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THE DESIGN AND EFFECTIVENESS OF INFOGRAPHICS FRAMEWORK FOR LEARNING DATA STRUCTURE AND ALGORITHMS AMONG UNIVERSITY STUDENTS

HUSNI NAPARIN

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THESIS PRESENTED TO QUALIFY FOR A
DOCTOR OF PHILOSOPHY

FACULTY OF COMPUTING AND META-TECHNOLOGY
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I, Husni Naparin, P20152002303, Faculty of Computing and Meta Technology (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled The Design and Effectiveness of Infographics Framework for Learning Data Structure and Algorithms Among University Students is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

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APPRECIATION

After difficulty, there is an ease, all praises to Allah SWT, the Lord of the universe, the owner of all the knowledge that has given the author the ability to complete the Thesis entitled "THE EFFECTIVENESS OF INFOGRAPHICS FRAMEWORK FOR GRAPH DATA STRUCTURE and ALGORITHMS". Help and support from various parties are invaluable. The author is grateful to Prof. Madya. Dr. Aslina binti Saad as the first Supervisor who has given her knowledge for 6 years with great patience and spent a lot of time. Dr. Ismail Yusuf Panessai, as the second Supervisor, always gives all directions and advice in solving every problem during the guidance. Dean of the Faculty of Computing and Meta-Technology, who has given ease in administration matters and helps provide the best facilities for UPSI education, as well as his wonderful hospitality. Deputy Dean of the Faculty of Computing and Meta-Technology, which also provides motivation and always opens a collaborative space in Computer education. The lecturer from the Faculty of Computing and Meta-Technology has given her knowledge and a very deep explanation of the Data Structure and Algorithm. All experts who have assisted in collecting research data and providing information based on their respective fields of expertise. All the Faculty of Computing and Meta-Technology Staff, for all assistance in solving problems, contributions of thought, attention, expectations and prayers that have been provided in the preparation of this thesis. To all who have been assisted that cannot be mentioned one by one, may Allah give a double reward for you. The author realized that this research still has many shortcomings. Therefore, it is hoped that criticisms, suggestions and constructive input will greatly assist the author in further research. Hopefully, this research is useful in the development of science.

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ABSTRACT

The aim of this study is to design and evaluate the effectiveness of an *Infodas* (Infographics framework for a Data Structures and Algorithms (*DAS*)) course on the topic of graphs. Its objective is to solve the difficulty of learning programming concepts, namely manipulation, program construction loops, structures control and algorithms, theoretical concepts and techniques, and write programs to solve problems. The research methodology is Design-Based Research (*DBR*), a comprehensive approach comprising analysis, design, development of an infographics framework and rigorous evaluation phases. The content of infographics design education was analyzed through a literature review and interviews. The Delphi method engaging seven design experts and five *DAS* content experts, was utilized up to the second cycle to evaluate expert opinions regarding on infographics elements and content related to *DAS*. The first phase of this research aimed to develop an infographics framework to assist educators in designing infographics for *DAS*. The elements included in the proposed framework are title, colors, text/fonts, graphics/charts/pictures/images, data, content and design. The second phase involves evaluating the constructed infographics, which were developed based on the framework, using quasi-experimental techniques. It included 30 students from class A (control class) and 31 from class D (experimental class). The subjects of the study are the first-semester students of the Information System and Information Technology Department from a local university in Banjarmasin, Indonesia, with the experimental study lasting two months. The T-Test result for the post-test was t (59) = - 7387, P = 0.000, indicating a significant difference in achievement between the experimental class that uses infographics and the control class that does not use an infographics framework. In conclusion, *Infodas* has a significant impact on students' ability to learn *DAS*. This study's implication is that it encourages the development of teaching materials by providing infographics development guidelines for courses that have similar characteristics.

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REKA BENTUK DAN KEBERKESANAN RANGKA KERJA INFOGRAFIK: PEMBANGUNAN DAN PENILAIAN UNTUK STRUKTUR DATA DAN ALGORITMA DALAM KALANGAN PELAJAR UNIVERSITI

ABSTRAK

Kajian ini bertujuan untuk mereka bentuk dan menilai keberkesanan *Infodas* (rangka kerja Infografik bagi kursus Struktur Data dan Algoritma (*DAS*)) mengenai topik graf. Ia bagi mengatasi kesukaran dalam mempelajari konsep pengaturcaraan, iaitu gelung pembinaan program, manipulasi, struktur dan algoritma kawalan, konsep dan teknik teori, dan menulis atur cara untuk menyelesaikan masalah. Metodologi kajian ialah Penyelidikan Berasaskan Reka Bentuk (*DBR*), yang terdiri daripada fasa analisis, reka bentuk, pembangunan rangka kerja infografik, dan penilaian. Kandungan reka bentuk infografik bagi pendidikan dianalisis melalui tinjauan literatur dan temu bual. Kaedah Delphi melibatkan tujuh pakar reka bentuk dan lima pakar kandungan *DAS*, digunakan sehingga kitaran ke-2 untuk menilai pendapat pakar tentang elemen infografik dan kandungan dari *DAS*. Peringkat pertama untuk penyelidikan ini ialah membangunkan rangka kerja infografik untuk membimbing para pendidik dalam membangunkan infografik untuk *DAS*. Elemen infografik dalam rangka kerja yang dicadangkan ialah tajuk, warna, teks/fon, grafik/carta/foto/imej, data, kandungan dan reka bentuk. Peringkat kedua ialah penilaian infografik yang dibina berdasarkan rangka kerja yang telah dinilai dengan menggunakan teknik eksperimen kuasi. Penyelidikan ini melibatkan 30 orang pelajar kelas A (kelas kawalan) dan 31 orang pelajar kelas D (kelas eksperimen). Subjek kajian adalah pelajar semester satu Jabatan Sistem Informasi dan Teknologi Informasi di universiti tempatan di Banjarmasin, Indonesia, yang mengambil masa dua (2) bulan untuk kajian eksperimen. Keputusan ujian T bagi ujian post ialah t (59) = - 7387, P = 0.000, menunjukkan terdapat perbezaan signifikan dari aspek pencapaian antara kelas eksperimen yang menggunakan infografik dan kelas kawalan yang tidak menggunakan kerangka infografik. Kesimpulannya, *Infodas* memberi impak yang berkesan terhadap keupayaan pelajar untuk mempelajari *DAS*. Implikasi kajian ini ialah menggalakkan pembangunan bahan pengajaran dengan menyediakan garis panduan pembangunan infografik bagi kursus yang mempunyai ciri yang sama.

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LIST OF ABBREVIATION

ADDIE	Analysis, Design, Development, Implementation, and Evaluation
AI	Artificial Intelligence
CLT	Cognitive Load Theory
CL	Cognitive Load
WM	Working Memory
CMM	Capability Maturity Model
DBR	Design Based Research
DI	Discrimination Index
DV	Dependent Variable
DDR	Design and Development Research
EFL	*English as Foreign Language*
EV	Extraneous Variable
GRE	Graduate Records Examination
IMOOC	Indonesian Massive Open Online Course
INFODAS	Infographics for Data Structure and Algorithms
IV	Independent Variable
LR	Literature Review
PNG	Portable Network Graphics
PR	Public Relation
RAI	Regional Authority *Index*

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SC	Social Cognitive
SCE	Social Cognitive Emotional
SDA	Structure Data and Algorithms
SPSS	Statistical Package for the Social Sciences
STEM	*Science, Technology, Engineering, and Mathematics*
UBL	Universitas Budi Luhur
UMP	Universitas Muhammadiyah Palangkaraya
UNISM	Universitas Sari Mulia
UPSI	University Pendidikan Sultan Idris
UX	User Experience

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The use of infographics for information display and communication has become widely accepted in popular culture. They can be found on websites for business, news, and social media. Since infographics combine attractive visualization with a powerful method of delivering straight information, they are a special type of visualization that may be utilized as a teaching tool for both students and teachers. Other than that, infographics have been shown to be effective at guiding non-expert audiences in making judgements about the messages they wish to convey based on their own needs.

Challenges in learning programming might be overcome by using infographics. According to studies, utilizing current technology in the classroom helps students learn more quickly, effectively, and with greater satisfaction from their attendance. Arifin et al. (2022), Mahajan et al. (2020), and Alemdag and Cagiltav (2018) reported in their studies that utilizing media for teaching audiences is very useful. Furthermore, it is valuable as well as efficient to use media in teaching students (Kamelia, 2019; Esteves

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& Neves, 2019). People are drawn to the visualizations, colors, and images of infographics, which suggests that this attraction is part of their very essence. An infographic can convey knowledge about a subject more quickly and efficiently than pure text. Nevertheless, this condition depends on the infographic's form and presentation.

When learning basic programming concepts, several challenges arise. For instance, this includes loops manipulation (Green & Chen, 2019), program construction (Karvelas & Becker, 2020; Robin, 2019), structures control and algorithms (Zavgorodniaia et al., 2021; Mcquaigue, 2018). According to other studies, the main causes of these challenges are ineffective teaching strategies, low levels of student participation in class, and a lack of interest (Marwan et al., 2020; Erümit et al., 2019; Islam et al., 2019; Cheah, 2020; Figueiredo & García-Peñalvo, 2022). In addition, novice students' lack of interest is typically linked to the fact that they view programming to be full of boring theoretical concepts and procedures (Mason et al., 2018; Medeiros et al., 2018; Luxton-Reilly et al., 2018; Xie et al., 2019). Basic programming is about data structure and algorithms material, and it needs to be explored and taught in the classroom.

Most students need to understand data structure and algorithms because all programming fields use them for concept learning (Xie et al., 2019). To start learning programming fields, data structure, and algorithms material usually in the university environment begins in semester one (1). One of the most important materials is data structure and algorithms and it must be improved through infographic media. In the

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teaching and learning process, to ensure lecturers or teachers that students can understand material programming in the first stage.

The infographics look more interesting and can show much information in many places, not only in the classroom but also in every place, such as roads, studios, government, private companies or websites, social media, and others. Students can see infographics many times every day, and they can take information from just one page to understand quickly and clearly (Wilke, 2019; Majooni et al., 2018). The information is not too much, which is why it is very easy to remember. The researcher chooses infographics as a new, interesting and creative media for learning.

Therefore, this research aims to design an infographics framework as a mechanism to assist students in learning data structure and algorithms materials. The design is concerned with utility, soundness and attractiveness as the categories of infographics design.

1.2 Research Background

Information visualization, emphasizes the use of interactive, functional visual representations of abstract data that are computer-assisted in order to enhance cognition (Ware, 2019; Mei et al., 2018; Prasad et al., 2022; Edler et al., 2020). Similarly, the visualization is related to aesthetic information and adopted more interpretive mapping techniques with extrinsic meaning to more effectively convey meanings underlying data sets (Cordeil et al., 2017; Ens et al., 2020; Mladenović et al., 2021; Jalalitabar &

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Wang, 2022). Additionally, data visualization can complement infographics' role in producing visuals with a clear visual message by acting as a potent instructional tool (Elvina et al., 2018; Ismaeel & Al Mulhim, 2021; Medrano & Pacis, 2022). Graphical displays make it easier to retain information because, for most individuals, visual memory is more lasting than verbal or auditory memory. They also make it easier to visualize and analyze the message included in the data (Darcy, 2019; Icht, 2020; Alotwi, 2021; Ibrahem & Alamro, 2021).

Infographics have three (3) main components that make up their structure. They are Knowledge, Visuals, and Content (Darcy, 2019); (Jahan et al., 2021); (Rahim, 2016). Infographics are a method of information visualization in computer science which is very appealing to readers because it can give information in just one page, so the student can see effective and interesting information (Wilke, 2019; Majooni et al., 2018). Infographics have been broadly utilized in many fields. In the education field, the researchers (Siricharoen & Siricharoen, 2016; Muir & Munroe-Chandler, 2020; Hernandez-Sanchez, 2021; Barlow, 2021; Zou et al., 2018; Linda et al., 2018; Rodríguez et al., 2021; Jumma, 2019; Baratzadeh et al., 2020; Almunive & Alshammari, 2018) conducted research on the infographics effect in numerous fields, for instance, health education, agricultural science, geographical information science, algorithms, education, as well as computer science. On the other hand, Opoku et al. (2021), Lyra et al. (2016), Alqudah et al. (2019), Becerra (2015), Jagtap and Singh (2021), and Albers (2014) analyzed the use of infographics in different areas and how to implement infographics in teaching. For example, this includes technology management, advanced learning technologies, curricula and teaching methods, applied psychology, education design, as well as general knowledge. On the other hand,

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Ozdamli et al. (2016), Fadzil (2018), Al-Tukruni (2019), Marouf et al. (2018), and Almasri et al. (2019) did research using infographics presentations in computer science, organic chemistry, mathematics, and information technology fields to solve students' difficulties. Their studies have revealed that presentation by infographics can be applied in many other courses. Good infographics should be designed to make them meaningful and useful in teaching and learning. Previous research has defined the characteristics of good infographics. It should consist of a good title (Dalton, 2014, Salim et al., 2021), suitable graphics/charts/pictures/images (Grieger & Leontyev, 2021; Zhao, 2016; Jagtap & Singh, 2021), readable text/font (Akhmad et al., 2018; Wilke, 2019), a clear content (Dunlap & Lowenthal 2016; Lyra et al., 2016), reliable data (Wilke, 2019; Salim et al., 2021; Akhmad et al., 2018), have excellent use of color (Chen et al., 2019; Zhao, 2015; Salim et al., 2021), and an appropriate design format (Grieger & Leontyev 2021; Tu et al., 2018; Ibrahem & Alamro, 2021; Egan et al., 2021; Doomgard & Park, 2021; Liu & Wu, 2021).

Information visualization can be delivered, especially in this research about learning programming. Several challenges emerged when learning basic programming concepts like program construction (Karvelas & Becker, 2020; Robin, 2019), loops manipulation (Greena & Chen, 2019) and structures control & algorithms (Zavgorodniaia et al., 2021; Mcquaigue, 2018. On the other hand, Jamil and Isiaq (2019), Durak et al. (2019) and Yildiz (2020) claimed that learning how to use programming languages to create programs that address problems is a challenging process for many students. Based on these problems of how to teach programming fields in classrooms, the infographics framework is offered by the researcher as the appropriate media for solving the difficulties in learning to program using infographics

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that contain useful information and interesting designs for students. This infographics framework offers various materials inserted, resulting in an interesting design. Infographics could be employed as a learning media to contribute greatly to teachers/lecturers in delivering learning material.

The elements of infographics are going to be formulated based on how many elements are in infographics, the elaboration of the elements, the position of the elements, and what the material will include in the elements for this research. The research was done in a private university in Indonesia in the first semester. The output for this research is an infographic framework in digital form (canva, pictochart, power point) and printed infographics.

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In this research, infographics are focused on all the elements to become a framework to convey material in data structure and algorithms (DAS). Formulating all the elements and design in infographics in education, especially for DAS material, so the framework infographics for data structure and algorithm *(infodas)* can be guidelines for lecturers or lectures.

1.3 Problems Statement

Delivering material with an interesting picture and effective sentences is one way to improve students' understanding in learning programming (Kaya-Hamza & Beheshti-Fezile, 2017; Bystrova, 2020; Rivers, 2021). In determining the design of the material, educators need more detail about the element of infographics and material to integrate with good design and easy to understand about the topic.

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Although many studies have been done on infographics, there is no standard for designing infographics in the education field, what the elements have to include in the infographics in education, data structure and algorithms material (Lyra et al., 2016; Ozdamli et al., 2016; Grieger and Leontyev (2021). There are many infographics in the business field, such as marketing, advertisement, banner, the performance of the data, pictures in health, and data with graphs. Many infographics have an attractive design, a lot of information, bright colors, and good illustrations. Nevertheless, there was no explanation of standard elements and no composition of the comparison of each element to be called an infographic, specifically in the education field. Infographics, in general, and other fields, can help the researcher establish detailed elements standardized for infographics in education (edugraphics).

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To make more detailed elements of edugraphics, it is crucial to investigate the elements based on infographics, the designer, and a literature review about infographics in the education field. The goal of finding detailed elements of the infographic is to develop the framework so that educators can refer to this framework in designing edugraphics.

According to studies, utilizing contemporary technology in the classroom allows students to pick up information more quickly, with better functionality, and with a greater sense of satisfaction from their attendance. People are drawn to the visualizations, colors, and images of infographics, which suggests that this attraction is part of their very essence. An infographic can convey knowledge about a subject more

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quickly and efficiently than pure text. Nevertheless, this condition depends on the infographic's design and presentation.

Since infographics combine attractive representation with a powerful method of delivering straight information and may be utilized as a learning tool for both teachers and students, they are also a distinctive style of visualization. It has been proven that infographics may be applied to inform non-expert audiences, enabling them to decide what messages they wish to convey based on their needs. Infographics should be designed by professionals if they are to convey data visualization effectively. Note that infographics' primary purpose will be served by design elements that accurately represent the data and a general layout that is appealing and easy to comprehend.

Before decorating, creators of infographics should prioritize structure, accuracy, reliability, depth, and functionality. Infographics require evaluation, analysis, and invention. It is necessary to apply graphs, statistical charts, or a geographic context to a tale with a map to display the vast amount of information in a large data set.

This study differs from earlier ones since it looked into infographic usage, infographic use in the realm of education, and infographic design. Moreover, it allows scholars and others to learn more about the use and design of infographics. This is due to the fact that students may find the teaching and learning process to be more engaging and clear. Hence, this study offers a thorough analysis of current initiatives to look into those three factors.

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Infographics are widely utilized in various contexts, including business, health, industry, advertising, e-commerce, and education. Note that an infographic's design should complement its purpose. For instance, an infographic can be employed as a marketing tool or to promote a service or product in the company. On the other hand, an infographic can be applied as a type of instructional media in the education field and is intended to improve students' comprehension of the subject's material. Thus, it is crucial to look at infographic design for instructional reasons. There have been discovered various components. This study aimed to select the right infographic components, particularly for programming-related infographics.

The need for this research is greatly increased by the numerous challenges that arise when learning basic programming concepts, for instance, loops manipulation (Ginat, 2004), program construction (Lahtinen et al., 2005), structures control and algorithms (Seppala et al., 2006). In addition, (Gomes & Mendes, 2007) claimed that learning computer programming is challenging. They indicated that many students struggle to write programs in programming languages to address issues and lack the skills to develop algorithms. Even utilizing fundamental ideas like control structures to build algorithms that solve specific issues is challenging for many inexperienced students. Since they affect memory faults and slow down memory speed if students do not understand how to apply those algorithms in operating computer programming, Data Structures and Algorithms (DAS) are crucial components in computer science and education. Hence, these materials are very helpful in ensuring that the program runs smoothly (Finocchi et al., 2009).

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Meanwhile, Wang et al. (2018); Cui et al. (2019); Tyagi et al. (2022) established students' difficulties in understanding the algorithm concepts taught in class, had not been conveyed correctly and easily understood by the students. Thus, in this research, experts in programming are required to share their experience teaching algorithms. Subsequently, the researcher presented that an infographic framework in education can solve the problem of teaching the concept of algorithms step-by-step procedure, which defines a set of instructions to be executed in a certain order to get the desired output based on the literature review, current infographics, expert statements in the design of infographics, and expert statements of the concepts of data structure and algorithms. This research integrates the infographic framework with DAS materials. The aim is to develop appropriate edugraphics and can be implemented in the class, not only in programming but also for all materials in the classroom. Other than that, edugraphics are made to display information according to the needs of teachers and students. The researcher will investigate the infographics' elements suitable in the education field, particularly for DAS courses. Consequently, the researcher will identify them based on students' learning needs so that the entire learning process can utilize infographics based on the framework developed through this research.

Information visualization with infographics focused on solving problem learning and teaching in programming, specifically through Data Structure and Algorithms (DAS) material. The framework of infographics for data structure and algorithms *(Infodas)* has not been explored before. The elements of infographics in education need to be integrated, including Data Structure and Algorithms (DAS) material. Current infographics in programming fields are not standard and need to be improved to make it easy to understand and good in design. Infographics were done by

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other researchers but not all elements were identified, and did not include specific material for use by lecturers or teachers. The researcher developed a framework for data structure and algorithms (*Infodas*) combined with a literature review, current infographics, expert design and expert programming.

1.4 Research Objectives

The framework for Data Structure and Algorithms (*Infodas*) in this research can be the solution for student difficulties in learning programming. It is more interactive, easy to understand, and easy to remember. Therefore, lecturers or teachers can use infographics to convey the material with interesting design and include all the standard elements in infographics design.

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The following are the research objectives:

1. To investigate the design of infographics for education and specifically for Data Structures and Algorithms (DAS) courses.
2. To identify elements of infographics design for education, especially for Data Structures and Algorithms (DAS).
3. To formulate an infographics framework for Data Structures and Algorithms (DAS) topic
4. To validate elements of infographics design for education, especially for Data Structures and Algorithms (DAS).
5. To evaluate the effectiveness of *Infodas* (infographics Data Structures and Algorithms (DAS)).

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1.5 Research Questions

The purpose of this study is to provide answers to the following questions:

1. What is the suitable infographics design for education?
2. What are the elements of infographics design, particularly for education, suitable for Data Structures and Algorithms (DAS)?
3. How can we identify elements of infographics design, particularly for education which are suitable for Data Structures and Algorithms (DAS)?
4. How to formulate an infographics framework?
5. How to validate *Infodas* (infographics Data Structures and Algorithms (DAS))?
6. How effective are *Infodas* (infographics Data Structures and Algorithms (DAS)) in assisting student learning?

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Table 1.1 presents the relation between the background, problem statement, objectives, and research questions.

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Table 1.1

Relation of background, problem statement, objectives and research questions

Objectives	Research Questions
To investigate the design of infographics for education, especially for Data Structures and Algorithms (DAS) courses.	What is the suitable infographics design for education?
To identify elements of infographics design for education, especially for Data Structures and Algorithms (DAS)	What are the elements of infographics design, particularly for education, suitable for Data Structures and Algorithms (DAS)? How can identify elements of infographics design, particularly for education, which is suitable for Data Structures and Algorithms (DAS)?
To formulate an infographics framework for Data Structures and Algorithms (DAS)	How to formulate an infographics framework?
To validate *Infodas* (infographics Data Structures and Algorithms (DAS)).	How to validate *Infodas* (infographics Data Structures and Algorithms (DAS))?
To evaluate the effectiveness of *Infodas* (infographics Data Structures and Algorithms (DAS)).	How effective are *Infodas* (infographics Data Structures and Algorithms (DAS)) in assisting student learning?

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1.6 Significance of the Research

This research will support teachers and lecturers, students, and other researchers in the same and different fields. This study identified the elements of edugraphics completely (Davis (2022); Tyagi et al. (2022); Xuan (2022); Sriborisutsakul et al. (2018); Santos et al. (2018). The authors stated that the elements of infographics could explain some important points such as the goals, relevance topic to the audience, meaningfulness, efficacy, effective narrative, originality of design, persuasiveness, and trusted data sources. Other than that, the infographics guidelines in this research will help educators

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appropriately design infographics for education. This infographics framework offers various materials included resulting in an interesting design.

Generating a framework for designing quality infographics is the main point of this study. This is in line with the statement infographics that good instructional media utilized for learners advance their cognitive ability and understanding (Klepsch & Seufert, 2020; Elaldi & Çifçi, 2021; Rios Higuera et al., 2022; Damyanov & Tsankov, 2018; Pazilah & Hashim, 2018).

In their study (Arifin et al., 2022; Mahajan et al., 2020; Alemdag & Cagiltav, 2018) note the importance of employing media to educate audiences. Numerous studies have demonstrated that mental visualization plays a significant and helpful role in retaining and remembering received information, including verbal and visual information (Kamelia, 2019; Esteves & Neves, 2019). Hence, this evidence relates to the present research project to make a standard framework for designing good infographics.

The researcher aims to help students understand the instructional clearly, specifically in infographics. Since visual memory is typically more lasting than verbal or auditory memory, infographics with graphical displays help individuals visualize and analyze the message included in data as well as make it easier for them to recall it (Darcy, 2019; Icht, 2020; Alotwi, 2021; Ibrahem & Alamro, 2021). Figure 1.1 describes the four points of significance of conducting this research.

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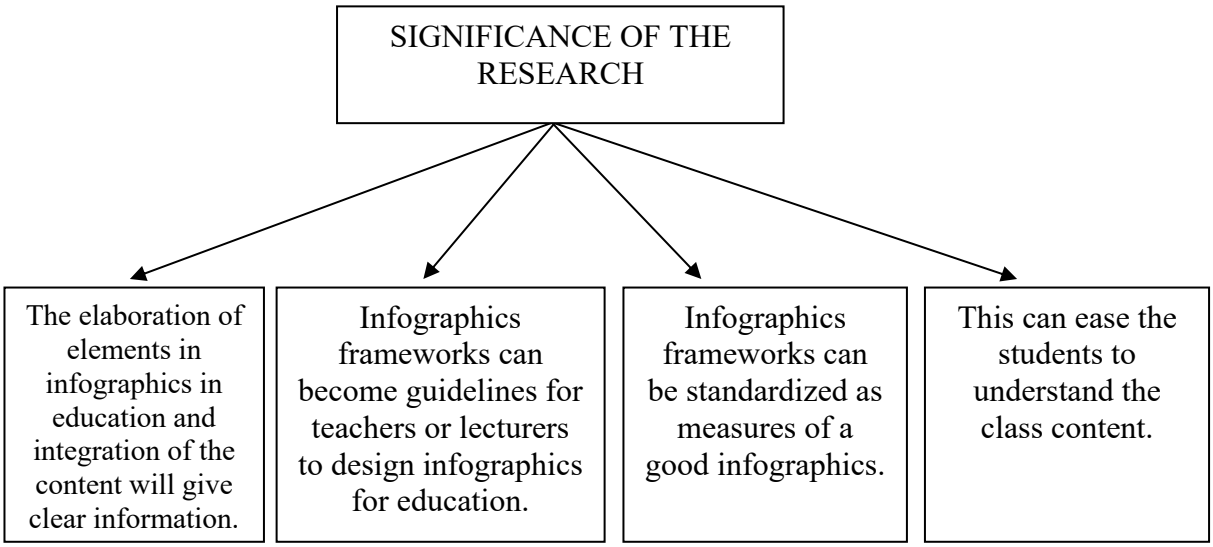

Figure 1.1. Significance of the research

1.7 Theoretical Framework of the Research

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Figure 1.2 illustrates the theoretical framework, especially the infographics framework, which starts from the information visualization theory, which explains infographics as part of a larger field. The instructional design theory applied is Cognitive Load Theory (CLT) (sweller,2016; İbili, 2019; Asma & Dallel, 2021; Stapleton & Stefaniak, 2019). CLT proposed that effective instruction can aid learning by directing cognitive resources toward learning-relevant activities (Sweller et al., 2019; Sweller, 2020). CLT goes some way to explaining why something happens and what lecturers or teachers can do to maximise the learning of individuals within classrooms (Sweller, 2016). The advantage of CLT is that it emphasizes methods to help students achieve optimal abilities based on how the cognitive system works. Working memory has internal capacity limitations to process large amounts of information together. Knowledge of

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the effects of CLT can be used as a reference for teachers in designing teaching materials that can help students gain understanding (İbili, 2019). Other than that, Castells et al. (2019); Sablić et al. (2021) described three (3) memory components for retrieving information from sensory memory and storing it in long-term memory. Note that CLT is characterized by three (3) types of learning experiences: germane load, intrinsic load, as well as extraneous load (Sweller et al., 2019); (Sweller, 2020).

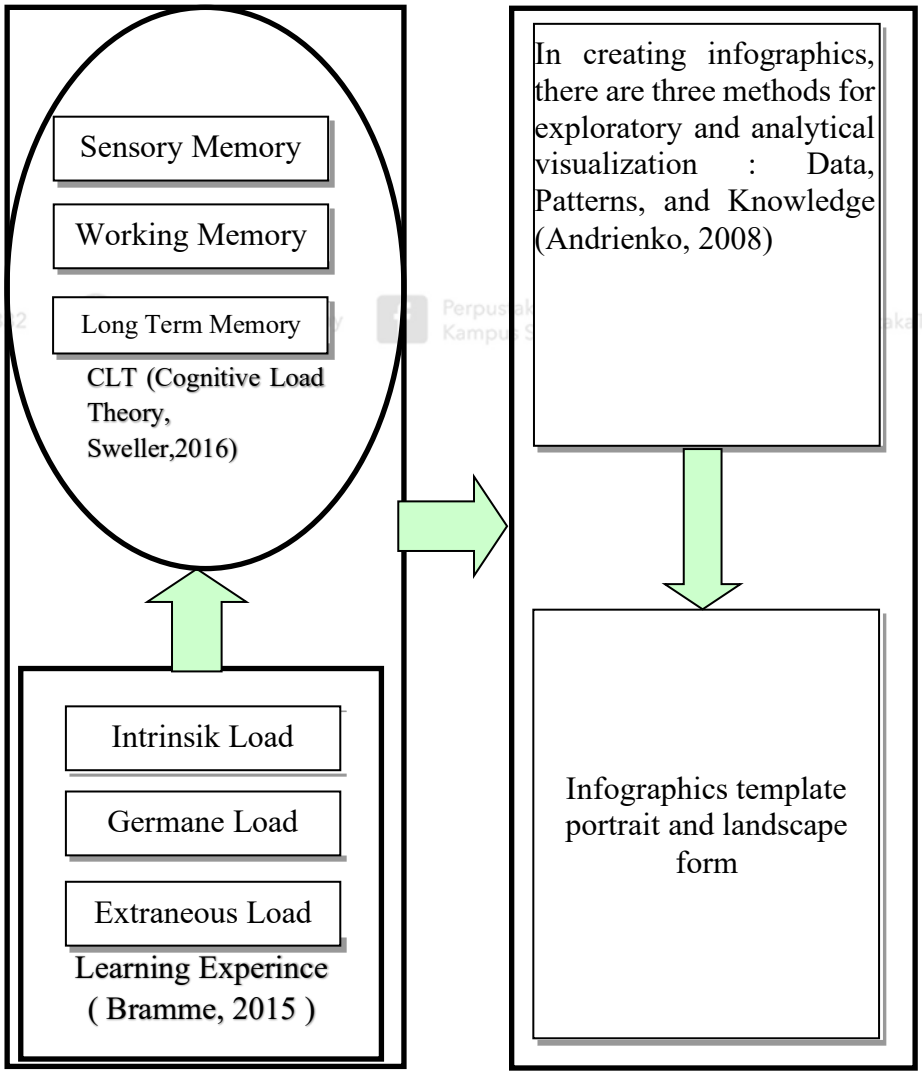

Figure 1.2. Theoretical Framework for Infographics Framework in Education fo Data Structure and Algorithms

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1.8 Conceptual Framework of the Research

Figure 1.3 demonstrates the theoretical framework for edugraphics. Infographics is an information visualization to represent abstract data and explanations (Ware, 2019; Mei et al.,2018). Here, infographics visualization are effective media in the teaching and learning process (Cordeil et al., 2017; Ens et al., 2020; Mladenović et al., 2021; Jalalitabar & Wang, 2022). The infographics are appropriate media to solve students' difficulties in understanding the primary concept of data structure as well as algorithms courses.

There are seven (7) elements of edugraphics, according to the literature research on their design: title, graphics/charts/pictures/images, content, text/font, data, colors, as well as design. To validate those elements, the researcher employed the Delphi method to obtain the infographics framework in education.

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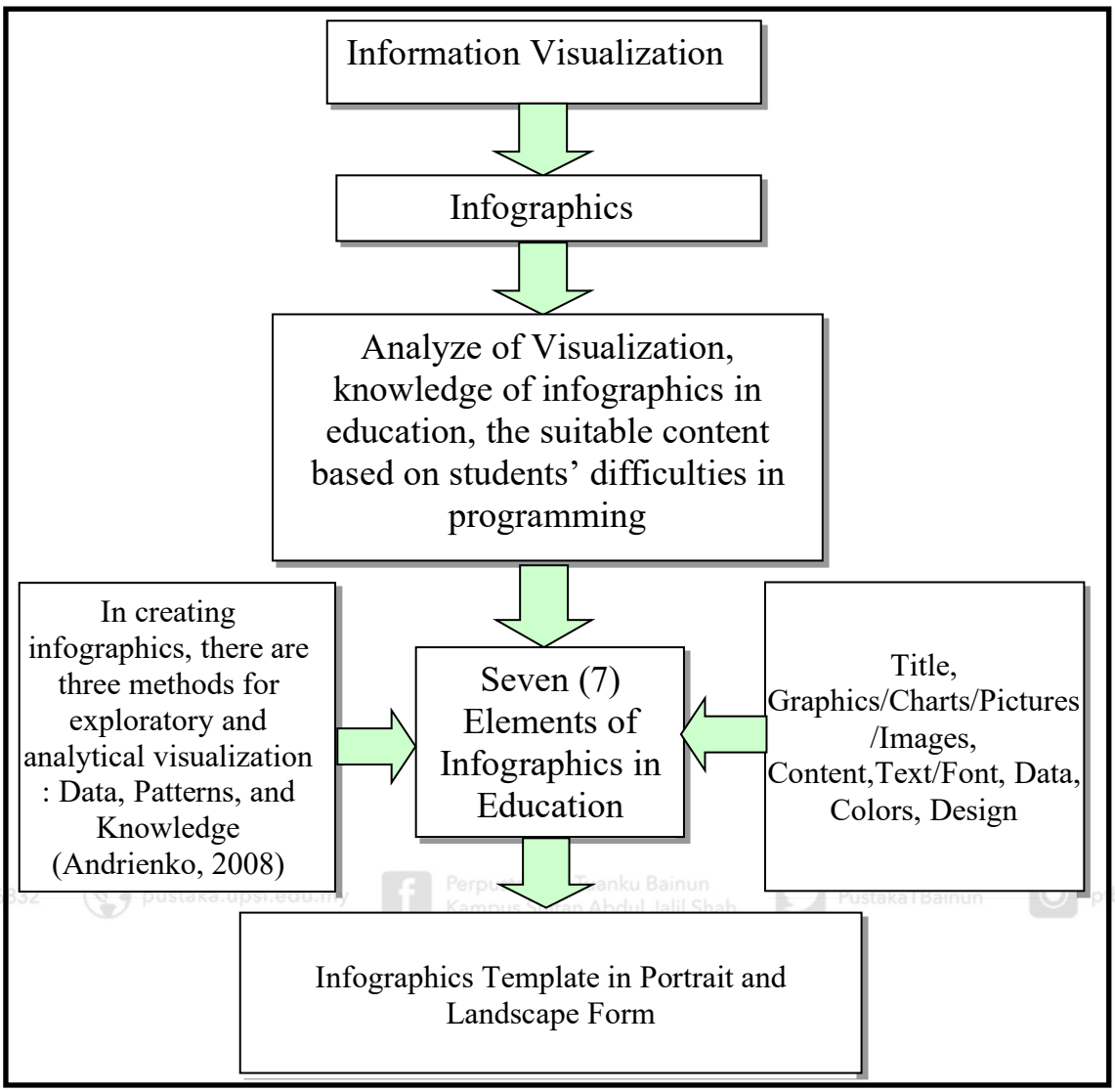

Figure 1.3. Conceptual Framework for Infographics Framework in Education for Data Structure and Algorithms

Subsequently, the researcher conducted extensive research and identified infographic elements in education as well as DAS materials. This is to develop and evaluate an educational infographics framework by applying data structure and algorithm content. The Delphi method is applied to validate the elements and materials of DAS. When all elements and materials are valid, it is referred to as an infographics framework for data structure and algorithms (*Infodas*). Note that the *Infodas* framework can become all subjects as a contribution to other subjects that can be displayed in visualization forms.

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1.9 Scope of the Research

The research scope focuses on designing infographics to assist students in understanding the material of DAS, which is difficult course, according to the findings of a previous study. Information visualization was the main field focusing on infographics media. Infographics ecompass many fields, but this research focused on infographics in the education field. Figure 1.3 demonstrates the scope of this research.

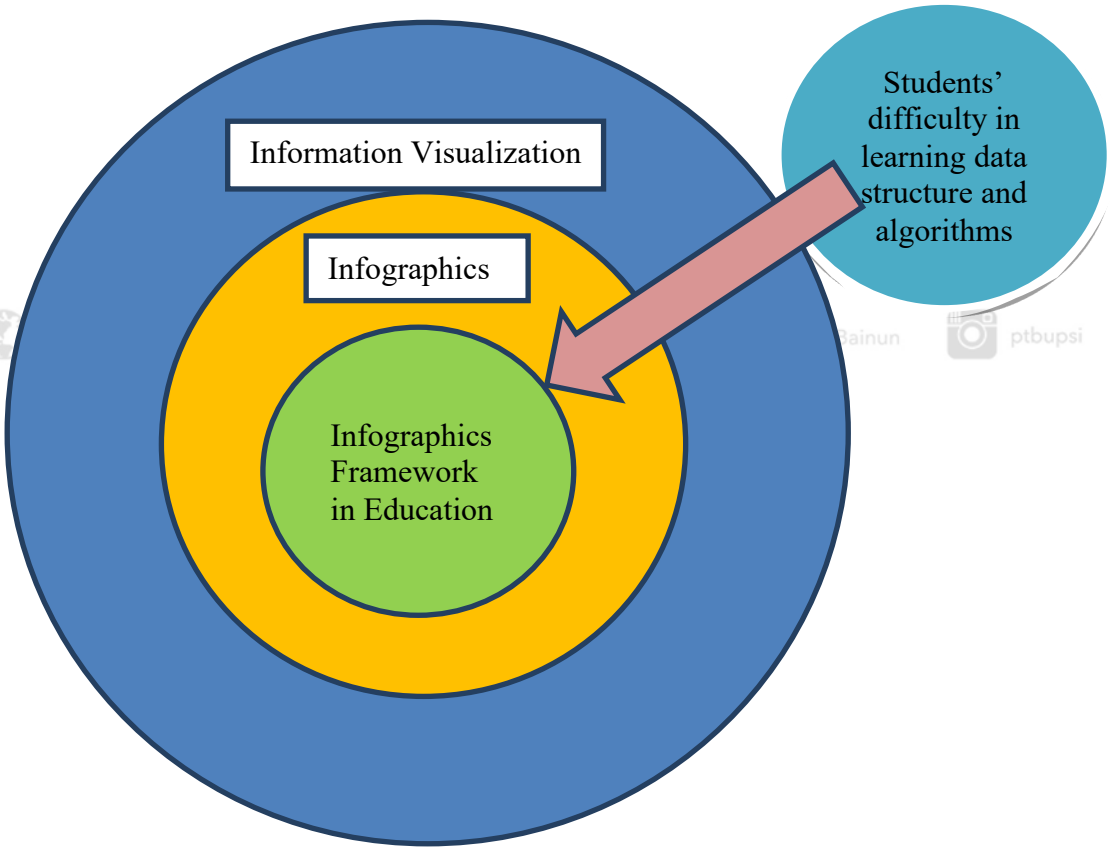

Figure 1.4. Scope of the Research

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1.10 Operational Definition

Some terms are being utilized in this research that needs to be comprehended according to these operational definitions to support the understanding of the research. Therefore, this section defines important terms as the following:

a. Information Visualization

Information visualization is typically thought of as a collection of techniques that help people comprehend and evaluate huge, complex data sets (Adar & Lee, 2020; Rees & Laramee, 2019; Frantiska, 2018). Other than that, academic research in information visualization has concentrated on assisting expert users in carrying out complex data exploration and analysis tasks as efficiently and effectively as possible. This is because of the field's historical roots in scientific reasoning, computer graphics, and algorithmic optimization (Healy, 2018; Virat & Laramee, 2019; Batt et al., 2020). In this research, infographics are a part of information visualization because the infographics must contain information visualization.

b. Infographics

Infographics are data visualization that utilizes signs, pictures, maps, graphics, and charts to rapidly and clearly explain complicated information. Infographics are a type of data visualization (Barlow et al., 2021; Gebre, 2018). Apart from that, infographics have three (3) main components that make up their structure namely Knowledge, Visuals, and Content (Darcy, 2019); (Jahan et al., 2021); (Rahim, 2016). In this research, infographics become media to convey the material in data structure and algorithms subject.

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c. Design

Design is an essential part of the information visualization development process. It would be advantageous to approach information visualization design more proactively and explicitly when dealing with information visualization practice, assessment, and dissemination. This study focuses on the debate surrounding a visualization's visual format. The goal is to draw attention to a visualization's most noticeable aesthetic feature (Arcia et al., 2019; Mohammed, 2020, Stonbraker et al., 2019). Note that the rationale is that deliberate design decisions will allow the field of information visualization to advance and become more compatible with the adjacent fields of business and artistic practice (Walny et al., 2019; Gorlewicz et al., 2020; Shahbazi et al., 2021). In this research, design is the phase to put the position of the elements and provide infographics performance interesting for the students.

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d. Infographics for Education

Infographics are one approach to presenting information in visual and graphic forms (Kaya-Hamza & Beheshti-Fezile, 2017; Gonzalez, 2018; Jaleniauskiene & Kasperiuniene, 2022). Educational graphics, or edugraphics, are a method of delivering information, in this case, knowledge through attractive visual communication designs, attractive and interactive (Melgar et al., 2022; Tsai et al., 2020). In this research, edugraphics are infographics employed by educators for teaching and learning.

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e. Element of Infographics

Infographic components will be incorporated into the design to serve as its primary building blocks (Teixeira, 2018; Knoll & Fuzer, 2019). This is essential to ensure that all relevant infographic contents are modelled properly and implemented in the design (Alyahya, 2019). In this research, various elements are being studied, and the most relevant are seven (7) elements, namely title, graphics/charts/pictures/images, text/fonts, content, data, colors, as well as design. First, the title is about the theme of infographics and the position on the top. Second, graphics/charts/pictures/images depend on the theme and choose the suitable elements between four (4) kinds of visual performance of information. Third is text/fonts to make infographics in variation and choose text/fonts suitable with design and explanation. Fourth is content; it is about information with a specific theme. Fifth is data, explained to the reader in numeric format. Sixth is color, which is used in infographics to present an infographic with clear and attractive colors. The last is design format, where design combines all the elements and attractive contemporary design.

f. ADDIE Model

The Analysis, Design, Development, Implementation, and Evaluation (ADDIE) Model is an iterative method for instructional design, and the outcomes of each phase's formative and summative evaluation may direct the instructional designer to a different phase (Chang, 2006, Alnajdi, 2018). In this research, ADDIE is the phase to approach every step to do this research.

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g. Data Structure and Algorithms (DAS)

DAS is a topic in the information technology field. In this research, the material is obtained from some books (Jamro, 2018; Friggstad et al., 2019; Knebl, 2020), journal articles (Megharaja et al., 2018; Codish et al., 2018; Kristo et al., 2020), as well as a lesson plan.

h. Framework

The authors utilize several consumer expectations and related concepts to illustrate how this framework contributes to integrating material data structure and algorithms (DAS). The framework is adaptable to any offline or online tools, such as canva, pictochart, powerpoint and others (Johnstone & Boyle, 2018). In this research, the framework can implement for including all material in education, especially Data Structure and Algorithms (DAS) material.

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