DEVELOPMENT OF SIXTH-FORM *HistoGuide* APPLICATION AND ITS IMPACT TOWARDS DRAWING SKILL, LABELLING SKILL AND MOTIVATION

TEOH CHERN ZHONG

SULTAN IDRIS EDUCATION UNIVERSITY

2024

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TEOH CHERN ZHONG

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

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DR. MUHAMAD IKHWAN BIN MAT SAAD
Jabatan Biologi
Fakulti Sains dan Matematik
Universiti Pendidikan Sultan Idris
35900 Tanjong Malim
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ABSTRACT

This research aims to develop a sixth-form *HistoGuide* application and study its impact on students' drawing skills, labelling skills and motivation. The *HistoGuide* is developed based on the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) Model, and to identify its impact, quasi-experimental research was employed. Two sets of instruments were utilised to measure the usability and motivation. A total of 194 sixth-form students were selected as respondents through the simple random sampling technique. The Content Validity Index (CVI) from 15 experts showed that the Item-level CVI (I-CVI) is high and the overall validity is excellent, with Scale-level CVI/Universal Agreement (S-CVI/UA) at 0.80 and Scale-level CVI/Average (S-CVI/Ave) at 0.96, respectively. Findings showed a high overall usability level (Mean (M) = 4.41; Standard Deviation (SD) = 0.39) with usefulness (M = 4.40; SD = 0.38), ease of use (M = 4.36; SD = 0.41), ease of learning (M = 4.45; SD = 0.45), and satisfaction (M = 4.47; SD = 0.45). Drawing and labelling skills showed no significant differences ($p \geq 0.05$) in the pre-test scores between the treatment and control groups. However, there were significant differences ($p < 0.05$) between pre and post-test scores for both treatment and control groups. Thus, the treatment group outperformed the control group in the drawing and labelling skills. As for the motivation, there were no significant differences ($p \geq 0.05$) in the pre-test scores between the treatment and control groups. However, there were significant differences ($p < 0.05$) between pre and post-test scores for the treatment. There were also significant differences ($p < 0.05$) in the post-test scores between the treatment and control groups. Hence, the treatment group performed better than the control group in motivation. In conclusion, students from the treatment group outperformed in drawing and labelling skills, and also in motivation as compared to students from the control group after using the *HistoGuide* application. The implication shows that the development of the virtual-based application, the *HistoGuide,* is able to support the overall Biology learning, especially in microscopy.

PEMBANGUNAN APLIKASI *HistoGuide* TINGKATAN ENAM DAN IMPAKNYA TERHADAP KEMAHIRAN MELUKIS, KEMAHIRAN MELABEL DAN MOTIVASI

ABSTRAK

Kajian ini bertujuan untuk membangunkan satu aplikasi *HistoGuide* tingkatan enam dan mengkaji impaknya terhadap kemahiran melukis, kemahiran melabel dan motivasi. *HistoGuide* ini dibangunkan berdasarkan Model ADDIE (*Analyze, Design, Develop, Implement,* dan *Evaluate*) dan bagi mengenalpasti impaknya, kajian ekperimen kuasi telah digunakan. Dua set instrumen digunakan untuk mengukur kebolehgunaan dan motivasi. Sejumlah 194 pelajar tingkatan enam telah dipilih menjadi responden melalui teknik persampelan rawak mudah. Indeks kesahan kandungan daripada 15 orang pakar menunjukkan kesahan *Item-level CVI* (*I-CVI)* adalah tinggi dan kesahan keseluruhan sangat baik, iaitu masing-masing *Scale-level CVI/Universal Agreement (S-CVI/UA)*, 0.80 dan *Scale-level CVI/Average (S-CVI/Ave)*, 0.96. Dapatan menunjukkan tahap keseluruhan kebolehgunaan yang tinggi (Min (M) = 4.41; Sisihan Piawai (SP) = 0.39) untuk kebergunaan (M = 4.40; SP = 0.38), kemudahan penggunaan (M = 4.36; SP = 0.41), kemudahan pembelajaran (M = 4.45; SP = 0.45), dan kepuasan (M = 4.47; SP = 0.45). Kemahiran melukis dan melabel menunjukkan tidak terdapat perbezaan yang signifikan ($p \geq 0.05$) dalam markah ujian pra antara kumpulan rawatan dan kawalan. Namun, terdapat perbezaan yang signifikan ($p < 0.05$) antara markah ujian pra dan pasca bagi kedua-dua kumpulan rawatan dan kawalan. Oleh itu, kumpulan rawatan menunjukkan prestasi yang lebih baik berbanding kumpulan kawalan dalam kemahiran melukis dan melabel. Bagi motivasi pula, tidak terdapat perbezaan yang signifikan ($p \geq 0.05$) dalam markah ujian pra antara kumpulan rawatan dan kawalan. Walau bagaimanapun, terdapat perbezaan yang signifikan ($p < 0.05$) antara markah ujian pra dan pasca bagi kumpulan rawatan. Terdapat juga perbezaan yang signifikan ($p < 0.05$) dalam markah ujian pasca antara kumpulan rawatan dan kawalan. Justeru itu, kumpulan rawatan menunjukkan prestasi yang lebih baik daripada kumpulan kawalan dalam motivasi. Kesimpulannya, pelajar kumpulan rawatan menunjukkan kemahiran melukis dan melabel yang lebih baik serta lebih bermotivasi berbanding pelajar kumpulan kawalan selepas menggunakan aplikasi *HistoGuide*. Implikasi kajian menunjukkan pembangunan *HistoGuide* berasaskan aplikasi maya mampu menyokong keseluruhan pembelajaran Biologi, khususnya dalam mikroskopi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADDIE	Analysis, Design, Development, Implementation, and Evaluation
ARCS	Attention, Relevance, Confidence, and Satisfaction
ARCS-V	Attention, Relevance, Confidence, Satisfaction, and Volition
CVI	Content Validity Index
FDDP	Feature Driven Development Process
Gen Z	Generation Z
ICT	Information and Communications Technology
IR 4.0	Industrial Revolution 4.0
I-CVI	Item-level Content Validity Index
IMMS	Instructional Materials Motivation Survey
KTE	Kolej Tingkatan Enam
OS	Operating System
PPPM	Pelan Pembangunan Pendidikan Malaysia
PTE	Pusat Tingkatan Enam
RIMMS	Reduced Instructional Materials Motivation Survey
SBA	School-based Assessment
SDL	Self-directed Learning
SMK	Sekolah Menengah Kebangsaan
SMJK	Sekolah Menengah Jenis Kebangsaan
SPM	Sijil Peperiksaan Malaysia
SPSS	Statistical Packages for Social Science
SRL	Self-regulated Learning
STAM	Sijil Tinggi Agama Malaysia
STEM	Science, Technology, Engineering and Mathematics
STPM	Sijil Tinggi Peperiksaan Malaysia
S-CVI	Scale-level Content Validity Index
S-CVI/UA	Scale-level Content Validity Index / Universal Agreement approach
S-CVI/Ave	Scale-level Content Validity Index / Average approach
USE	Usefulness, Satisfaction, and Ease of Use

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

A comprehensive guideline is necessary to guide students in executing Biology microscopic practicals. Hence, a guide application is essential to help students draw and label precisely, besides applying magnification and scale, bearing in mind the usefulness, ease of use, ease of learning and satisfaction the application causes to the students. The guide application usage is hoped to increase students' confidence level and motivation in executing the microscopic practicals, besides improving the achievement of drawing and labelling skills. However, there is a lack of comprehensive guidelines for after-secondary education in Malaysia.

Post-secondary education is for individuals completing their upper secondary education but does not include tertiary education. Sixth-form education is one of the after-secondary education offered to those individuals obtaining a pass in Sijil

Peperiksaan Malaysia (SPM). If they choose sixth-form education, they must sit for the Sijil Tinggi Peperiksaan Malaysia (STPM). Apart from matriculation and Sijil Tinggi Agama Malaysia (STAM), it is one of the prerequisites to enter tertiary education.

Starting from 2013, in line with the Pelan Pembangunan Pendidikan Malaysia (PPPM) or National Education Blueprint (2013-2025), many initiatives have been taken to rebrand the sixth-form education to be the favourite choice in pursuing tertiary education. The primary aim is to provide a quality education through a standardized curriculum, examination specifications and assessment. It is to increase the self-ability of students in aspects of intellectual, leadership skills, identity and high spirit to prepare them for tertiary education in or out of the country (Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, 2017).

Science, Technology, Engineering and Mathematics (STEM) education is one of the initiatives in the PPPM to prepare individuals for the future. One of the main pillars of STEM education is increasing individuals' interest through new learning approaches and curriculum enhancement. It includes incorporating high-order thinking skills, increasing practical teaching resources, and making learning relevant to daily life (Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, 2017). In this 21st century, education is often associated with 21st-century learning and Industrial Revolution 4.0 (IR 4.0). Generation Z (Gen Z) students can learn anywhere and at any time, according to 21st-century learning in ubiquitous learning (Yáñez-Aldecoa et al., 2015). 21st-century learning includes the 4Cs: creativity, critical learning and problem-solving, communication and collaboration (Partnership for 21st Century, 2019).

Meanwhile, `Adlina Abdul Khalil et al. (2020) mentioned that the Industrial Revolution mainly referred to the development and advancement of robotic technology, cyber-physical systems, the Internet of Things, and cloud computing. These open-sky technologies will impact humanity as a whole (Mohamad Suzalie, 2003). Hence, integrating disciplines in the STEM approach, education elements (education policy, curriculum, learning environment, teachers, and students) and industrial sectors in society are important to prepare students for the future (Elayyan, 2021).

Elayyan (2021) emphasized that student-centred learning and transformation from knowledge to soft skills are also important to prepare students for IR 4.0. It includes improving digital skills (blogging, filming, podcasting, wiki building and uploading by preparing a virtual learning environment) and using technology in schools. Meanwhile, Sutherland et al. (2004) described how teachers and researchers developed ways to embed information and communications technology (ICT) into everyday classroom practices to enhance learning. The emphasis is on teaching and learning across various subjects, including Biology. The influence of young people using ICT in learning is also discussed. In addition, Becta (2006) stated that ICT supports the teaching and learning processes and suggested various methods to develop effective ICT integration in the classroom.

Technologies have changed and evolved rapidly. School administrators and teachers constantly search for new ways to prepare students for the future. The education system has evolved faster than ever (Nicholas, 2019). Using technology as a learning tool in school is to familiarise the students before they start inventing new technology and incorporate high-order thinking skills in the learning process. Thus, this aligns with STEM education, moving from being a technology user to innovating technology (Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, 2017).

1.2 Background of the Study

STEM education is incorporated into the subject of Biology in sixth-form education. In Malaysia, there has been a steady decrease in the enrollment of students taking Biology in STPM, as shown in Table 1.1.

Although, the rebranding of sixth-form education took place in 2013. Biology has the smallest number of student enrolments among all the science subjects (Prokop et al., 2007), as observed by other countries. This declining trend is observed in other countries as well. Researchers conduct studies worldwide to identify the decline in enrollment of Biology students in their own countries and difficulties in learning Biology (Bahar et al., 1999; Lazarowitz & Penso, 1992).

Table 1.1

Number of Students Taking STPM Biology Subject in Malaysia

	Number of students		
Year	Semester 1	Semester 2	Semester 3
2013	5545	5129	4984
2014	4265	4107	4030
2015	3830	3740	3629
2016	3743	3622	3545
2017	3080	3055	3025
2018	2339	2331	2325
2019	2214	2197	2187
2020	1890	1862	1857
2021	1886	1878	1872

Note. Adapted from Malaysian Examinations Council (2013-2022)

Students face difficulties in learning biological concepts, and there are many reasons for this (Çimer, 2012; Cimer et al., 2010; Lazarowitz & Penso, 1992; Tekkaya et al., 2001; Zeidan, 2010). Students show little interest in learning Biology because it is deemed complicated (Bramwell-Lalor & Rainford, 2014; Rosamsi et al., 2019). It can be partly due to the teaching methods employed by their teachers and the nature of science itself. According to Lazarowitz and Penso (1992), Biology is difficult to learn because of the abstract level of the concepts and the biological level of organization. It is supported by Rosamsi et al. (2019).

Therefore, if the teacher uses various visual teaching and learning materials and tools, such as models, images, computer simulations, 3-D materials, videos, and real-life objects, both the teaching and learning of Biology may become more effective (Çimer, 2007, 2012; Cimer et al., 2010). Teaching with visual materials can make lessons more interesting to students, give more concrete meaning to words, show relationships and connections among ideas explicitly, and provide a useful channel of communication and strong verbal messages and memorable images in students' minds (Çimer, 2007, 2012; Cimer et al., 2010; Cyrs, 1997; Harlen, 1999; Newton, 2002). Meanwhile, Nawawi et al. (2021) found that using interactive multimedia increases students' understanding of Biology concepts.

Khan and Masood (2014) mentioned that Biology has a promising future in school. However, it is perceived as a difficult subject compared to other sciences. In Biology, only abstract concepts were generally taught to the students, as Brown and Schwartz (2009) revealed. The abstract concepts taught influenced these difficulties (Khan & Masood, 2014; Rosamsi et al., 2019). Students cannot explain the science concepts better due to ineffective teaching techniques and poor assessment. Therefore, interactive teaching techniques should be employed to avoid misconceptions about science concepts (Bramwell-Lalor & Rainford, 2014). These misconceptions are due to the students' cognition.

Cognition is the conditions and processes of knowing, including judgment and perception. Simply put, cognition is thinking. Cognition refers to the unconscious and conscious processes by which knowledge is gathered, such as recognizing, perceiving, conceiving, and reasoning (Britannica, 2021). When students learn, they build up their thoughts about the concepts differently due to prior knowledge. Ormrod (2006) emphasized that students are exposed to first-hand experience of the scientific inquiry process and constructing conceptual knowledge through a designed student-centred investigative method. Thus, misconceptions and factual errors are bound to happen in thinking. Maskiewicz and Lineback (2013) viewed students' misconceptions as resources for refinement rather than impediments that must be replaced. This new concept of student thinking may lead to more effective educational practices in the classroom (Maskiewicz & Lineback, 2013).

Students learn actively by doing and experiencing in the Biology laboratories. Mwangu and Sibanda (2017) revealed that teachers used student-centred and teacher-centred methods to teach practical Biology lessons. However, Rocard et al. (2007) mentioned that a practical lesson is deemed successful if it is inquiry-based rather than deductive-based learning. Learning by convincing students that what they are being taught exists or happens in the real world can be done through practical lessons (Dillon, 2008). Students can test, rethink and reconstruct their ideas and thoughts when engaging in the practical lesson (Çimer, 2007, 2012). A student or group can develop their ideas within their class through investigative practice (Haigh, 2007). Students can engage with and fully participate in the practical lesson (Gott & Duggan, 2002).

One of the important aspects of practical lessons is enabling students to acquire manipulative skills or abilities, besides science process skills and the thinking skills (Malaysian Examinations Council, 2012). Handling and manipulating materials and apparatus in scientific study and the capacity to follow instructions and make accurate observations are examples of manipulative skills (Hidayah Mohd Fadzil & Rohaida Mohd Saat, 2013). In science, the capacity to conduct psychomotor or manipulative skills is vital and interdependent with students' ability to improve their intellectual and cognitive skills (Hidayah Mohd Fadzil & Rohaida Mohd Saat, 2017). Understanding Biology is obtained in this context through executing experiments and constructing concepts in the laboratory to produce their own discoveries rather than simply reading from the theories.

1.3 Problem Statement

From the students' need analysis study, sixth-form Biology students are weak in drawing and labelling microscopic slides. Preliminary findings from one of the sixth-form centres showed that 68.8% of students scored below five marks in the results section of the school-based assessment. Drawing, labelling, and applying magnification and scales encompass about 40.0% of the marks allocated in the single assessment, which consisted of manipulative skills (A), results (B), discussion (C), and conclusion (D). Students are considered weak in drawing, labelling and applying magnification and scales, based on data from Table 2.2. Drawing and labelling aspects must be fulfilled together to acquire the allocated marks. The findings were supported by Cheung and Winterbottom (2021) and Susiyawati and Treagust (2021), who explored students' visualization competence and found that they are weak in perceiving microscopic entities through drawing and labelling. They reported that 60.0% of the students could not label their biological drawings (Cheung & Winterbottom, 2021), and a higher proportion tended to give fewer labels (Susiyawati & Treagust, 2021).

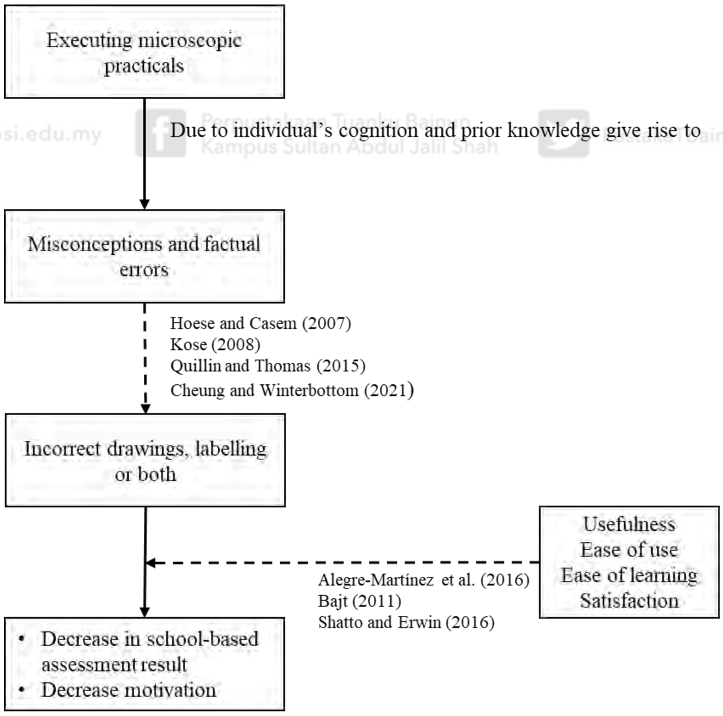
Besides that, microscopes and slides are found to be the most difficult among all the topics in laboratory practicals in the need analysis study. The microscope and slides include the topics of cell Biology, plant anatomy, and histology, as in Table 2.3. Thus, students must connect different topics to effectively learn Biology concepts (Law & Lee, 2004), especially in histology practicals. The skills and concepts they learn in the practical are needed as prior knowledge for the next practical.

Meanwhile, the student's problems in the microscopic drawings and labellings are shown in Figure 2.3 and Figure 2.4. These problems are reflected in the report submitted by students as a school-based assessment. From the analysis of students' reports in the school-based assessment, students faced difficulty drawing and labelling microscopic slides, including applying the magnification and scale of the drawing. Only 9.4% of students scored full marks in the results section (B), which emphasized drawing and labelling. Drawings and labelling usually accompany all microscopic practicals as a report submitted as a school-based assessment at the end of the practicals.

The incorrect drawings, labelling or both are identified as the observable symptoms of the problem. Hoese and Casem (2007) mentioned that teachers could gather large amounts of data on students' mental models of scientific concepts using microscopic drawings. The drawings are used to determine conceptual understanding and misconceptions (Köse, 2008). Drawing exposes misconceptions (Quillin & Thomas, 2015). The researchers gave samples of references that reveal misconceptions through drawings. These incorrect drawings and labelling or both will decrease the school-based assessment and students' motivation to execute practicals, as shown in Figure 1.1. It is due to the inability of students to draw and label, apply magnification and scale and observe details as there is a lack of quality images for practicals (García et al., 2019).

Figure 1.1

Symptoms/Issues Arise during the Execution of Microscopic Practicals



Thus, from the literature review of studies in histology, it can be concluded that virtual microscopy and slides should be employed to address the mentioned students' inabilities, as suggested by Alegre-Martínez et al. (2016). Students constantly seek to employ digital technology in their learning (Bajt, 2011). Students wanted dynamic, participatory, and meaningful learning incorporating observation and practice (Shatto & Erwin, 2016). The technology employed has usability constructs of usefulness, ease of use, ease of learning, and satisfaction, as Lund (2001) suggested. However, Liu and Pantanowitz (2019) noted high costs, lack of familiarity, and difficulty incorporating virtual microscopy.

Meanwhile, Simok et al. (2019) mentioned that virtual microscopy failed to stimulate students' motivation compared to optical microscopy. The researchers suspected it might be due to the module's lack of a motivational model. Cromley et al. (2020) concluded that combinations of cognitive and motivational interventions were offered to increase students' performance with minimal additional work for the instructors. Meanwhile, van Wyk (2019) mentioned that the ARCS-V motivational design model is appropriate for designing motivational features in a course. Hence, it was found especially valid and useful when integrating motivational aspects at each level of the ADDIE design process (van Wyk et al., 2020).

In summary, web-based virtual microscopy and slides, the *HistoGuide* application, based on a motivational model, as self-regulated learning to complement the practical lessons, is proposed in this study to address the mentioned problems. The students' misconceptions in drawing, labelling, and applying magnification and scale could be addressed effectively with good images that complement microscopic works collaboratively. The all-in-one *HistoGuide* application also addresses the high cost of conventional virtual microscopy and slides. Then, after the evaluation phase of the developmental design, the *HistoGuide* application will be employed to analyse the impact on students' drawing and labelling skills achievement and motivation in sixth-form microscopic practicals.

1.4 Research Objectives

The objectives of this study include the following:

1. To develop the *HistoGuide* application in sixth-form microscopic practicals with a high validity index.
2. To determine the usability of the *HistoGuide* application in sixth-form microscopic practicals.
3. To identify the impact of the *HistoGuide* application on students' drawing and labelling skills achievement in sixth-form microscopic practicals.
4. To identify the impact of the *HistoGuide* application on students' motivation in sixth-form microscopic practicals.

1.4.1 Research Questions

The questions of this study include:

1. What is the validity index of the *HistoGuide* application in sixth-form microscopic practicals?
2. What is the level of usability of the *HistoGuide* application in sixth-form microscopic practicals?

   a) Usefulness?
   b) Ease of use?
   c) Ease of learning?
   d) Satisfaction?

3. Four research subquestions are included for research objective 3:

a) Is there any significant difference in students' drawing and labelling skills achievement between the treatment group and control group scores in the pre-test?
b) Is there any significant difference in students' drawing and labelling skills achievement between pre-test and post-test scores for the treatment group?
c) Is there any significant difference in students' drawing and labelling skills achievement between pre-test and post-test scores for the control group?
d) Is there any significant difference in students' drawing and labelling skills achievement between the treatment group and control group scores in the post-test?

4. Four research subquestions are included for research objective 4:

a) Is there any significant difference in students' motivation between the treatment group and control group scores in the pre-test?
b) Is there any significant difference in students' motivation between pre-test and post-test scores for the treatment group?
c) Is there any significant difference in students' motivation between pre-test and post-test scores for the control group?
d) Is there any significant difference in students' motivation between the treatment group and control group scores in the post-test?

1.4.2 Research Hypothesis

The four null hypotheses for research objective 3 are:

H_{01}: There is no significant difference in students' drawing and labelling skills achievement between the treatment group and control group scores in the pre-test.

H_{02}: There is no significant difference in students' drawing and labelling skills achievement between pre-test and post-test scores for the treatment group.

H_{03}: There is no significant difference in students' drawing and labelling skills achievement between pre-test and post-test scores for the control group.

H_{04}: There is no significant difference in students' drawing and labelling skills achievement between the treatment group and control group scores in the post-test.

The four null hypotheses for research objective 4 are:

H_{05}: There is no significant difference in students' motivation between the treatment group and control group scores in the pre-test.

H_{06}: There is no significant difference in students' motivation between pre-test and post-test scores for the treatment group.

H_{07}: There is no significant difference in students' motivation between pre-test and post-test scores for the control group.

H_{08}: There is no significant difference in students' motivation between the treatment group and control group scores in the post-test.

1.5 Conceptual Framework

The conceptual framework illustrates the relationships between the variables in any academic study (Chua, 2020a; Ghazali Darusalam & Sufean Hussin, 2016). This study involves three major phases mainly. Phase I is for the need analysis phase. Phase II is reserved for developing the *HistoGuide* application, using a developmental design by Branch (2009) based on the ADDIE model (Branch & Gustafson, 1998), and determining the content, pedagogical and technology aspects of validity. Besides that, the usability of the *HistoGuide* application is also determined. Then, for Phase III, the *HistoGuide* application as self-regulated learning is also used to study the impact on students' drawing and labelling skills achievement and motivation in sixth-form microscopic practicals. The *HistoGuide* application is complementary and is added to conventional microscopic learning.

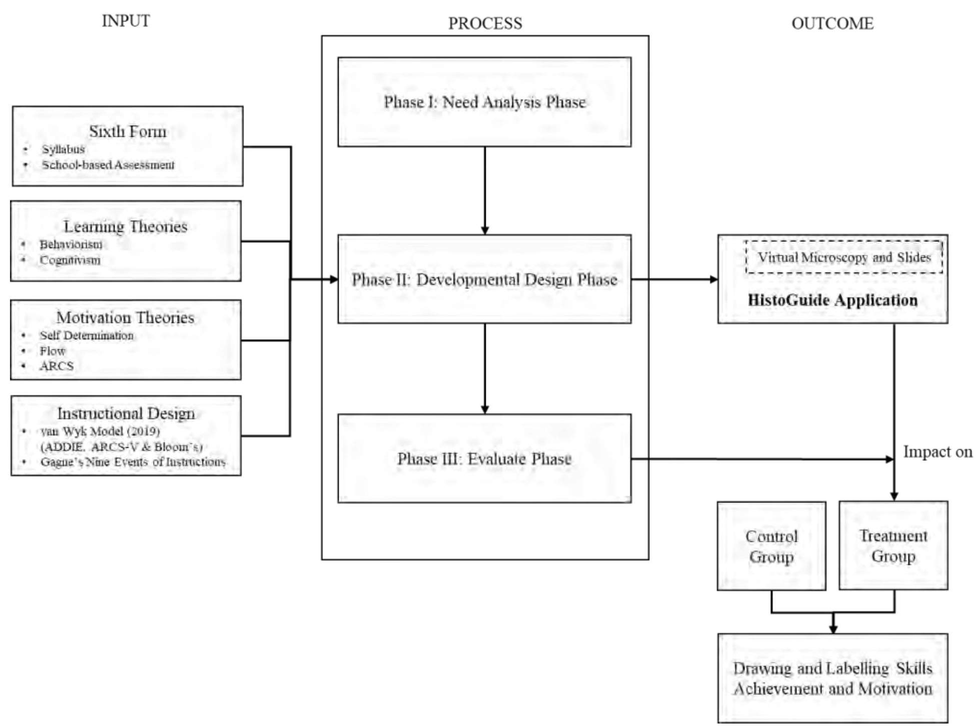
In the development of *HistoGuide*, two main learning theories, behaviourism and cognitivism, were used. Behaviourist theory was chosen because the student's drawing and labelling could be improved based on practices, guidance, hints and self-assessment provided in the *HistoGuide* application. The operant conditioning theory is the most widely used version of the behavioural perspective on motivation (Skinner, 1938, 1957). The cognitivist theories applied in the development of *HistoGuide* include cognitive load theory, information processing theory and cognitive theory of multimedia learning. The *HistoGuide* application could be an interactive resource to address students' misconceptions in drawing, labelling, and applying magnification and scale to improve their understanding and motivation to carry out the school-based assessment's microscopic practicals.

The *HistoGuide* application is designed based on cognitive load theory. The learning of drawing, labelling, and applying magnification and scale is repeated in the sub-module. Students will learn through self-regulated learning, where the motivation for learning is derived solely from achieving higher performance in school-based assessment. The motivational theories included are self-determination theory, flow and the ARCS.

The instructional design models used in this study are mainly the ADDIE model and ARCS-V model, as proposed by van Wyk (2019), including Bloom's Taxonomy. Gagne's nine events of instructions are applied to provide systematic procedures in developing the *HistoGuide* application. Both models work together to produce a quality self-regulated learning *HistoGuide* application, discussed in chapters 2 and 4. The conceptual framework of the study is shown in Figure 1.4.

Figure 1.2

Conceptual Framework of Study



1.6 Significance of the Study

The findings of the study are beneficial to the relevant parties listed below:

1.6.1 Sixth-form Students

With the research findings of the *HistoGuide* application, the researcher hopes that students can improve their drawing, labelling, and applying magnification and scale through self-regulated learning pre-laboratory or during laboratory microscopic practicals. The *HistoGuide* optimizes Gen Z's learning styles. According to the syllabus, students must visualize the histology and plant anatomy images in different magnification settings. Students could also be guided to draw and label accordingly, including applying magnification and scale through self-check hints in the *HistoGuide* application. A self-check assessment at the end of each sub-module is also included in the application. Students' preparedness for microscopic works will increase, enhancing the motivational aspects of students' microscopic works. Therefore, the *HistoGuide* application can be considered another reference source for sixth-form students in self-regulated learning apart from the reference books, lecture notes, assessment manual and tutorial questions.

It is hoped that by using the *HistoGuide* application, misconceptions in drawing, labelling, and applying magnification and scale could be addressed. Thus increasing students' achievement in the school-based assessment. This research is the first step towards using information technologies in collaborative contexts pre-laboratory and during the microscopic practicals instead of the usually individual-based microscopic practicals. The *HistoGuide* application allows students to upload images and communicate anonymously through the chatroom (synchronous communication tool).

1.6.2 Sixth-form Teachers

With students using the *HistoGuide* application pre-laboratory as self-regulated learning and during the laboratory practical itself, teachers can then concentrate on procedural guidance and implement the school-based assessment of students. Microscopic practicals involve a lot of technical skills in preparing microscopic slides, so the students require ample guidance from the teacher. The teaching approach is not limited to lecture notes, modules, reference books, and tutorial questions but interactive teaching materials like the *HistoGuide* application.

The development of the *HistoGuide* application can help sixth-form teachers deliver practical lessons in the classroom and beyond. It shifted to ubiquitous learning, where guidance can still be given to students even after school. Using self-regulated learning, such as the *HistoGuide* application, can create more student preparedness and engagement for microscopic practicals.

Detailed descriptions given to teachers could give an idea on how to manage time effectively and efficiently when using the *HistoGuide* pre-laboratory and during the practical. This research can help teachers plan self-regulated learning suitable for Gen Z's learning styles. The sixth-form teachers can also share the findings to enhance students' preparedness for microscopic practicals and overcome students' weaknesses in drawing, labelling, and applying magnification and scale. It could be a reference for other researchers, especially in improving the quality of teaching and learning microscopic Biology practicals in sixth-form. Moreover, it contributes to Biology education, where new teaching and learning information could be used for further research. The teaching of usually individual-based microscopic practicals can be explored collaboratively.

1.6.3 Ministry of Education

Benefiting from the research findings, the researcher hoped that the result of the school-based assessment in Paper 4 STPM could be improved and, eventually, in the overall examination of STPM Biology. The private STPM candidates can also use it as self-regulated learning in preparing them for assessment in Paper 5 STPM. Thus, producing and preparing students for their undergraduate studies in universities in STEM that can fulfil employment needs for the 21st century. The *HistoGuide* application in self-regulated learning is one of the strategies to leverage ICT, especially mobile technology, to improve students' learning quality. The *HistoGuide* application enables Gen Z to learn in ubiquitous learning according to their own pace. It indirectly harnesses Gen Z's digital skills and competencies of using mobile technology to complement their learning. Besides, ICT can be leveraged by selecting or creating tools that complement the content and pedagogical knowledge.

1.7 Scope and Limitations of The Study

Anyanwu et al. (2012) mentioned that although the modest virtual slides cannot be regarded as good, effective, or efficient as traditional virtual microscopy, students can learn the value of this small invention's difference in histology and plant anatomy learning. Research demonstrated that many students are still interested in traditional microscopes (Anyanwu et al., 2012). So, while promoting the convenience and usefulness of the simple virtual slides and their adoption in classrooms, it is not recommended that traditional microscopes be completely phased out. The advocation is to supplement microscopic practical lessons because of the importance of developing microscopy skills and practical knowledge.

The *HistoGuide* application complements students learning microscopic practicals, paying attention to drawing, labelling, and applying magnification and scale based on the sixth-form Biology syllabus for STPM in Malaysia. Although the research is confined to sixth-form practicals, the research's benefit can still be applied even in the lower and upper secondary general science subjects and in upper secondary pure science Biology. However, the researcher would not assess the suitability of this learning tool in a different context, for instance, being used in out of sixth-form context. The population of this research is all the Biology students in sixth-form STPM in Malaysia. In contrast, the samples of the actual research are only from the states of Penang and Kuala Lumpur for the pilot studies.

The *HistoGuide* application only supports Android-based operating systems 7.1 and above. It requires internet connectivity. Alternatively, this application can be accessed using Chrome in the iOS operating system (Apple). Although a digital copy of the *HistoGuide* manual is available for the students, it is still the best option to leverage the *HistoGuide* application. It encourages students' collaboration and image manipulation (ability to zoom). Besides that, the *HistoGuide* application only uses free access multimedia available, such as *YouTube*, Microsoft Office, *WordPress* and educational resources from *BioNetwork* and *VirtualLabs*.

In this research, the main focus lies in developing valid and reliable questionnaires for gauging the usability of the *HistoGuide* application and students' drawing and labelling skills achievement and motivation. The adaptation of questionnaires will be discussed in chapter 3. The research only employed two types of instruments for evaluation by the students, mainly the USE questionnaire and RIMMS and volition questionnaire.

Research contamination of the control and treatment groups was possible. Because this study was conducted via an application of self-regulated learning, it was impossible to foresee the samples' relationships. There was no guarantee that the samples would not contact one other in social or academic contexts. However, there was no reason to believe they did. Actions on threats to validity in the research were taken, discussed in detail in Chapter 3.7.4.1.

Furthermore, there was no guarantee that students would complete the task independently with self-regulated learning; this has not been a notable concern for this study. Academic honesty is assumed.

1.8 Operational Definition

There are a few terms or definitions used in this study, and they were defined as follows:

1.8.1 Learning Application

Sidek Mohd Noah and Jamaludin Ahmad (2005) explained that the educational module as a part of the teaching and learning unit is arranged systematically to make students understand easily. Usually, the learning module is designed to help students academically. A module is a plan template of a learning unit or a package comprising many subunits (Faridah Salam, 2015). Meanwhile, Alijah Ujang (2016) describes a learning module as a learning unit comprising hierarchical components completed with relevant resources used in self-regulated learning to achieve certain purposes. Jamalludin Harun and Zaidatun Tasir (2003) state that multimedia is an interactive process based on computer technology, covering media like texts, graphics, audio, videos, and animations. Meanwhile, Norshahila Ibrahim (2011) referred to multimedia as combining and integrating multiple media. The self-regulated multimedia-based learning term is derived.

Hence, in this study, the *HistoGuide* application was developed based on Android multimedia learning, available in *Playstore* to prepare students pre-laboratory and during laboratory practicals. It guides students to draw and label correctly, including applying magnification and scale, complementing conventional microscopic learning.

1.8.2 Validity

A validity test must be carried out to determine whether any modules developed in compliance. Thompson (2013) mentioned that Messick (1989) referred to validity as an essential evaluative assessment determining how empirical evidence and theoretical reasons support the conclusion compatibility and other actions based on the value or other measurement modes. Learning manual validity could be estimated through three criteria, according to Karnela et al. (2018). The three criteria are didactic validity, constructs validity and technical validity (Karnela et al., 2018).

In this study, the *HistoGuide* application validity was checked by experts in three major aspects: content, pedagogy and technology. Experts validated the content of the *HistoGuide* application based on the coherency between learning outcomes of microscopic practicals in the STPM syllabus and the prototype of the *HistoGuide* application. The pedagogical validity of the *HistoGuide* application was evaluated based on the coherency between the two learning theories, motivational theories and the learning modules' instructional materials. The two learning theories are cognitivism and behaviourism. The technology validity of the *HistoGuide* application was evaluated based on the coherency between the multimedia elements within the learning modules in the *HistoGuide* application. All experts' validities were performed by using the evaluation checklist. Cohen's kappa coefficient was used to analyze the data from the evaluation checklist and, later, strengthen it with the content validity index, CVI.

1.8.3 Usability

Usability questionnaires are used to obtain self-reported data from users about their interactions with a particular product or system. The usefulness, satisfaction, and ease of use (USE) questionnaire by Lund (2001) measures a product's or service's subjective usability. Items in the USE questionnaire also have strong face validity, with clear and relevant descriptions. However, little published research has reported the USE's reliability or validity. Because it is non-proprietary, this instrument can be applied to various usability assessment scenarios. The lack of reliability and validity makes researchers hesitant to use the USE questionnaire. Hence, the items underwent a complete psychometric instrument development process to develop a standardized instrument (Gao et al., 2018). By using the USE questionnaire, Hariyanto et al. (2020) revealed in their research that the adaptive e-learning system's usability for students was initially well-approved in all dimensions of usability.

In this study, usability testing refers to testing the usability of the *HistoGuide* application through four constructs: usefulness, ease of use, ease of learning and satisfaction. Usability testing uses the survey method of distributing survey instruments to the samples. The survey has 30 items from the USE questionnaire (Lund, 2001), adapted from Hariyanto et al. (2020). The data is analyzed to gauge the usability of the *HistoGuide* application.

1.8.4 The Impact

The impact is a change due to an action or other causes. The positive impact or benefits produced when self-regulated learning, such as the *HistoGuide* application, produces a desired or positive impact on the outcome to make the learning process efficient and to motivate (Giannakas et al., 2018; Lavasani et al., 2011). On the other hand, the negative impact happens when negative effects are produced on the outcomes.

In this study, the impact is associated with the competence of the *HistoGuide* application as a student's learning tool to gauge their drawing and labelling skills achievement in the school-based assessment and motivation in microscopic practicals. Both impacts are measured by the differences in the mean score of students' pre and post-tests for both control and treatment groups.

1.8.5 Students' Drawing and Labelling Skills

This study employed the school-based assessments by the ministry as post-tests since they are highly valid and reliable. The result of the school-based assessment will reflect their drawing and labelling skills. The pre-tests are designed similarly to the post-tests, where microscopic slide samples are changed (e.g., the *Amoeba* sp. slide is interchangeable with the *Paramecium* sp. slide).

This study uses a quasi-experimental design, and the students' achievement of drawing and labelling skills is analysed based on pre-and post-test mean scores.

1.8.6 Students' Motivation

Motivation has been defined as external environmental conditioning through deprivation and reinforcement regimens (Skinner, 1953). Motivation is the extent and direction learners expend effort to pursue success (Möller et al., 2005). Meanwhile, Keller (2010) defined motivation as the human needs, choices, and abilities to achieve something. Wray (2012) classified motivation as both intrinsic motivation (e.g. desire to gain knowledge) and extrinsic motivation (e.g. desire for high marks and awareness for a new skill). According to Keller (2010), motivation is classified in this study into four categories: attention, relevance, confidence, and satisfaction. The adapted version of the ARCS-V Model is used as the instructional design for the *HistoGuide* application. The Reduced Instructional Materials Motivation Survey (RIMMS) by Loorbach et al. (2015) originated from the Instructional Material Motivational Scale (IMMS) questionnaire by Keller (2010), together with the volition survey (Keller et al., 2020) is employed to gauge students' motivational levels.

Hence, for this study, motivation is an internal, sustained state of an individual that arouses, directs, and maintains behaviour to pursue success (Raber, 2020), which can be affected by external conditions (Skinner, 1953). A quasi-experimental design is carried out for the study, and the student's motivation is analysed based on pre-and post-test mean scores.

1.9 Summary

The problem sixth-form students face when learning microscopic practicals is misconceptions in drawing and labelling, including applying magnification and scale. Besides that, there is also a lack of quality images to guide the students. Students aren't able to observe details. Hence, the *HistoGuide* application is suggested to overcome students' learning problems in microscopic practicals. The *HistoGuide* application is designed based on the digitalization and automation concept in Industrial Revolution 4.0. It can cater to Gen Z's different learning preferences through its features of scaffolding guidance in self-regulated learning through hints and assessment, collaborative image upload, real-time feedback and chatroom pre-laboratory or during laboratory microscopic practicals. The learning is supported by a mobile smartphone application that could go beyond the classroom in ubiquitous learning and follow the learner's pace. Therefore, a website's mobile application, like the *HistoGuide* application, can be an ideal learning material or reference to complement the microscopic laboratory practicals.