world elements, (b) which is interactive in real-time, and which (c) is listed in 3D (Azuma 1993).

Figure 1. Augmented Reality Technology



Conceptually, there are two types of augmented environments: (1) Augmented Reality (AR) which makes the real world and the real environment the background (2) Augmented Reality inserts computer-generated content, and adds quality, where the computer-generated world functions as a background while real-world data is combined and supervised, as Figure 2 illustrates a mixed spectrum of reality (MR), or Continuum of Reality-Virtuality (RV) (Milgram et al. 1994).

Figure 2. Reality-Virtuality (VR) Continuum



Source: Milgram,P. & Kishino.F (1994). A Taxonomy of Mixed Reality Visual Displays. IEICE Transactions on Information Systems, 77(12)

The components of augmented reality are:

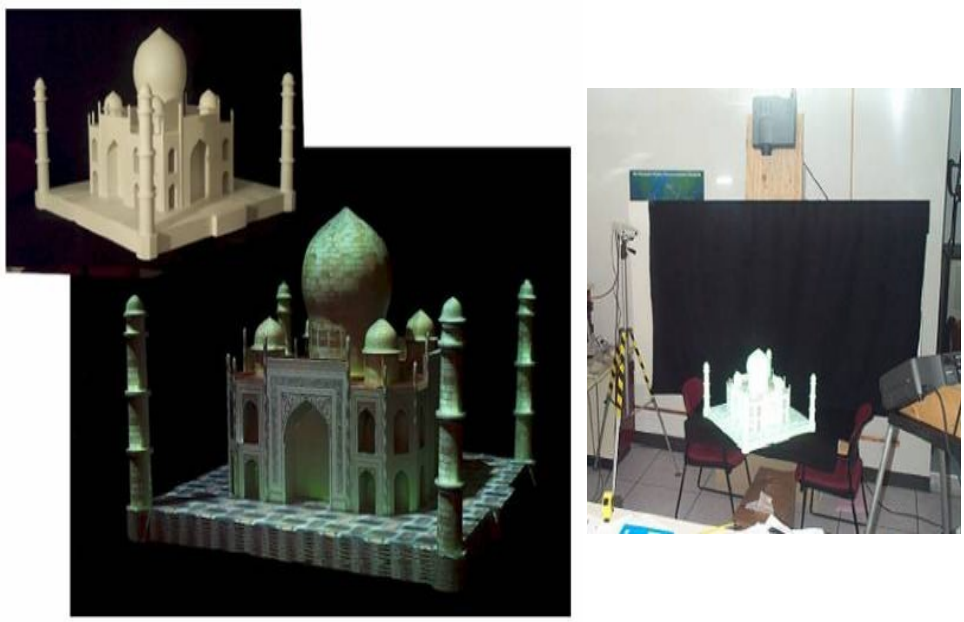
Scene Generator

A Scene Generator is a device or software that is responsible for creating scenes. Current rendering is not one of the main problems in AR, because some virtual objects need to be drawn, and they often do not need to be rendered realistically to serve the purpose of the application.

Tracking System

The Tracking System is one of the most important problems in the AR system mainly due to registration problems. Objects in the real and virtual world must be properly aligned with each other, or the illusion that the two worlds living side by side will be compromised. For industries, many applications require accurate registration (Garzón and Acevedo 2019). Approaching these technological goals is not yet practical and they are not small enough, easy, and cheap. However, in recent years there have been several advances in transparent display technology, such as Figure 3.

Figure 3. Visualization Augmented Reality



Display

Technology for AR is still under development, and the solution depends on the design decision. Display technology continues to be a limiting factor in the development of AR systems. There is still no transparent display that has enough brightness, resolution, field of view and contrasts

to seamlessly integrate a variety of real and virtual images (Sherman and Craig 2003). Besides, many technologies that began in figure 1.

Research Methodology

This research is included in development research (RnD). This research is intended to develop learning media for student worksheets (augmented reality technology-based worksheets) using the Four D approach. The four D development model consists of four procedures that must be carried out starting with defining, designing, developing and disseminating (Yulastri et al. 2017). To measure product validity, this is done through Expert Judgment. Meanwhile, the practicality of the product is tested through the application of the product to students in the form of the practicality of the product questionnaire. To test the effectiveness of the product, an action research study was carried out with a pre-test group design and post-test experiment. Following the 4D development model, the development procedure consists of four stages, namely:

Define Phase

The define phase is done to get a picture of the conditions in the field. This stage analyses the needs (needs analysis) needed for the AR job sheet development process including (1) Analysis of Student, (2) task analysis, (3) Concept analysis. (4) System analysis.

Design Phase

The results of the analysis of the define phase are used for the next stage, namely the design stage (design), At this stage, the following steps are carried out: (1) System analysis, (2)System Functionality, (3) System Design.

Development Phase

At this stage, the following steps were taken. The validation stage of the skills assessment design was designed by the constituent elements of the design of the skills assessment. The development test phase is carried out to evaluate whether the initial design can be used following expectations and effectively tie the quality of student skills assessment. Practicality phase is carried out to test on one group and several teachers on the design of this assessment. The effectiveness phase is carried out in the learning evaluation process which uses a skills assessment design in assessing student learning outcomes

Result and Discussion

Define Phase

This AR Jobsheet was developed specifically as a learning medium for the CNC programming subjects of Universitas Negeri Padang students in helping to improve the quality of learning in these subjects. Jobsheet AR is a form of digital learning media, where digital learning media is very relevant in learning in the industrial revolutionary era 4.0. Research on the use of digital learning media has been done and has shown positive results in improving the quality and learning outcomes (Martono Kurniawan and Nurhayati Oky 2014)(Kaiful Umam 2013).

Table 1: Need Analysis

Needs Analysis	Results
Analysis of Students	Students have difficulty in reading work drawings and visualising work drawings so that making CNC programs tends to be wrong. Therefore it needs a learning media that can connect 2-dimensional images and 3-dimensional images.
Task Analysis	Analysis of content structure, procedural, concept, and formulating content to be developed in this AR worksheet prepared following the syllabus of lectures and the need for the analysis conducted.
Concept Analysis	Jobsheet AR Developed with an android application that is easy and practical to use.
Analysis System	This jobsheet based augmented reality application was designed using the C # programming language. Jobsheet AR was built with the help of the Unity 3 Version 2018.2.10f application

From table 1 found the problems, phenomena, and obstacles that were found to be the initial reference in the development of this AR worksheet. Next review of the availability of CNC reference books in the library and laboratory is still limited so that students have difficulty in accessing material related to CNC program loaders. Furthermore, a review of the jobsheets in the CNC laboratories and CAM of Universitas Negeri Padang only displayed detailed drawings and very little information related to making the CNC program.

Design Phase

System Analysis

Analysis and design need to be done in making and developing a system. System analysis is the stage to identify the problems found in the system/application and provide an overview of the system/application to be designed (Rahmat Fadillah, 2019).

Stages of analysis contain identification and evaluation of the problems found and what the needs in designing this application. The design of this application is expected to be able to help students in understanding the reading of work drawings on the jobsheet and improve students' ability to design CNC programs and help students to learn independently.

This augmented reality-based jobsheet application was designed using the C # programming language. The C # programming language is felt to be quite powerful in developing applications that will be installed on android mobile. Jobsheet AR was built with the help of the Unity 3 Version 2018.2.10f application where this application already supports the Vuforia library which is integrated with various types of platforms. At least the android series must support the multi-touch function because the AR jobsheet application work process must use hand stimulant touch.

System Functionality

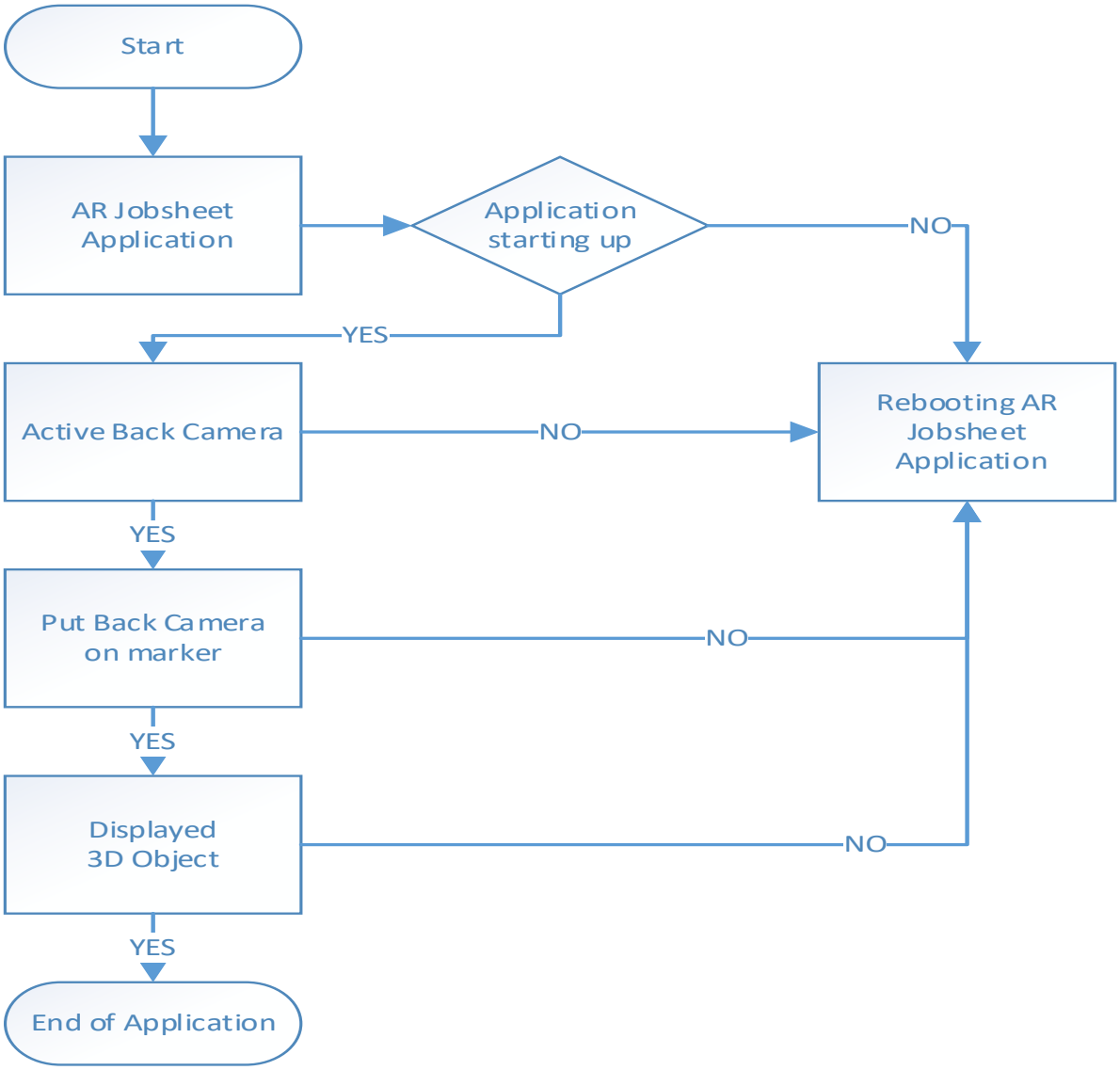
This jobsheet AR application is a single user or only accessed by one user. This application requires marker media to operate it. The user has a role as a controller in the running of the Jobsheet AR application. Because this application does not occur in client interaction or better than in the process of operating, it suits only one user. Markers, as well as coordinates in this application, must have been defined in the system at the implementation stage of the program code. Detection of the coordinates of the emergence of the object cannot be changed or fixed; this will make it easier to adjust the display position.

Steps for operating the AR jobsheet application with android:

a. The application is opened via an Android operating system smartphone that has previously installed the AR jobsheet application
b. The application will activate the back camera of the smartphone which functions to mark the marker.
c. The user places a marker within the reach of the smartphone's camera as the camera's coordinate marking automatically
d. Android smartphone will track the marker that has been registered
e. 3D objects will appear in the marker area detected by the camera on an Android smartphone according to their coordinates

The application can perform dynamic movements simultaneously on the coordinates of these markers so that 3D objects can appear perfectly. These steps can be described to more concisely the work process of this application will be illustrated in the diagram flow below.

Figure 4. Flow Chart Design of Jobsheet Application AR



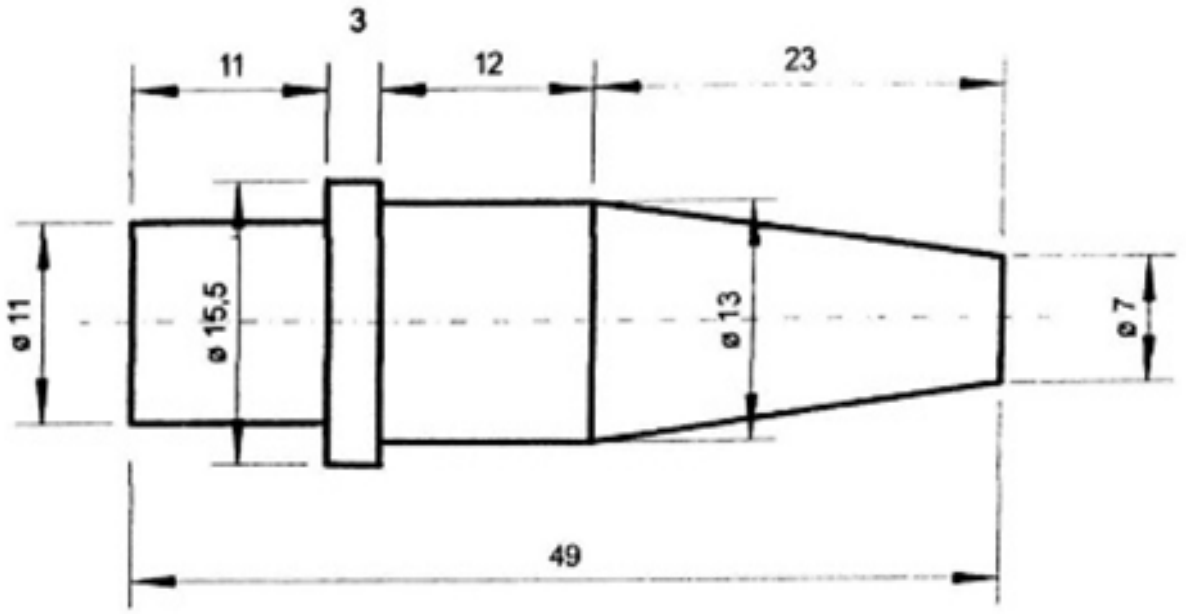
System planning

Operating System Design

The system that will be built on this application can be operated on Android-based devices with android version 4.4.2 (Kitkat) up to the latest android version 8.0 Oreo. In designing the system, it will first be made a marker media that is determined by the appearance of the 3D object coordinates. The object that will appear is the 3D object of the workpiece from the jobsheet of the CNC programming course. Each marker on each print jobsheet will display one 3D object of the workpiece following the pre-determined shapes and standards. The 3D object of this workpiece can also bring up the size (dimension) so that the user can identify the type of machining process to be performed. This machining process can be converted to code

commands for CNC machines making it easier for users to compile the workmanship program from the workpiece earlier.

Figure 5. AR Jobsheet Marker



In Figure 5, the AR design worksheet marker will be used to bring up the 3D object of the workpiece. The size button is used to display the size of each 3D component in the formed coordinates.

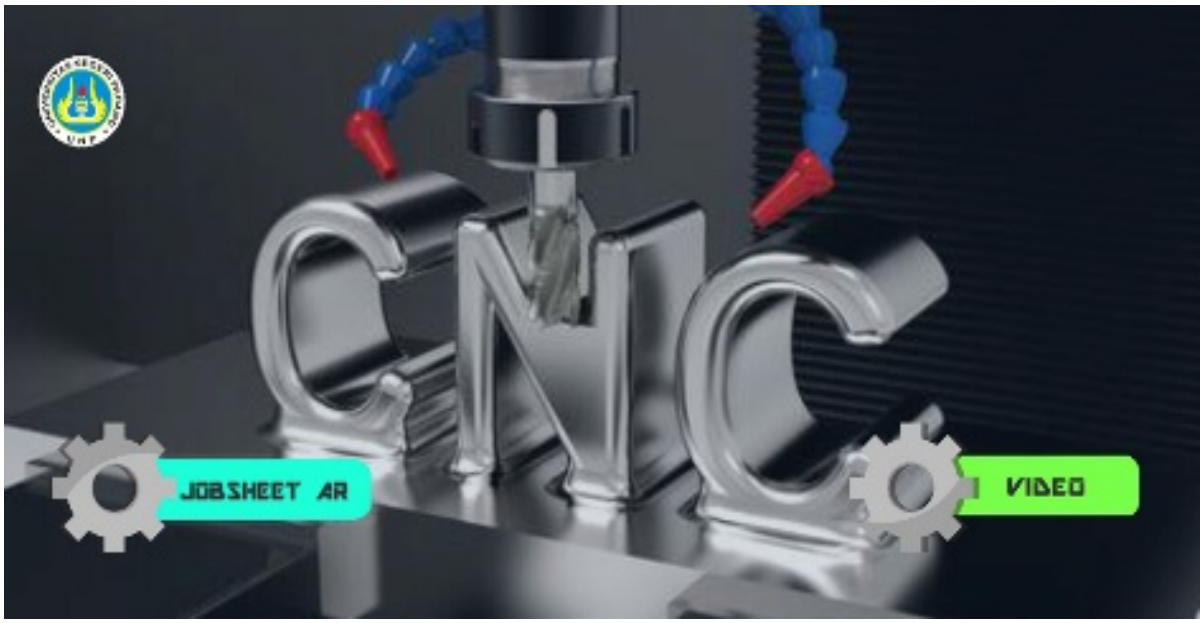
Figure 6. System Design

Interface Design

Interface interaction of this augmented reality jobsheet application will be designed user-friendly so that this application is easier to use by users. The user interface design that will be

built as below.

Figure 7. User Main Menu Interface



The initial appearance of this application will provide two main menus namely the AR and video jobsheets. The AR jobsheet menu is used to run the augmented reality application from the AR jobsheet. While the video menu is a menu used to view video lessons about the operation of CNC turning and milling machines.

Development Phase

Validity Test

The validity process is carried out through a group discussion forum (FGD) with experts in the field of digital learning media, expert lecturers in the field of CNC, language experts regarding improvements to the AR jobsheet created. Validity results are also assessed using a validated questionnaire to see its validity. From the results of the AR Jobsheet validity test questionnaire obtained:

Table 2: Lattice Sheet Validity

No	aspect Assessment	Indicator of Assessment	Validity Score
1	Content of design sheet assessment	a) Aspects design conformance with the syllabus contents	0,830
		b) Material	0,850
		a) Completeness of presentation	0.8-0
2	Language	a) Straightforward	0.700
		b) Communicative	0.714
		c) Dialogic and interactive	0.740
		d) Easy to understand	0,710
		e) Use of terms, symbols, and icons	0.730
3	Graphics	a) Easy to understand b) Attractive c) colors match the original	0,870 0,885 0.830
4	AR Jobsheet formatting	a) Aspects of Jobsheet formatting b) aspects Characteristics Jobsheet	0.840 0.820

The four aspects of the evaluation of validation The design of the AR course sheet on the CNC programming course shows an average score above 0.600, this means that the whole assessment shows valid results by experts who validate.

Practicality Test

Jobsheets based on Augmented Reality must meet the practical aspects of understanding and implementing the teaching material. The purpose of the practicality test is to find out the extent and ease of this AR jobsheet in assessing learning outcomes in CNC programming. Design practicality assessment based on a questionnaire that has been filled out by practitioners is analysed to determine the practicality of the product being developed. Practicality analysis using a Likert Scalewth a percentage formula

$$\boldsymbol{P} = \frac{\boldsymbol{f}}{\boldsymbol{N}} \text{ x } 100\ \%$$

The practicality category can be seen in Table 2. Following this

Tabel 2: Practicality Category Table

No	Grade	Category
1	80% < x ≤ 100%	Very practical
2	60% < x ≤ 80 %	Practical
3	40% < x ≤ 60 %	Practical enough
4	20% < x ≤ 40 %	Less practical
5	0% < x ≤ 20 %	Not practical

Modified from (Riduwan 2009).

Based on the analysis of practicality questionnaire above obtained practicality value of 78.83%, which is in the practical category.

Effectiveness

To determine the effectiveness of the design of CNC programming skills assessment in vocational high schools, the draft in students majoring in Mechanical Engineering Universitas Negeri Padang in the July-December 2019 semester. The effectiveness of jobsheet design data was taken from test results through small group trials by conducting both written and practical tests on students by applying jobsheet AR. The correlated t-test is used to see the comparison of the average value of students before the use of the design of the CNC programming skills (pretest) with after the use of the design of the CNC programming skills (post-test). The effectiveness test was carried out using SPSS version 20.00. The results showed that t table (3,025> 2,228) at a significance level of 95%, which means that there are differences in the results between the pretest and posttest on student ability and the ability of students at this time is better after the posttest than the pretest.

Conclusion

The increasing demands of the ministries of research and higher education on improving the performance of lecturers cause moreand more resources in the form of time and money are devoted to meeting these demands. So that lecturers do not have enough time in creating effective learning in the classroom. Therefore, lecturers need to design and make careful decisions in the design and development of teaching materials that utilise digital technology in the classroom. Although some research findings find ambiguity from the use of digital technology in the classroom in terms of feedback, student collaboration and lecturer access in guiding learning if examined the cause of ambiguity is not due to the use of digital technology but rather to the user of the technology.

Augmented Reality-based jobsheets were built using the Exploratory Tutorial Method of CNC programming courses majoring in mechanical engineering of Universitas Negeri Padang. The concept built in this media is Exploratory Tutorial, which allows students to access (explorations) the menu provided. Where students are given the freedom to choose the menu according to what they need students can also do independent learning without guidance or direction from the lecturer.

From the results of the research, we found related to the development of augmented reality-based jobsheets in the learning of CNC programming in diploma III students majoring in mechanical engineering, Universitas Negeri Padang, showed positive results. This positive result is a good response by students and lecturers as users of this application. This application has also been tested for validity, effectiveness, and practicality by involving several experts and thus has obtained valid, practical and effective results to support the quality of CNC programming learning of Mechanical Engineering students at Universitas Negeri Padang

Learning environments using AR jobsheets is more effective than using ordinary jobsheets, with overall effect sizes doubling. This is a major contribution to the field of using augmented reality technology for teaching because there is limited evidence of its effectiveness. Although Sitzmann (2011) and Vogel et al. (2006) also saw the enormous potential of Augmented Reality technology in helping practical lessons.

Studies differ in the size of learning outcomes for simulations, where studies assessing students' level of knowledge are found to be more effective than studies assessing the level of skills. This may be because it may be easier for students to remember factual information later to develop the skills they hope to obtain from simulations because skill acquisition is a gradual process and may need to be repeated

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