DEVELOPMENT AND USABILITY OF POLYCOMPASS IN POLYGON TOPIC AMONG FORM TWO STUDENTS

GAN PEI QI

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DEVELOPMENT AND USABILITY OF POLYCOMPASS IN POLYGON TOPIC AMONG FORM TWO STUDENTS

GAN PEI QI

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ABSTRACT

This study aims to develop PolyCompass for the polygon topic and to evaluate its validity and usability among students. The research design adopted the Design and Development Research (DDR) approach, combined with the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model, to ensure a systematic development process. The research involved 140 Form Two students who were selected through simple random sampling. Two instruments were employed: the PolyCompass Validation Forms and the PolyCompass Usability Form. Expert evaluation revealed that PolyCompass achieved a perfect Content Validity Index value of 1.00, indicating complete agreement among experts regarding the clarity, relevance, and suitability of its content. Usability analysis, based on mean scores, produced an average of 3.95, confirming PolyCompass has a high level of usability as a teaching aid. In conclusion, the developed PolyCompass demonstrates satisfactory validity and a good level of usability. This indicates the potential of PolyCompass to be used in the classroom to enhance teaching and learning for the topic of polygons. Consequently, PolyCompass demonstrates significant potential to enrich the teaching and learning of polygons. Its positive impact extends beyond students and teachers to school authorities and the Ministry of Education Malaysia (MoE), reinforcing its value as an effective educational innovation.

PEMBANGUNAN DAN KEBOLEHGUNAAN POLYCOMPASS BAGI TOPIK POLIGON DALAM KALANGAN MURID TINGKATAN DUA

ABSTRAK

Kajian ini bertujuan untuk membangunkan PolyCompass bagi topik poligon serta menilai kesahan dan kebolehgunaannya dalam kalangan murid. Reka bentuk kajian berasaskan Kajian Reka Bentuk dan Pembangunan (DDR) yang digabungkan dengan model Analisis, Reka Bentuk, Pembangunan, Pelaksanaan dan Penilaian (ADDIE), bagi memastikan proses pembangunan PolyCompass dilaksanakan secara sistematik. Kajian ini melibatkan seramai 140 orang murid tingkatan dua yang dipilih secara pensampelan rawak mudah. Dua instrumen digunakan, iaitu Borang Kesahan PolyCompass dan Borang Kebolehgunaan PolyCompass. Hasil penilaian pakar mendapati bahawa PolyCompass, memperoleh Indeks Kesahan Kandungan yang sempurna iaitu 1.00, sekaligus menunjukkan persetujuan penuh pakar terhadap aspek kejelasan, kerelevanan dan kesesuaian kandungan PolyCompass. Analisis kebolehgunaan berdasarkan skor min menunjukkan nilai purata sebanyak 3.95, yang mengesahkan bahawa PolyCompass mempunyai tahap kebolehgunaan yang tinggi sebagai alat bantu mengajar. Secara kesimpulan, Polycompass yang dibangunkan mempunyai kesahan yang memuaskan dan tahap kebolehgunaan yang baik. Hal ini menunjukkan potensi Polycompass untuk digunakan dalam bilik darjah bagi meningkatkan pengajaran dalm pembelajaran bagi topik poligon. Implikasinya, PolyCompass menunjukkan potensi besar dalam memperkayakan pengajaran dan pembelajaran poligon. Kesan positifnya bukan sahaja melibatkan murid dan guru, tetapi turut memberi manfaat kepada pihak sekolah serta Kementerian Pendidikan Malaysia (KPM), sekali gus mengukuhkan nilainya sebagai satu inovasi pendidikan yang berkesan.

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LIST OF ABBREVIATIONS

ADDIE	Analysis, Design, Development, Implementation and Evaluation
ASSURE	Analyze Learners, State Objectives, Select Methods, Media, and Materials, Utilize Media and Materials, Require Learner Participation, and Evaluate and Revise
CVI	Content Validity Index
DDR	Design and Development Research
DSKP	Standard Curriculum and Assessment Document
DVDs	Digital Versatile Discs
EFL	English as a Foreign Language
EPRD	Educational Planning and Research Division
I-BOX	Digital Toolbox for Innovation in Nursing Education
I-CVI	Item-Level Content Validity Index
IEA	International Association for the Evaluation of Educational Achievement
ISD	Instructional Systems Design
KBSM	Integrated Secondary School Curriculum
KSSM	Standard-Based Curriculum for Secondary Schools
L2	Second-language
LPs	Long-Playing records

MoE	Ministry of Education Malaysia
OECD	Organisation for Economic Co-operation and Development
PBL	Project-Based Learning
PISA	Programme for International Student Assessment
PUF	PolyCompass Usability Form
PVF	PolyCompass Validation Form
S-CVI	Scale-Level Content Validity Index
S-CVI/Ave	the average of I-CVI for all the items on the scale
S-CVI/UA	the proportion of items achieving scale 3 or 4 by all of the experts
SPSS	Statistical Package for the Social Sciences
TIMSS	Trends in International Mathematics and Science Study

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter details the research background and focuses on the main problems in the field of education, especially in mathematics teaching. This chapter also summarizes the challenges encountered by teachers and students in mathematics education, particularly in relation to the topic of polygons. The conceptual framework is guided by the Design and Development Research (DDR) approach, incorporating the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model as the main process framework. Additionally, the study is grounded in the principles of constructivism theory and cooperative learning, which serve as fundamental theoretical foundations.

This chapter also explains the research objectives and questions, clarifying the total goals of the research and the critical issues that need to be solved. The significance of the research is emphasised, highlighting the potential contribution to students, educators, school administrators, and the Ministry of Education Malaysia (MoE).

Lastly, this chapter points out the current limitations and defines basic terms used in the study to secure clarity and consistency in the subsequent discussion.

1.2 Research Background

According to the National Education Philosophy, Malaysian education system aims to develop the well-rounded individuals, producing those who are intellectually, spiritually, emotionally and physically balanced, and guided by faith and devotion to God (Rosli et al., 2022). The implementation of the Malaysia Education Blueprint 2013–2025 reflects the Ministry of Education's strong commitment to providing high-quality education for all students, ultimately shaping a generation capable of contributing knowledge and skills while remaining globally competitive (Kementerian Pendidikan Malaysia, 2020).

Mathematics is one of the core subjects in the Standard-Based Curriculum for Secondary Schools (KSSM). Mathematics plays various roles in human daily life, leading to different interpretations. The wide application of mathematics in everyday

situations helps everyone recognize the importance of this field. Aprinastuti (2020) describes that mathematics is not just a subject, but also emphasizes the critical role in cultivating strategic, organizational, analytical and complete abilities. Mathematics helps organize the mind, nurtures problem-solving skills, and is applied in many aspects of life, making this discipline particularly critical in today's society. This subject is seen as a critical part of education to equip Malaysians with essential skills for the 21st century (Liew & Teoh, 2022). Observe how widely the concepts, structures, quantities, and spaces in mathematics are implemented across various fields. This discipline truly aligns with the pace of educational development and globalization in Malaysia. Therefore, the national mathematics curriculum has been revised and adjusted to ensure that students can acquire the necessary knowledge and skills (Chuan et al., 2021).

In 2017, KSSM was launched, replacing the previous Integrated Secondary School Curriculum (KBSM). This transformation draws on the experiences of countries that perform well in international assessments to ensure that Malaysia's curriculum remains up to date and aligned with international standards (Kong & Rosli, 2024). The secondary-level mathematics curriculum builds upon foundational knowledge and skills acquired in primary education. The primary objective of this curriculum is to develop students' numerical understanding, computational abilities, comprehension of fundamental mathematical concepts, and the capacity to apply mathematical knowledge effectively and responsibly in real-life situations. MoE focuses on developing students not only to master numerical concepts, but also to apply these concepts in everyday life, based on the principles of problem-solving, communication, reasoning, making connections, representation, and technology.

Sole reliance on teacher-centered instructional approaches can result in passive learning and reduced student enthusiasm, since such methods position learners as mere recipients of knowledge and restrict opportunities for meaningful engagement (Alqahtani & Alhamami, 2024). While teaching approaches have become more cutting-edge, many schools still stick to the old teaching model by focusing solely on theories and textbook reading in class, without using teaching aids or engaging in interactive exercises. Spitzer and Musslick (2021) argue that the absence of instructional materials can hinder learning and limit students' ability to understand. Similarly, Tamalene et al. (2022) highlight that inadequate physical resources for concept demonstrations hinder the development of visualization skills and make several abstract numerical concepts difficult to grasp. In such situations, students' interest and participation in mathematics may gradually decline, eventually leading to a reduction in academic performance. Therefore, the integration of innovative teaching aids is crucial for helping students understand mathematical concepts and enhancing learning efficiency.

By observing students' responses to the teaching aids, the efficiency of the learning process can be evaluated. Selecting appropriate teaching aids is particularly critical in classroom settings because these aids can increase student participation and improve content comprehension. Research has shown that integrating teaching aids into the learning environment enhances overall teaching and learning effectiveness, especially in mathematics education. These aids make lessons more engaging and memorable, assist in addressing learning difficulties, and support the understanding of abstract numerical concepts (Hubulo et al., 2022).

Therefore, educators must master the selection of appropriate teaching aids and demonstrate skillful application during instruction. This is because the effectiveness of teaching depends largely on the ability to choose suitable approaches and strategies (Ramli & Tajudin, 2021). One of the most effective approaches involves incorporating teaching aids into teaching practice. The integration of teaching aids in mathematics lessons can enhance students' interest and support the understanding of seemingly abstract numerical concepts.

Thus, this research aims to develop and explore the use of PolyCompass as a potential solution to challenges in achieving an effective teaching and learning process. In addition, this study is intended to help students gain a deeper understanding of polygons in a more efficient and engaging way.

1.3 Problem Statement

Geometry is a fundamental branch of mathematics that significantly enhances spatial reasoning and problem-solving skills. Among the most essential topics in this field, polygon studies are emphasized, as this area serves as the cornerstone for learning more advanced mathematical concepts. However, many students find polygon-related concepts difficult to understand, which creates challenges in mastering overall mathematical skills.

One of the main difficulties in understanding polygons is the overreliance on rote memorization when applying formulas, rather than using logical reasoning. Darmawan (2020) observes that students frequently apply standard formulas from memory without fully grasping the underlying geometric relationships. Consequently, students encounter challenges when applying these formulas in unfamiliar situations. Similarly, Rzyankina et al. (2024) note that proficiency in formula manipulation does not necessarily reflect deep conceptual understanding, which hinders the effective application of mathematical principles in both problem-solving and real-world contexts. Additionally, Hajar et al. (2023) demonstrate that misconceptions, coupled with procedurally-oriented learning approaches, significantly hinder students' understanding, with particular impact on topics involving angles and polygons.

Another significant pedagogical challenge involves difficulties in comprehending angle properties, which stem from an overreliance on procedural methods rather than reasoning. Bello and Rosario (2020) point out that many students lack a solid grasp of basic angle concepts, which directly undermines students' ability to accurately apply geometric principles in problem-solving contexts. Fortunately, structured problem-solving techniques, such as Pólya's heuristics, have proven effective in enhancing comprehension by fostering logical thinking and promoting active participation. Furthermore, Bernabeu et al. (2021) indicate that students often struggle to classify polygons due to the distinct characteristics of each shape. This confusion is compounded by misunderstandings surrounding interior angle properties, which severely limit learners' analytical skills. Saad and Mamat (2022) also note that when dealing with polygon-related topics of varying complexity, students frequently rely on memorization without striving to understand the underlying concepts.

A specific difficulty in geometry involves understanding why the sum of exterior angles in any polygon always equals 360°. This challenge often arises from a lack of hands-on practice, which prevents deeper conceptual learning. Traditional instructional methods emphasize memorization over exploration and reasoning, thereby limiting students' ability to comprehend the mathematical reasoning behind this fundamental property. Cullen et al. (2020) emphasize the importance of interactive learning experiences that allow students to test hypotheses, explore geometric relationships intuitively, and build strong reasoning skills. The absence of experiential learning opportunities restricts students' ability to apply mathematical concepts beyond basic calculations, ultimately resulting in difficulty understanding and solving real-world problems.

In addition to conceptual challenges, mathematics anxiety presents a common challenge that often reduces students' enthusiasm for learning and academic performance. Many students develop a fear of mathematics due to anxiety stemming from fear of failure (Bhat & Arumugam, 2020). This anxiety often stems from inadequate learning experiences, social pressures, and difficulties in grasping mathematical concepts, ultimately discouraging active participation. Hidayat et al. (2023) find that ongoing struggles with mathematical topics often lead to feelings of helplessness, which in turn heighten anxiety and obstruct academic progress. This creates a cycle where polygon learning becomes increasingly difficult as students' confidence diminishes.

Compounding these issues, a lack of interactive teaching methods further intensifies these challenges. In many classrooms, mathematics instruction remains teacher-centered, with content delivered through lectures and minimal student engagement. This passive approach restricts conceptual exploration and weakens long-term retention. Specifically, in lessons about polygons, interior and exterior angles are often introduced through theoretical explanation and formula application, rather than interactive or exploratory methods. Without the integration of tools such as dynamic geometry software, collaborative tasks, or real-life applications, students often struggle to understand the relevance of abstract mathematical concepts.

This concern was validated through a needs analysis conducted by the researcher involving 30 Form Two students, where the majority (63.3%) rated their understanding of polygons as poor or very poor. Moreover, 90% of the students reported difficulties in remembering or deriving the formula for the sum of interior angles of a polygon, while 83.3% struggled to understand why exterior angles always sum to 360 degrees. Significantly, 80% attributed these challenges to the lack of interactive learning tools. When asked about preferred learning strategies, 63.3% favoured physical models or manipulatives, whereas interest in textbooks, digital platforms, or video-based resources was minimal. These findings clearly demonstrate the need for more interactive, hands-on teaching aids in polygon instruction.

Despite mounting evidence supporting interactive approaches, conventional methods remain dominant in many classrooms. Susanti et al. (2022) find that traditional instructional methods generally fail to engage students, which leads to greater difficulty

in understanding mathematical concepts when interactive sessions are absent. Similarly, Adnyani (2020) observes that student interest declines when learning is based solely on textbooks, while Afzal (2023) notes that rigid instructional strategies contribute to disengagement. Moreover, Che Ibrahim et al. (2021) highlight the continued use of the "Chalk and Talk" method, which lacks opportunities for creativity, critical thinking, and problem-solving, thereby weakening the application of mathematical knowledge. Abdul Hanid et al. (2022) emphasize that memorizing geometry content without understanding leads to poor academic performance. Consequently, Ramli and Tajudin (2021) assert that effective instructional strategies are essential for academic success, and Mahat et al. (2020) stress the value of innovative teaching aids in enhancing knowledge acquisition. Supporting this view, Fauzi and Abdullah (2021) demonstrate that teaching aids improve engagement and help simplify difficult concepts. However, despite the growing support for innovative practices, traditional teaching persists due to teacher familiarity, limited time, and insufficient access to professional development.

The fundamental importance of geometry in mathematics education has been extensively documented in scholarly literature, with researchers emphasizing the significance of this mathematical domain at all educational stages. Madjunun and Abd Karim (2023) highlight the significance of visual representation, particularly in secondary education for learning polygon-related concepts. Concurrently, Sunzuma (2023) describes geometry as inherently abstract and difficult, posing challenges for both teachers and students. According to Adisasongko et al. (2021), a solid foundation in basic geometry is essential for technical drawing, a key subject in vocational education. However, many vocational students view geometry as difficult, which lowers engagement and motivation. Without the implementation of effective, research-

informed solutions, these issues continue to hinder the development of strong conceptual understanding in geometry, especially in polygon studies.

In response to these issues, this study introduces a teaching aid called PolyCompass, specifically designed to help Form Two students learn and understand polygons more effectively. PolyCompass provides a more interactive and engaging way to explore polygon-related concepts, fostering deeper understanding and greater participation in class. This aid supports conceptual learning and significantly enriches the overall educational experience in geometry instruction.

1.4 Research Objective

This research has been attempted with the following objectives:

1. To develop the PolyCompass for Form Two Polygon topic with acceptable level of validity.

2. To measure the usability of PolyCompass for Polygon topic among Form Two students.

1.5 Research Question

This research is conducted to answer the following research questions:

1. Does PolyCompass for Form Two Polygon topic have acceptable level of validity?

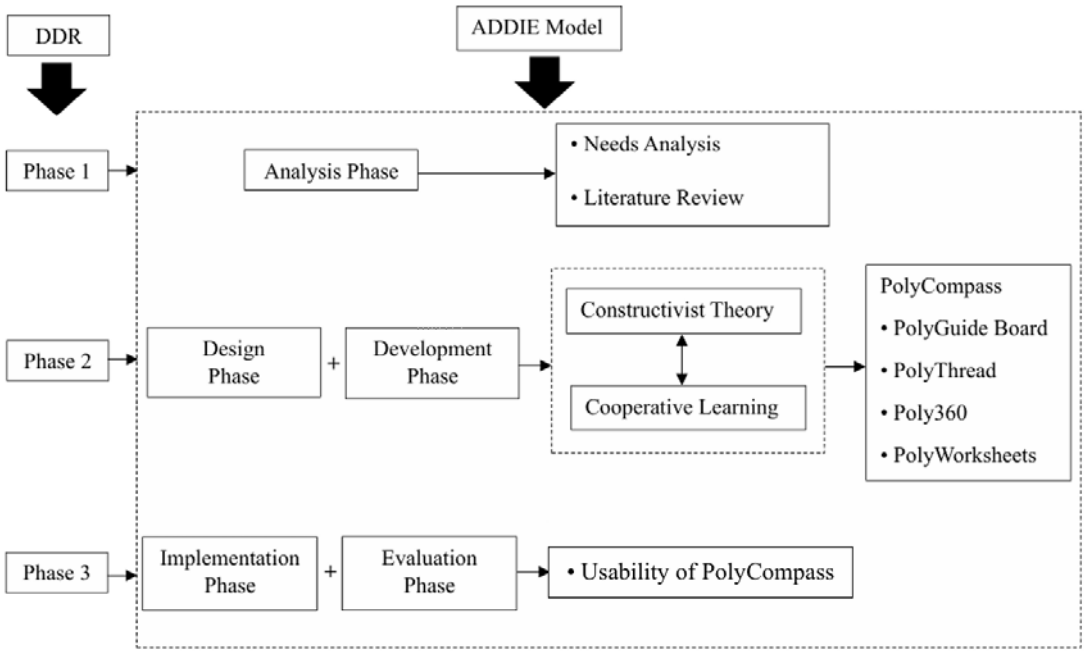
2. Does PolyCompass for Polygon topic among Form Two students have excellent usability?

1.6 Conceptual Framework

The conceptual framework organizes core ideas and fundamental concepts in an orderly manner, drawing from existing theories, key research findings, policy guidelines, and expert opinions to provide a solid foundation for the research (Shikalepo, 2020). Through this framework, the study clarifies the key elements and references that guide the research. The conceptual framework is presented in Figure 1.1, adapted from Idris et al. (2022) and Nadzrin et al. (2022).

Figure 1.1

Conceptual Framework



Within this framework, PolyCompass is developed using the Design and Development Research (DDR) approach in combination with the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model.

The initial phase, corresponding to the Analysis stage of the ADDIE model, involves a comprehensive needs analysis and literature review to identify challenges faced by students in learning the topic of polygons. This diagnostic phase informs the subsequent design of the instructional tool by highlighting specific content gaps and pedagogical needs.

In the next stage, the Design and Development phases of the ADDIE model are implemented concurrently. PolyCompass is structured based on the principles of constructivist theory and cooperative learning. Constructivism emphasizes a student-centered approach, allowing learners to build knowledge independently based on prior understanding (Alam, 2023). This approach encourages active engagement, teamwork, and inquiry-driven learning, with teachers serving primarily as facilitators (Alam, 2023). Meanwhile, cooperative learning is an instructional strategy that involves students working collaboratively in small groups toward shared goals, enhancing comprehension through peer interaction and collective problem-solving (Suryadi et al., 2024).

The Development phase involves the construction of PolyCompass using various materials, including an A3-sized cardboard sheet, two A3 paper sheets, eight 180° protractors, one 360° protractor, nine push pins, a roll of cotton thread, three A4-sized cardboard sheets, five A4 paper sheets, coloured paper, and multiple Velcro dots. The teaching aid comprises four main components: PolyGuide Board, PolyThread, Poly360, and PolyWorksheets. Each component is thoughtfully designed to enhance students' understanding of polygon concepts through interactive and visually engaging learning experiences. The Development phase also includes the establishment of face validity and content validity through expert review.

The final stage integrates the Implementation and Evaluation phases of the ADDIE model. This stage involves determining the reliability of the research

instruments and assessing the usability of PolyCompass. These aspects are analysed using Cronbach's alpha and descriptive analysis.

1.7 Research Significance

This research primarily focuses on the development of PolyCompass for the topic of polygons, with the aim of stimulating students' interest and making the educational process smoother and more efficient. The implementation of PolyCompass in this study holds significant value for various stakeholders:

1.7.1 Students

The introduction of PolyCompass greatly supports students in understanding and mastering the topic of polygons. Additionally, PolyCompass is specifically designed for Form Two students studying this topic. This teaching aid helps students stay focused during lessons by stimulating interest and encouraging active participation. As a result, learning efficiency increases significantly, with more opportunities for peer interaction and cooperative learning.

1.7.2 Educators

The integration of PolyCompass provides educators with an innovative method for conducting lessons and fresh ideas for delivering mathematical concepts. This invention enables mathematics teachers to move beyond a single teaching model by emphasizing the value of diversified instructional methods and reinforcing a deeper understanding of teaching practices. As a result, students are more likely to stay focused and develop greater interest in the subject. In addition, educators can also introduce PolyCompass to trainee teachers as a practical teaching aid for classroom activities to promote a more interactive and effective learning environment.

1.7.3 School Authorities

The development of PolyCompass can provide students with a more vivid and practical educational experience. High-quality and engaging teaching aids benefit all students by supporting the development of critical and creative thinking. Additionally, the use of effective teaching aids enhances problem-solving skills and equips students to keep pace with the demands of a rapidly changing world.

1.7.4 Ministry of Education Malaysia

This research provides significant insights into the educational benefits of implementing PolyCompass in the teaching and learning process. Given the demonstrated advantages of this pedagogical tool, Ministry of Education Malaysia (MoE) can encourage teachers to integrate PolyCompass into mathematics instruction. Incorporating PolyCompass into classroom practice has the potential to elevate student engagement and sustain attention throughout mathematical learning activities.

1.8 Limitation

This study has several limitations. Firstly, this research focuses solely on the development and usability of PolyCompass, while the impact on students' academic achievement remains unexamined.

Furthermore, the investigation is confined to the Polygon topic within the Form Two mathematics curriculum. Research findings may differ considerably when conducted with students from other academic levels, as mathematical comprehension varies significantly across educational stages.

The time-restricted nature of this study presents another notable limitation. Expected changes in future educational curricula may affect the accuracy and applicability of the conclusions, potentially making these results less relevant as a reference for future research.

1.9 Conceptual and Operational Definition

This research requires precise clarification of key terms to ensure accurate interpretation of the study. The definitions presented herein correspond directly with the research objectives and scope, thereby avoiding unnecessary misunderstandings. Well-articulated operational terms are critical for maintaining consistency throughout the study. Three fundamental concepts underpin this study: development, usability, and Polygon topic.

1.9.1 Development

Hornby (2020) describes development as a process of creating or improving something to achieve a new or enhanced form. Stapa and Mohammad (2019) define development as a systematic method for building models, creating software, or designing modules.

In the context of this study, development specifically refers to the creation of PolyCompass as a teaching aid for the Polygon topic.

1.9.2 Usability

Usability refers to the degree of user satisfaction during product interaction, encompassing elements such as ease of use, effectiveness, safety, and behavioural patterns observed during engagement with the tool (Chang & Johnson, 2021). Furthermore, usability plays a critical role in both the evaluation and implementation phases of educational programs. Challenges related to usability may hinder learning objectives, ultimately affecting improvements in educational standards and students' understanding of mathematical concepts.

According to Sedrakyan et al. (2020), the three primary aspects of usability are effectiveness, efficiency, and satisfaction. Effectiveness measures the accuracy and completeness with which users accomplish tasks. Efficiency evaluates the extent to which resources are utilized to achieve objectives while maintaining accuracy. Satisfaction reflects the level of comfort and enthusiasm users experience when interacting with the system.

In this research, the effectiveness of PolyCompass is assessed based on design quality and content appropriateness. Efficiency is measured by evaluating accessibility

and the feasibility of integration within the teaching and learning process. Satisfaction is determined through participants' preferences and experiential feedback regarding the learning experience.

1.9.3 Polygon topic

Polygon topic is a fundamental component of the Form Two Mathematics syllabus, providing students with essential geometric foundations that support further mathematical development throughout secondary education. This topic emphasizes understanding the characteristics of polygons, methods of classification and construction, as well as the relationships between interior and exterior angles.

1.9.4 PolyCompass

PolyCompass serves as an effective teaching aid, enabling learners to actively explore polygon construction and angle calculation through hands-on activities. Through physical manipulation of geometric forms, students not only develop a deeper understanding of geometric principles but also gain a stronger grasp of mathematical concepts such as the sum of interior and exterior angles. This experiential pedagogical

approach enhances visual-spatial skills while simultaneously fostering analytical thinking, engagement, and mathematical reasoning.

1.10 Summary

Overall, this chapter discusses the foundational elements of the study, such as the introduction, research background, problem statement, research objectives, research questions, conceptual framework, research significance, limitations, and conceptual and operational definitions. The study focuses on developing PolyCompass for the Form Two Polygon topic, with the goal of helping students better grasp and understand the content. The application of PolyCompass enables learners to navigate the complexities and challenges inherent in polygon comprehension more effectively. The outcomes of this research are expected to serve as a valuable resource for educators, particularly mathematics teachers, by offering an innovative methodological approach to enrich instructional and learning experiences.