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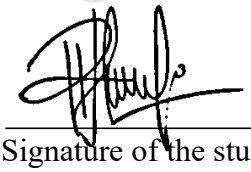
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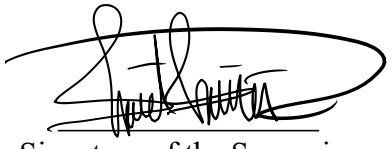


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ABSTRACT

The Game-based Learning Analytics Platform (GBLAP) is an innovative solution to the challenges currently facing the education sector. Its main benefits include improving assessment accuracy and providing more personalized and engaging data-driven learning experiences. This study examines the effectiveness of GBLAP in enhancing the accuracy of creativity and logic assessments in 3-4 year-old children compared to traditional methods, evaluates its acceptability among teachers and parents, and assesses the effectiveness of machine learning models in classifying child development data based on game interactions. The platform integrates artificial intelligence to create a more personalized and optimized learning environment. The System Usability Scale (SUS) instrument was adopted and adapted to obtain feedback from 2 teachers, 10 parents, and 10 children from Manhajul Husna Early Childhood Education, South Kalimantan, Indonesia, and 2 teachers, 10 parents, and 10 children from TASKA PERMATA Universiti Pendidikan Sultan Idris. The children's creativity and logic development data were classified using machine learning techniques by comparing three classification algorithms: Naïve Bayes, Multilayer Perceptron, and Decision Tree, into three categories: Good, Medium, and Low. The usability study demonstrated that GBLAP is an effective tool for real-time tracking of children's progress in creativity and logic assessments. The high average SUS score, above 70, indicates that the platform is well-accepted. For classification, the Multilayer Perceptron algorithm showed the best performance, with an accuracy of 72.97% on training data and 79.17% on testing data. The results suggest that GBLAP is effective, efficient, and engaging, and capable of providing accurate analysis of child development. This system offers valuable insights into children's understanding in the areas of creativity and logical thinking.

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PLATFORM ANALITIK PEMBELAJARAN BERASASKAN PERMAINAN UNTUK PENILAI PERKEMBANGAN KREATIVITI DAN LOGIK DALAM KANAK-KANAK BERUMUR 3-4 TAHUN

ABSTRAK

Platform Analitik Pembelajaran Berasaskan Permainan (GBLAP) adalah penyelesaian inovatif kepada cabaran yang dihadapi dalam sektor pendidikan masa kini. Faedah utamanya termasuk peningkatan ketepatan penilaian dan penyediaan pengalaman pembelajaran yang lebih diperibadikan dan menarik berdasarkan data. Kajian ini menilai keberkesanan GBLAP dalam meningkatkan ketepatan penilaian kreativiti dan logik kanak-kanak berumur 3-4 tahun berbanding kaedah tradisional, menilai kebolehterimaan GBLAP dalam kalangan guru dan ibu bapa, serta menilai keberkesanan model pembelajaran mesin dalam mengklasifikasikan data perkembangan kanak-kanak berdasarkan interaksi permainan. Platform ini mengintegrasikan kecerdasan buatan untuk mencipta persekitaran pembelajaran yang lebih diperibadikan dan dioptimumkan. Instrumen Skala Kebolehgunaan Sistem (SUS) telah diterima dan diubah suai untuk mendapatkan maklum balas daripada 2 orang guru, 10 orang ibu bapa, dan 10 orang kanak-kanak dari Pendidikan Awal Kanak-Kanak Manhajul Husna, Kalimantan Selatan, Indonesia, serta 2 orang guru, 10 orang ibu bapa, dan 10 orang kanak-kanak dari TASKA PERMATA Universiti Pendidikan Sultan Idris. Data perkembangan kreativiti dan logik kanak-kanak telah diklasifikasikan menggunakan teknik pembelajaran mesin dengan membandingkan tiga algoritma klasifikasi: Naïve Bayes, Multilayer Perceptron, dan Decision Tree, ke dalam tiga kategori: Baik, Sederhana, dan Rendah. Kajian kebolehgunaan menunjukkan bahawa GBLAP adalah alat yang berkesan untuk penjejakan masa nyata kemajuan kanak-kanak dalam penilaian kreativiti dan logik. Skor purata SUS yang tinggi, melebihi 70, menunjukkan bahawa platform ini diterima baik. Bagi klasifikasi, algoritma Multilayer Perceptron menunjukkan prestasi terbaik, dengan ketepatan 72.97% pada data latihan dan 79.17% pada data ujian. Hasil kajian mencadangkan bahawa GBLAP adalah berkesan, cekap, dan menarik, serta mampu menyediakan analisis yang tepat tentang perkembangan kanak-kanak. Platform ini menawarkan pandangan berharga mengenai pemahaman kanak-kanak dalam bidang kreativiti dan pemikiran logik.

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LIST OF ABBREVIATIONS

A	Able
AI	Artificial Intelligence
ANN	Artificial Neural Network
CL	Collaborative Learning
DT	Decision Tree
EDM	Education Data Mining
GBLAP	Game Based Learning Analytics
IP	In Progress
LA	Learning Analytics
LAP	Learning Analytics Platform
LMS	Learning Management System
ML	Machine Learning
MLP	Multilayer Perceptron
MOOC	Massive Open Online Courses
MSE	Mean Squared Error
NA	Not Able
NB	Naïve Bayes
NCDC	The National Child Data Center
NCDRC	The National Child Development Research Center
PAUD	Pendidikan Anak Usia Dini

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SUS	System Usability Scale
TAP	Technology And Play
TASKA	Taman Asuhan Kanak-Kanak
UPSI	Universiti Pendidikan Sultan Idris
VMTwG	Virtual Math Team with Geogebra

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2. "Educational Game for Learning Skills in Creative and Logic Development on Children Aged Three Years ", International Journal of Advanced Research in Technology and Innovation, Vol. 1, No. 3, 12-20, 2019, e-ISSN: 2682 -8324.
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CHAPTER 1

INTRODUCTION

1.1 Introduction

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This chapter is an introduction to the research topic, the problem statement, and the research objectives. It also presents and describes the scope of the study as well as the experimental and technical aspects of the study. The background to the research is presented in Section 1.2. In section 1.3 the problem statement is presented, which forms the basis for the direction of the research. The research objectives are described in section 1.4. Section 1.5 is a discussion of the scope of the research, while section 1.6 is a provides a brief outline of how the final Dissertation gets structured. Finally, section 1.7 provides a summary of this chapter.

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1.2 Research background

The Covid-19 pandemic has had a profound effect on the education sector throughout the country. The response to this event has created a challenge to innovate, necessitating extraordinary adjustments in all aspects of education. In response to the challenges posed by the pandemic, educational institutions and countries have implemented a range of innovative measures, including the introduction of new forms of learning, the integration of online courses, and the provision of teacher training. The increasing requirement for distance learning, the rapid adaptation to technology, and the focus on child welfare have emphasised the importance of flexible and resilient learning solutions. It is imperative that platforms continue to evolve in order to remain effective and useful tools in supporting children's learning during and after the pandemic.

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There were early successes in the integration of interactive technologies into learning in initiatives such as that of (Roberts et al., 2016) prior to the COVID-19 pandemic. The application of learning analytics platforms to analysed children's interactions with mathematical materials showed great potential for understanding how children learn and develop in an educational context. This approach, focusing on children aged 2 to 8, demonstrates an awareness of the importance of starting interactive and engaging learning at an early age.

The use of interactive technologies, such as educational games and learning platforms, has long been recognised as an effective means of increasing children's engagement in learning. This approach not only makes learning more engaging but also

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enables personalisation of the learning process, which can help customise the curriculum and learning experiences according to children's individual needs.

The study conducted by Morata et al. (2019) indicates that game-based learning analytics is an invaluable instrument for comprehending and fostering children's academic advancement. The utilisation of this technology enables the collection of more pertinent and comprehensive data on children's interactions with learning games. This, in turn, provides valuable insights for teachers, thereby facilitating more effective teaching and learning. The data generated by in-game learning analytics can demonstrate the specific skills that children are developing or that require further attention (Morata et al., 2019).

By adopting the approach outlined by (M. A. Chatti et al., 2012) this research can make a valuable contribution to the field of game-based learning and learning analytics, with a particular focus on the collection, measurement, analysis and reporting of data on children's interactions with interactive learning platforms. The learning analytics process, as outlined by (Bodily & Verbert, 2017), can be divided into several important stages, including data collection, analysis and intervention, and post-processing. The initial stage of the learning analytics process is data collection and pre-processing. This involves recording user activities from interactions with the platform, after which the data is normalised and transformed for analysis. The process of data analysis and intervention involves the identification of patterns through the application of statistical techniques, machine learning, or analytical algorithms to the pre-processed data. Post-processing is the evaluation of analysis and intervention results for the purpose of continuous improvement, as depicted in Figure 1.1. By following these

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stages, learning analytics can make a significant contribution to the improvement of children's learning processes, thereby enabling teachers and decision-makers to design developmental and effective learning (Siemens & Baker, 2012). The role of teachers and parents in the management of the educational changes brought about by interactive technologies is of crucial importance. They have an important role to play in ensuring that these developments proceed smoothly and that they provide the maximum possible advantages for children (Ansari & Purtell, 2017; Hu et al., 2017)

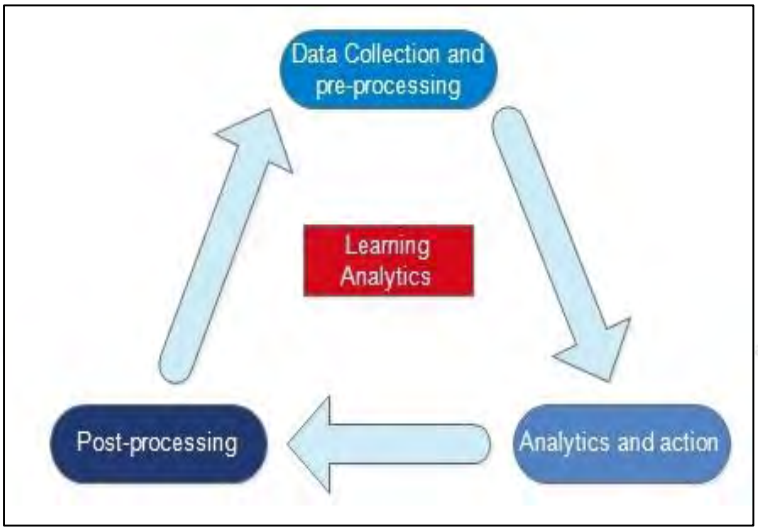


Figure 1.1. Learning Analytics Process (Bodily & Verbert, 2017)

Technology education is very important for children between the ages of three and four, as this is a critical early period in children's development. During this period, children are highly receptive to information and can absorb knowledge at a rapid pace (Hinostroza et al., 2013). The use of technology, including smartphones, by children between the ages of two and five years is amazing. According to a study by (Roskos et al., 2017), children in this age group continue to develop their fine motor, cognitive, and creative skills, which allow them to interact with technological devices at a high

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level of proficiency. The ability to swipe, tap and use smartphone touchscreens, for example, helps with fine motor development.

The approaches and systems in place for early childhood education in Malaysia and Indonesia highlight the importance of paying special attention to this crucial period in a child's development. In Malaysia, there is a framework, PERMATA Negara, for the learning of children under the age of four, reinforced by national standards. The education centres that work with children under the age of four are known as TASKA. This approach allows for the implementation of a consistent set of standards and a structured curriculum to support children's development at an early age.

In Indonesia, a similar framework is provided by MERDEKA PAUD, which sets national standards for the education of children under the age of the four years. Educational centres that provide services to children under the age of four are known as PAUD (Pendidikan Anak Usia Dini). The purpose of the programme is to provide good and equitable education for children in this age group. They are particularly vulnerable to environmental influences and require special attention in their development.

The two countries have a structured and clear approach to the support of early childhood development through a standardised national curriculum. The focus on the education of children aged four and under highlights the importance of this period in the development of cognitive skills. As such, the effort to provide good quality, standardised educational services at an early age are a very important step in the development of education in both countries.

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Developed by the National Child Development Research Centre (NCDRC) at the Universiti Pendidikan Sultan Idris (UPSI) in Malaysia, the National Child Data Centre (NCDC) plays an important part in providing integrated data on children's education. Offering a holistic picture of child development in Malaysia, the NCDC has a varied and comprehensive set of data. As a result, the NCDC is a very important resource for stakeholders to obtain detailed insights into the development of children and to be able to make more informed and better-informed decisions.

The PAUD programme in Indonesia is playing a key role in helping to build a strong foundation for children to develop from a very young age. Focusing on the importance of quality education, individual attention, a developmental approach and collaboration with parents and communities, the programme aims to create a supportive environment for the optimal growth and learning of Indonesia's children.

In this regard, the development of Game-based Learning Analytics (GBLAP) for children aged 3-4 at TASKA PERMATA UPSI, NCDRC in Malaysia and Manhajul Husna Early Childhood Education (PAUD) in South Kalimantan, Indonesia serves to illustrate the significance of integrating technology in early childhood education. This research demonstrates the potential of GBLAP to foster creativity and logical thinking in children at this age. Creativity development through GBLAP is designed to stimulate and develop children's creativity from the age of three years old. The decision to focus on the 3-4 age group for research on game-based learning analytics platforms is based on a number of well-founded considerations related to the developmental stage of children at this age. This phase of development is of great consequence for the establishment of the fundamentals of cognitive, social, emotional and creative skills.

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By focusing research on this age group, it is hoped that the positive impact of game-based learning platforms will be maximised, developmental barriers will be detected and addressed at an early stage, and valuable insights will be provided for educators and parents in supporting children's holistic growth.

Games can serve as an engaging tool for children to engage in creative thinking, imagination, and self-expression (Hui et al., 2014; Malaeb et al., 2015; Neumann, 2018a; Siddoo et al., 2016). In addition to fostering creativity, activities in specially designed games also aim to stimulate children's logic skills. These games can include activities that require problem solving, critical thinking, and abstract thinking skills in an age-appropriate setting (Fraassen, 2011). By developing creativity and logic skills through GBLAP, new opportunities may be created to support the building of these important foundations at an early stage of development.

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1.3 Research Problem

Early childhood education faces significant challenges in measuring and developing children's creativity and logic. At 3-4 years old, children are at a critical stage of development when their brains are highly receptive to new information. Often referred to as the sensitive period, this is an ideal time to introduce educational technologies that can support their cognitive development (Hinostroza et al., 2013). This period of development is characterised by an increased capacity to absorb a wide variety of information, including technological information (Mertala, 2019). It is often the conclusion of researchers that traditional assessment methods are ineffective in

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providing deep insights into individual progress (Quansah, 2018). This presents a challenge for educators attempting to provide timely and appropriate interventions. In light of these challenges, it is imperative to explore novel approaches to assessment and teaching methodologies. Consequently, it is imperative to implement effective assessment strategies to enhance the accuracy of assessment and facilitate a more personalised and engaging learning experience.

The Game-based Learning Analytics Platform offers a potential solution by utilising game interaction data to gather deep insights into children's learning. The subsequent question then becomes how learning analytics can be effectively integrated with game elements in order to provide useful insights for curriculum development and learning methods. As Learning Analytics and Games (Morata et al., 2019) demonstrate, the utilisation of these two fields offers advantages in the acquisition of data from children's engagement with games. This is achieved through the provision of real-time information, which facilitates more effective assessment by educators. Such in-game assessments provide evidence-based data on children's knowledge, as cited by Cariaga and Feria (2016) and Tlili, Essalmi, Jemni, and Kinshuk (2017). The Games-based Learning Analytics methodology enables more effective assessment of early childhood development by utilising data generated from interactions with educational games. The data generated from educational games can provide valuable insights into various aspects of children's development, including cognitive, motor and social skills. The application of game-based learning analytics can optimise the utilisation of educational games in the classroom. This has the potential to alleviate the burden on teachers (Emerson et al., 2020). This approach enables the use of game-based learning analytics

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to overcome challenges in childhood developmental assessment, and provides data that can be used to improve teaching methods and learning outcomes.

1.4 Research Objective

The research's main objective is to develop a game-based learning analysis (GBLAP) that focuses on the development of creativity and logic in children between the ages of 3-4 years old. A number of objectives have been identified in order to achieve the main objective, which are as follows:

1. To investigate the factors that 'Do Not Achieve' the development of creativity and logic in children 3-4 years old.
2. To identify the elements and attributes used in educational games and the process of evaluation of the development of creativity and logic on the basis of objective 1.
3. To develop a Game-Based Learning Analytics Platform (GBLAP) with a focus on creativity and logic development based on objectives 1 and 2.
4. To conduct a usability study of the Game-Based Learning Analytics Platform (GBLAP) through using the System Usability Scale (SUS).
5. To validate and evaluate the Game Based Learning Analytics Platform (GBLAP), which has been constructed for creativity and logic development.

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1.5 Research Question

The questions to be asked in objective research are the following:

1. What are the factors that are 'Do Not Achieve' the development of creativity and logic in children aged 3-4 years?
2. What elements and attributes are always used in the evaluation process of creativity and logic development, especially in educational games?
3. How to develop a Game-Based Learning Analytics Platform (GBLAP) with a focus on creativity and logic development?
4. How to evaluate the usability study of Game-Based Learning Analytics Platform (GBLAP) using System Usability Scale (SUS)?
5. How to validate and evaluate the Game Based Learning Analytics Platform (GBLAP)?

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1.6 Research Scope

This study focuses on the development of game-based learning analytics to develop and improve educational methods that focus on the use of educational games and children's interaction data to improve the teaching of creativity and logic development. The children in this study are between the ages of 3 and 4. It is important to select children at the age of 3 to 4 years because this is their early developmental period, which is a critical period in the formation of the foundations of child development (Hinostroza et al., 2013).

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Children in this age group have a high level of information intake from different types of information, including technology (Lehto et al., 2012). The development of creativity and logic in children between the ages of 3 and 4 years is a significant process in the formation of developmental foundations (Fraassen, 2011; Mumford & Gustafson, 1988). An environment that pays attention to the development of creativity and logic in children at this age can contribute significantly to the optimisation of skill development and help them become more flexible and creative learners in the future (C. H. Yoon, 2017). The limitations of this study, therefore, are the development of a game-based learning analytics platform for the assessment of the development of creativity and logic in children between the ages of 3 and 4 years.

The platform provides a powerful tool for teachers, parents and the children themselves to support the development of skills and provide the required support for children who need extra help in their learning process. This framework provides a strong foundation for the various people involved in the learning process of 3-4year-olds. It also gives clear direction and enables early years professionals and others to support children's development at a critical stage.

1.7 Research Organization

The research is divided into five sections. which are briefly summarised in the following section:

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CHAPTER 1 INTRODUCTION

This chapter provides an overview of the background to the study, the research questions, the research objectives and the scope of the study.

CHAPTER 2 LITERATURE REVIEW

This chapter discusses the development of creativity and logic in children between the ages of 3 and 4. It also reviews the literature on game-based learning analysis. A brief description is also given of the PERMATA curriculum and the MERDEKA PAUD curriculum, which are used as a basis for learning for 3–4-year-olds.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter provides a comprehensive explanation of the research methodology, which consists of several stages: preliminary study, identification, development, and validation and evaluation. Each stage has one or more research objectives and is in response to one or more research questions.

CHAPTER 4 RESULT AND DISCUSSION

This chapter presents the results and discussion of the research conducted using the proposed method for the development of a game-based learning analytics platform. The chapter is divided into eight sections for discussion.

CHAPTER 5 DISCUSSION AND FUTURE RESEARCH

Finally, in this chapter, the conclusions and the contributions of the study are presented. Suggestions for future research areas are also provided.

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1.8 Chapter Summary

This chapter presents the background to the development of a game-based learning analytics platform for the assessment of the development of creativity and logic in children between the ages of 3 and 4 years. The statement of the problem, the objectives of the research, the scope and the limitations of the research are presented. The final part of this chapter provides an overview of the other chapters of this thesis.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

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This chapter presents a detailed literature review as background to this research, which includes. Section 2.2 presents a protocol for a systematic review of learning analytics. Section 2.3 present an overview of learning analytics. Section 2.4 discusses Learning Analytics: Distributed Learning Environment. Section 2.5 discusses Learning Analytics: The Education of Early Years. Section 2.6 discusses Learning Analytics: A Section on The Process of Learning. Section 2.7 discusses Game-based Learning Analytics. Section 2.8 present Framework and Guidelines for The Education of Children. Section 2.9 presents the data mining techniques used in game-based learning analytics. Section 2.10 summarises the chapter. Figure 2.1 An illustration of the structure of the review of the literature for this chapter.

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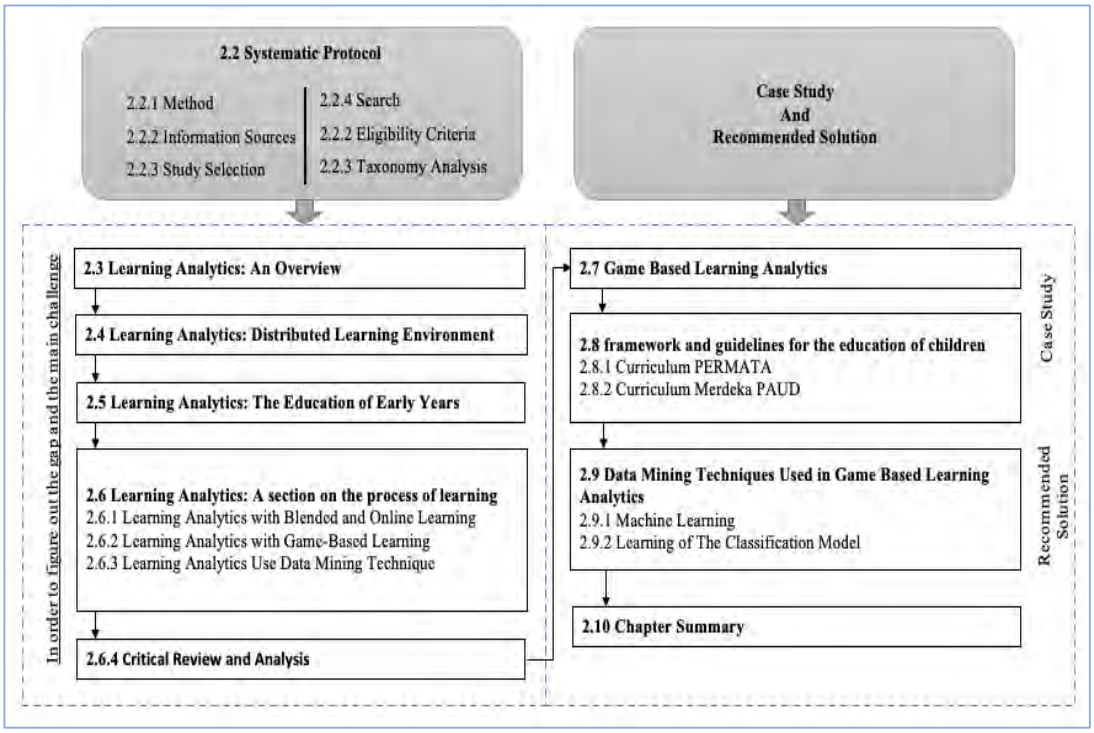


Figure 2.1. Literature Review Structure

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2.2 Systematic Review Protocol

This section describes the methodology of the systematic review, the sources of information, the selection of studies and the search and eligibility criteria used in this study.

2.2.1 Method

The most important keyword in the scope of this research is 'learning analytics and education for children'. It is important to note that this term excludes research related

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to deep analytics. Specifically, the scope is limited to English-language literature considering all areas related to machine learning. This research uses a combination of keywords to guide the search for literature that is focused and specific to the use of learning analytics in children's education, with relevant aspects of machine learning taken into context.

2.2.2 Information Sources

The search for target articles was to be carried out in two digital databases. Firstly, the IEEE Xplore Library, which contains technical literature in the field of engineering and technology. Secondly, ScienceDirect, which provides access to articles from science and technology journals. The motivation for this selection was to include literature on learning analytics and education for children, and to get a comprehensive view of the work of researchers in different specialisations.

2.2.3 Study Selection

The process of study selection involves searching for literature sources, followed by two iterations of screening and filtering. In the first iteration, duplicate and irrelevant articles are excluded by scanning the title and the abstract. In the second iteration, the articles are filtered after a thorough reading of the full text. These two iterations provided the researcher with assurance that the articles included in the study met the

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research objectives, as the same eligibility criteria were applied in this stepwise approach.

2.2.4 Search

The search for literature began in August 2012, using the databases of ScienceDirect and IEEE Xplore through their search engines. A combination of keywords such as 'learning analytics', 'learning', 'learn', 'analytics', 'e-learning', 'education data mining', 'data mining', 'prediction', 'computational intelligence' and 'artificial intelligence' were used in various combinations with the 'OR' operator. The detailed text of the keywords is shown in Figure 2.2.

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2.2.5 Eligibility Criteria

All the articles that fulfilled the criteria listed in Figure 2.2 were included. The researcher initially set the goal of mapping the research space on learning analytics and children's education into a common taxonomy consisting of four categories. After removing duplicates, articles were screened and filtered, and some were excluded.

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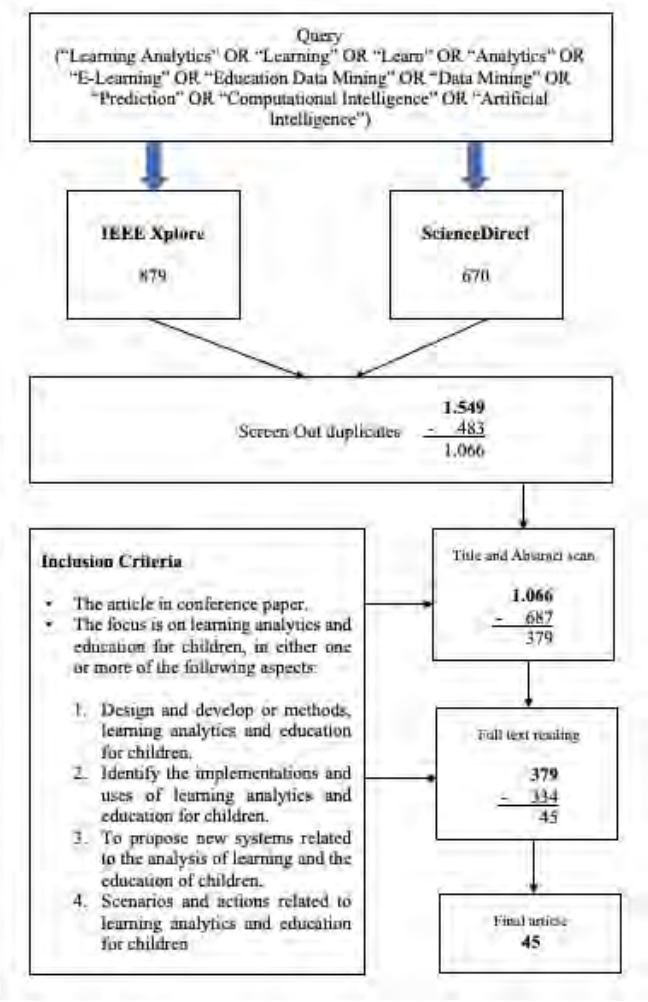


Figure 2.2. Flowchart of study selection on literature review

2.2.6 Taxonomy Analysis

The search initially resulted in a total of 1,549 articles from the years 2012 to 2019. IEEE Xplore and 670 from ScienceDirect. 483 articles were duplicated between the two databases. After screening the titles and abstracts, 687 articles were excluded. From the remaining 379 articles, 334 were excluded after reading the full text, leaving 45 articles. These were reviewed in detail in order to provide an overview of the research that has been conducted on this evolving topic.

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As a result of the taxonomy analysis, the researcher observed specific patterns and general categories. Figure 2.3 illustrates the mapping of learning analytics.

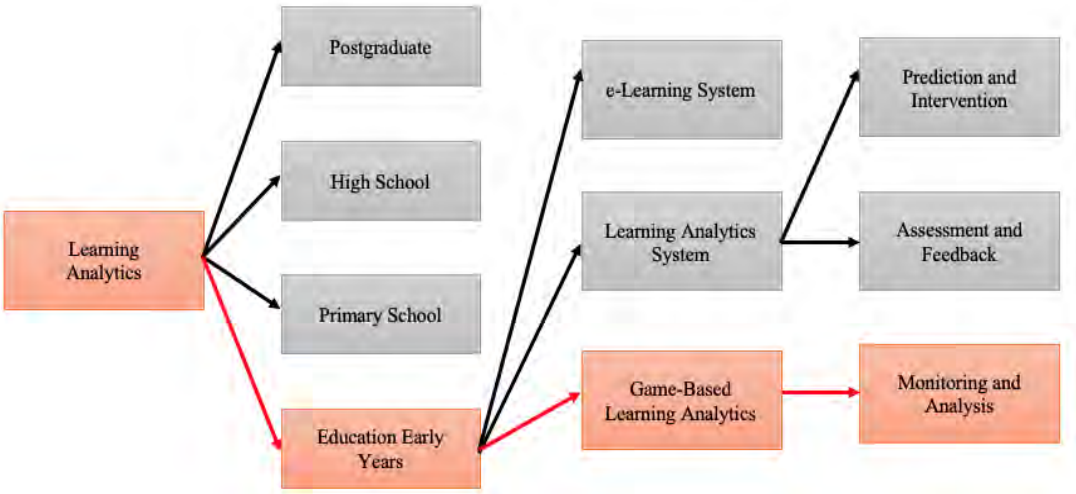


Figure 2.3. Taxonomy of research literature on learning analytics

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2.3 Learning Analytics: An Overview

Learning analytics (LA) is a multidisciplinary field that utilises various techniques and approaches to analyse educational data and gain insights into the learning process (M. Chatti et al., 2012). LA involves elements such as machine learning, artificial intelligence, information retrieval, statistics, and data visualisation. Machine learning is a method that enables computers to learn from data and make predictions or decisions based on patterns found in the data (Mahesh Batta, 2020). In the context of LA, machine learning is used to analyse learning patterns and student behaviour (Siemens et al., 2011).

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Artificial intelligence (AI) in the context of LA provides a framework for the creation of intelligent systems that are able to make optimal decisions or take actions in the context of learning (Yannakakis & Togelius, 2017). In the case of educational data, the process of identifying useful patterns is carried out by using information retrieval technology, which involves the extraction and evaluation of information from large and diverse educational data (Jadav et al., 2016). Statistics is an important tool in the field of LA in order to gain valuable insights into the performance of the learners (Ramos-Soto et al., 2015). Data visualisation, on the other hand, is a technique for the presentation of data in a graphical form that enhances the understanding and interpretation and helps the decision makers in the learning context (Scheffel, 2015). Through the combination of these elements, LA provides tools and techniques to enhance the understanding of the learning process, to analyse the learning data and to provide in-depth patterns that help to improve the learning experience of students (Agus & Mohamad Samuri, 2018).

Furthermore, as reported by (M. A. Chatti et al., 2012), the fields that are closely related to LA and technology enhanced learning (TEL) are academic analytics, action research, educational data mining, recommender systems, and personalised adaptive learning. The combination of these fields with LA can optimise the use of technology in education, provide deep insights, and improve the overall effectiveness of learning for students.

According to (Marks et al., 2016), there is a close relationship between education analytics and learner analytics (LA) when it comes to using data to improve the educational process. Education analytics uses data on test scores, grades, and

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attendance to assess the academic performance of students and educational institutions. In a similar way, LA uses data on digital interactions to understand how students are learning.

The goal of action research and LA, according to (Shamrova & Cummings, 2017) is to improve educational practice. The focus of action research is on learning through reflection, action planning, implementation and evaluation. While LA focuses on analysing data to understand and improve the learning process. Although they have different methodological approaches, the purpose of action research and LA is to improve educational practice based on the analysis of facts and data.

Educational data mining (EDM) is an important part of learning analysis (LA) (Siemens & Baker, 2012). The primary objective of LA is the application of data mining and analysis techniques to educational data in order to understand and improve the learning process. Important concepts in EDM in the context of LA include: learning patterns and trends, prediction of student progress, analysis of student interactions, clustering of students, and learning recommendations.

Meanwhile, recommender systems and learning analytics are technologies that are used to recommend specific items to users based on the preferences and behaviours of students. In the context of education, recommender systems can provide recommendations on learning materials and other resources that are appropriate to the preferences or level of understanding of the students. The data that is analysed in the recommender system can come from the interaction of the students with the learning materials or from the results of assessments (Bodily & Verbert, 2017).

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Adaptive personalisation is an approach to learning in which learning materials and methods are tailored to the needs, preferences and level of ability of the individual student. It makes use of data and technology to create a personalised learning experience for each individual student (van Klaveren et al., 2017). According to (Siemens et al., 2011), the purpose of LA is the adaptation of educational tasks to the needs and abilities of individual learners through interventions and feedback. LA provides a clear and informative picture of the interaction with the learning platform and helps decision makers to improve the learning process. All of these represent the common goal of improving educational practice by using educational data to support and provide insights to improve the learning experience and overall educational performance.

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2.4 Learning Analytics: Distributed Learning Environment

There has been significant growth in the use of LA during the last years. It has become a major focus in education. This is due to its potential to optimise the learning process. Factors that have contributed to the increased attention on LA include the availability of digital data, technology and artificial intelligence, the demand for personalised learning, the increased awareness of learning effectiveness and the support from education policy (Tempelaar et al., 2018). As a result, learning analytics (LA) has become a valuable tool for the improvement of the learning process. Through the analysis of available data, LA can provide useful patterns and insights to decision makers in the field of education.

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According to M. A. Chatti et al. (2012), the LA reference model comprises four main dimensions for identifying research challenges and opportunities in the LA context: data and environment (what), stakeholders (who), objectives (why), and methods (how). Figure 2.4 provides an overview of the LA dimensions. The (what?) dimension is the technical dimension of LA, including the infrastructure, technology, analytical tools and methods used to collect, store and analyse learning data. The (Who?) dimension is the pedagogical dimension, focusing on the use of LA to support learning objectives. The (Why?) dimension is the social dimension, which focuses on the social aspects of LA, such as privacy, ethics and the social implications of using analytics in an educational context. Finally, the 'How?' dimension refers to the visualisation and user interface aspect of presenting information from data analysis to users. This fragment discusses data visualisation, interface design, and information generation.

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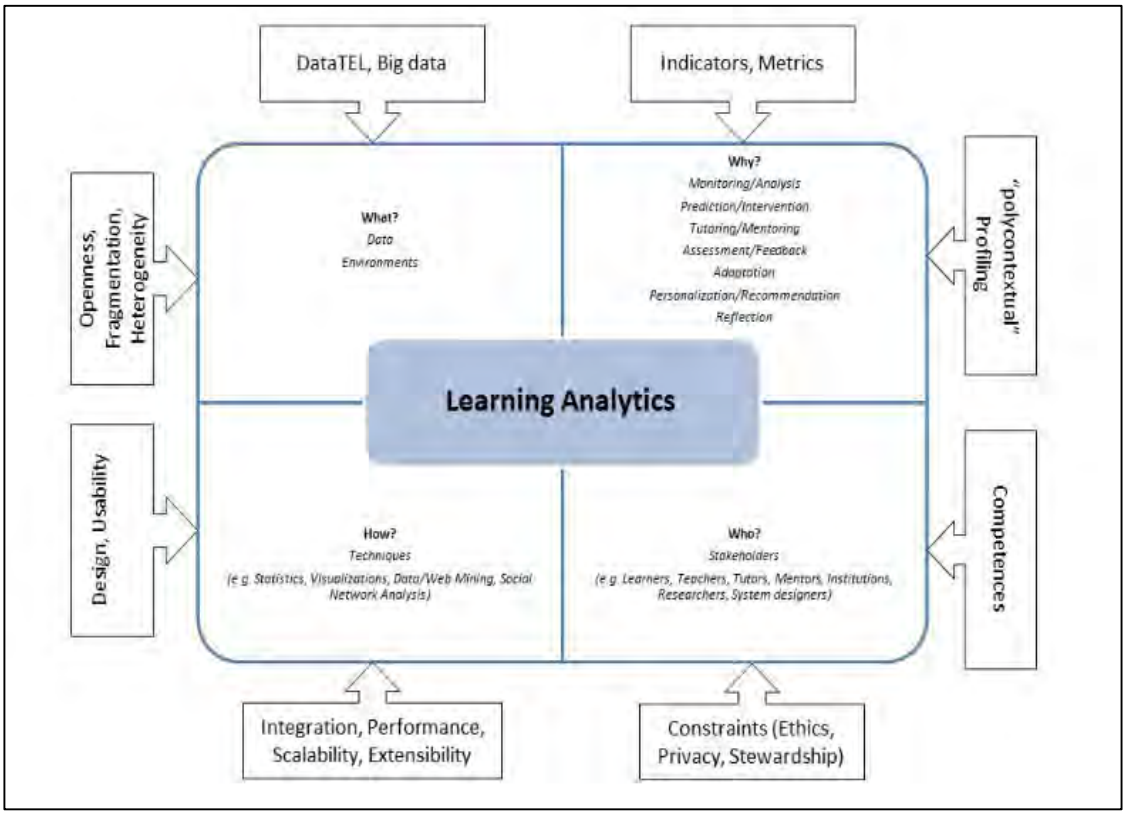


Figure 2.4. LA Reference Model (M. A. Chatti et al., 2012)

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LA in the context of distributed learning environments refers to the use of analytical methods and tools to understand and improve learning in environments where students and learning resources are geographically dispersed or connected online (Van Leeuwen et al., 2014). It involves the collection and analysis of digital data generated during the course of learning (Ravi et al., 2018). The goal of LA in distributed environments is the understanding of the learning process, enhancing the learning experience, customizing learning, and optimizing learning efficiency (Tomberg et al., 2012). Learning process understanding is the analysis of how students interact with online learning content and platforms, as well as how they respond to different teaching methods (Furukawa et al., 2017).

Improving the learning experience involves the use of data insights to improve the design of the curriculum, to provide better feedback to students, and to identify areas in which they may be having difficulty (Macfadyen & Dawson, 2010). The personalisation of learning involves the use of data to customize the learning experience for each individual student, allowing them to access materials that are relevant to their learning needs. In order to optimise the efficiency of learning, analytics can be used to evaluate the effectiveness of learning methods and to plan for improvements or changes where these are needed (Agudo-Peregrina et al., 2014).

In distributed educational environments, LA has an important contribution to make in improving the effectiveness of online or distance learning by providing educators and policy makers with detailed insights to design better and more efficient learning experiences. According to (Tempelaar et al., 2018), such research highlights the importance of cluster analysis in the context of e-tutorial traces to classify students

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into different groups. This approach allows for the implementation of pedagogical interventions that are better suited to the needs and characteristics of the groups of students. Teachers or learning systems can provide tailored feedback, customised materials, or different learning approaches for each group by understanding the specific characteristics of each group of students. Research by (Gutiérrez et al., 2020) also shows that the use of the Learning Analytics Dashboard for Advisors (LADA) can play an important role in supporting the decision-making process of academic advisors. LADA provides academic advisors with access to comparative and predictive analytics that enable them to make more informed and efficient decisions about their students. These findings demonstrate the significant potential of implementing Learning Analytics (LA) technology in the context of education. Through the further development of tools such as e-tutorials and LADA, it can make a significant contribution to improving the effectiveness of the education system and help decision makers to provide better support for students and the educational environment.

2.5 Learning Analytics: The Education of Early Years

In the context of early years education, LA involves using data to understand, improve, and enhance young children's learning experiences. LA can refer to a variety of things, including the evaluation of learning experiences, assessment of children's performance, improvement of learning design, specialized interventions and support where children may need additional attention, and collaboration with parents (Agus & Mohamad Samuri, 2018).

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The main objective of LA in early childhood education is to facilitate the development of children in a comprehensive and integrated manner. Data collected from children's interactions and responses allows educators to use the data to make more informed decisions, understand individual needs, and improve learning experiences that are effective and interesting for children (Crescenzi-Lanna, 2020).

Educators have the opportunity to provide more targeted attention and help each child reach his or her full potential through the wise use of data. Moreover, in the early stages of a child's development, LAs have an important responsibility to create a supportive environment for optimal growth and learning. This research (Roberts, Chung, & Parks, 2016) developed a Learning Analytics Platform (LAP) prototype to analyse back-end data from children's interactions with PBS KIDS transmedia content and provide customised reports to parents to help them better identify their child's learning needs. The platform provides customised reports to parents, and the information provided by the LAP allows parents to identify their child's preferences, interests and level of understanding of the learning material.

An interesting step with the potential to significantly support the development of children aged 3-4 is the article on the application of Learning Analytics for Children's Logic Development (LACLOD) in 2021. The benefits of this application, through LACLOD and its application (LACLOD APP) connected to Google Analytics (GA) plug-in to track user interaction, can evaluate in more detail children's interaction with learning materials, get feedback from teachers and children using LACLOD APP, identify trends and teachers' needs for learning materials. The LACLOD APP is an example of the integration of technology and data analysis to provide a more

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meaningful understanding of the responses and needs of children in the learning process (Mohamad Samuri et al., 2021).

The results provide valuable insights into the potential of the implementation of LA technology in the context of the early education of children. Such implementation has an important contribution to make in creating an environment that supports optimal growth in the early stages of children's development. LA technology has several benefits, firstly, effective collaboration by supporting parents and teachers in understanding children's needs, interests and progress; secondly, better and more effective decision making; and thirdly, more adaptive learning, where data from LA technology can be used to improve and personalise learning approaches according to children's individual needs.

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2.6 Learning Analytics: A Section on The Process of Learning

This section explains how data is analysed, understood, and used to improve learning effectiveness, to provide timely responses, and to personalise the learning experience to meet the individual needs of each student. The overview contains three sub-sections: 2.6.1 Learning Analytics with Blended and Online Learning, 2.6.2 Learning Analytics with Game-Based Learning, and 2.6.3 Learning Analytics using Data Mining Techniques. And 2.6.4 subsections that present descriptions of the three sections.

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2.6.1 Learning analytics with blended and online learning

This sub-section concentrates on the application of Learning Analytics (LA) in the framework of blended or completely online educational experiences, with the important goal of understanding how students learn and interact with learning platforms. A significant example of the online learning transformation is MOOCs (Massive Open Online Courses), which are providing access to education for millions of students all over the world.

The use of LA and MOOC provides a means of identifying students at risk, of predicting their performance, as well as of the most appropriate feedback. This identification process makes it possible for course organisers or instructors to give extra attention to students who may require additional support, to optimise their learning experience and to improve their overall academic success. Thus, it can be seen that LAs play a role in the enhancement of diverse learning experiences and support of student progress in complex online learning environments (Khalil & Ebner, 2015; Kizilcec et al., 2017; Laveti et al., 2017; Srilekshmi et al., 2017).

Integrating LA into an online learning environment, such as Moodle, allows teachers to have access to more in-depth information about how students interact with the platform and how they construct knowledge from the resources available to them. The references provided highlight the importance of the integration of LA in online learning management for the understanding of students' interaction patterns and the measurement of their performance (Aguilar & Valdiviezo-Díaz, 2017). Through the use of this information, teachers are able to adjust their teaching methods and learning

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resources in order to better respond to the individual needs of their students. This allows for the implementation of more effective and adaptive teaching practices in a blended learning environment or a fully online learning environment (Al-Ashmoery & Messoussi, 2015).

Adapting LA in decision-making models in higher education institutions involves relevant data collection, data processing, detailed analysis, modelling and prediction, and policy development, as well as evaluation and adjustment (Vanessa Niet et al., 2016). The first step is to collect data from various sources, such as student interactions, academic records, and tests from online learning platforms.

Data processing involves cleaning and collating collected data to identify relevant trends and patterns in student performance. Deep analysis applies appropriate data analysis techniques to identify correlations, predictive patterns and insights that can support decision-making. Techniques such as data mining, machine learning, and statistical analysis may be used. Modelling and prediction are based on the insights provided by LA. Evaluation and adjustment involve assessing decisions and updating strategies based on the results. This provides a continuous improvement in the effectiveness of the policies implemented.

A significant amount of literature has been published on the research and development of LA applications in online learning environments in order to improve student learning experiences and outcomes. This allows educational institutions to make continuous improvements to the education that they provide. By comprehending how students learn, teaching can be tailored to meet their individual needs. Analysing

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student interactions with online learning platforms helps to enhance the overall learning experience.

2.6.2 Learning Analytics with Game-Based Learning

This sub-section is an investigation of the use of LA in the context of game-based learning. Data collected from the interaction of students with educational games is the focus of the collection and analysis of data. The objective is to explore the students' level of involvement, performance and areas for improvement in game-based learning (Cariaga & Feria, 2016; Serrano-Laguna et al., 2014).

In this context, educational games can be used to explore patterns of student learning. Educational games can provide valuable insights into the factors that impact student achievement. For example, patterns of high and low achievers were identified in a study (Sung et al., 2017). Their findings suggest that monitoring and providing intervention for those students who display different patterns of performance could be carried out more accurately.

Teachers can provide additional support or interventions to students who are experiencing difficulties in order to help them overcome the difficulties they are finding. The results also provide a useful reference point for teachers in schools who are planning to implement this approach to learning. There has been considerable interest in research on LA in the context of game-based learning. The interaction

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between LA and the use of games in the learning process has been investigated in several studies. The results of these studies are presented in Table 2.1.

Table 2.1

A Review of The Research: Learning Analytics and Game-Based Learning

Author	Year	Title	Process
A. Tlili, F. Essalmi, L. Ayed et al	2016	A Smart Education Game to Model Personality using LA	Modelling of the personality of the learner on the basis of the learning tracks generated during the learning game process
M. Ali, S. Shatabda, and M. Ahmed	2018	Impact of LA on Product Marketing with Serious Games in Bangladesh	Serious Games (SG) with LA in the area of Product Marketing
Serrano-Laguna, J. Torrente, P. Moreno-Ger, and B.F Manjon	2012	Tracing a Little for big improvements: Application of LA and Videogame for Student Assessment	Identify part of the assessment of the students in a semi-automatic way, by the recording of the interaction with the educational video games.
A.A Cariaga	2016	LA through a Digital Game-Based Learning Environment	Development of a model for learning analytics in a game-based learning environment.
H.Y. Sung, P.H. Wu, G.J. Hwang, and D.C. Lin	2017	A Learning Analytics approach to investigating the impacts of Education Gaming behavioral patterns on Students' Learning Achievements	Investigation of patterns of behaviour in educational games that have an impact on student performance.
Serrano-Laguna, J. Torrente, P. Moreno-Ger, and B.F. Manjon	2014	Application of Learning Analytics in Educational Video Games	LA can be applied for assessment purposes by studying the way in which students interact with games. However, one of the

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Table 2.1 *(continue)*

Author	Year	Title	Process
			biggest problems with this approach is the wide variety of video games. There are many different genres and types.
J.D. Roberts, G.K.W.K. Chung, and C.B.Parks	2016	Supporting children's progress through the PBS KIDS Learning Analytics Platform	Providing a special report to better identify and support children in the process
A. Emerson, E.B. Cloude, R. Azevedo and J. Lester	2020	Multimodal Learning Analytics for Game-based learning	This paper presents a multimodal learning analytics approach that integrates student gameplay, eye tracking, and facial expression data to predict student post-test performance and interest after interacting with a game-based learning environment, Crystal Island.
M. Priyaadharshini, N. NathaMayil, R. Dakshina et al.	2020	Learning analytics: Game-based Learning for Programming Course in Higher Education	The game-based learning for programming course stimulates learning desire and a better understanding of programming concepts.
C. Alonso-Fernandez, I. Martinez-Ortiz, R. Caballero et al.	2020	Predicting students' knowledge after playing a serious game based on learning analytics data: A case study	This is a case study in which pre-experiments and post-experiments were conducted with 227 students playing a previously validated serious game on first response techniques. Student interaction data was collected during gameplay using a game learning analytics infrastructure and the standard data format Experience API for Serious Games.

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There are a number of important conclusions that can be drawn from the table above, such as the following: The use of LA in game-based learning allows for better personalisation of the learning experience. Data analysed from game activations helps to identify the individual needs of students in order to personalise teaching styles and curriculum (Sung et al., 2017). Students' interactions can be better understood through LA, and data analysis can reveal levels of engagement and challenges faced by students, helping educators to design more effective learning strategies (Priyaadharshini et al., 2020). This improvement in game development allows for the optimisation of game features, levels of difficulty and interactions in order to strengthen the learning process (Alonso-Fernández et al., 2020).

Analytics provides support in the assessment of the level to which learning objectives are being achieved in the context of the game. It offers insight into the performance of the students and allows for adjustments and improvements to be made to learning strategies (Emerson et al., 2020). The analysis of data from game-based learning provides a stronger basis for decision making with relation to learning strategies and curriculum improvement (Barzilai & Blau, 2014). Early intervention through LA allows for the early identification of student learning problems and enables teachers to provide appropriate support to students who are experiencing difficulties (Mohamad Samuri et al., 2021). Application of LA provides a more systematic way of measuring student performance in the context of game-based learning. more targeted and customized learning that is individually designed to meet the needs of each learner.

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2.6.3 Learning Analytics Use Data Mining Technique

This sub-section is a discussion of the use of data mining techniques in LA. Data mining is used to investigate patterns and trends in large and complex educational data and includes predicting student learning behaviour, identifying significant patterns in academic progress, and understanding learning preferences (R. S. Baker et al., 2016).

Identifying patterns and trends, making predictions and performing predictive analysis, personalising learning, supporting evidence-based decision making and performing retrospective analysis are the main objectives of data mining and learning analytics in education. Through the use of data mining techniques, the education sector is able to utilise the great potential of data generated from learning management systems to support smarter decision making and to enhance the learning process (Siemens & Baker, 2012). The prediction of student performance is an important area of data mining in the education sector that has been receiving a great deal of attention from researchers (Roy & Singh, 2017). In this context, data mining techniques are applied for the prediction of student performance and behaviour on the basis of the patterns in historical data (Mishra et al., 2017).

The research on LA in the context of data mining education has received a significant amount of interest. Several studies have investigated the interaction between LA and the use of data mining in the learning process. For more details on this please refer to Table 2.2.

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Table 2.2

A Review of The Research: Learning Analytics Use Data Mining Technique

Author	Year	Title	Process
M. Fernandez-Delgado, M. Mucientes, B. Vazquez-Barreiros	2015	Learning analytics for the prediction of the educational objectives achievement	The prediction of the achievement of the outcomes of the subject on the basis of the previous results enables the teacher to adapt the learning design of the subject to the teaching-learning process.
R. Baker, T. Martin, L. Rossi	2016	Educational data mining and learning analytics – Educational Assistance for Teaching and Learning	The collection of a significant amount of data on students' performance in their assessments in order to identify those at risk of failure in the final examination.
F. Matsebula, E. Mnkandla	2017	A big data architecture for learning analytics in higher education	The purpose of this paper is to propose an architecture for the analysis of big data in the higher education sector.
J. Aguilar, P. Valdiviezo-Diaz	2017	Learning analytic in a smart classroom to improve the eEducation	In this paper, different data mining techniques are used to develop learning analytics tasks to understand the learning process in an intelligent classroom.
A. Vwen, Y. Lee, E. Koh et al	2023	AI in Education and Learning Analytics in	This paper provides an overview of AI in

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Table 2.2 *(continue)*

Author	Year	Title	Process
		Singapore : An Overview of Key Projects and Initiatives	education and LA projects and initiatives in Singapore, categorised according to the type of technology involved. The projects and initiatives identified are using a variety of techniques and systems to achieve personalised learning, to improve student engagement, to optimise resources, and to predict student success among a list of educational achievements.

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The table above highlights the wide range of applications of predicting student performance to improve education, enabling educational institutions to provide more effective support, make better decisions, and tailor learning approaches to support the needs of individual students. Techniques for predicting student performance in LA and in educational data mining applications include classification, regression, clustering, artificial neural networks, and machine learning algorithms (Siemens & Baker, 2012; Vwen et al., 2023).

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2.6.4 Critical Review and Analysis

The importance of LA in the understanding of the learning patterns, the availability of timely responses, the optimisation of the learning experience and the improvement of the quality of teaching is also highlighted in the Executive Summary. This is supported by (Crescenzi-Lanna, 2020) who have highlighted that LA enables early identification of developmental patterns and provides deep insights into user preferences and readiness in the context of learning.

The use of data in education not only allows for the identification of problems or potential at an early stage, but also facilitates more responsive and personalised decision making in LA (Siemens & Long, 2011). This leads the way to improvements in the provision of more appropriate and effective educational materials and the tailoring of learning strategies to the specific preferences and preparation of students. In addition, the importance of learning analytics to the understanding and improvement of the learning process includes the following:

1. LA helps in the identification of effective patterns of learning from the interaction of the students with the online and offline learning platforms or resources.
2. Through data analysis, LA gives teachers the intelligence to respond more quickly to the needs of individual students who are getting behind or who are missing learning materials.

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3. Through an understanding of learning data, LA helps to improve the learning experience for students in both online and offline settings by providing learning methods that are customized to meet individual needs.
4. The LA provided an objective insight into the suitability of the curriculum. It also offered the required feedback to improve the learning materials.
5. Through the use of data analysis and a comprehensive understanding of students' learning patterns, LA makes it possible to improve the quality of teaching by designing more effective teaching methods

Therefore, LA provides a good basis for ongoing research and development in an effort to develop and improve learning methods. Based on the research question, the researcher's approach was implemented. This has been done through a case study of the development of a game-based learning analytics platform. Additionally, the following section describes the game-based LA to be implemented.

2.7 Game Based Learning Analytics

In this section, the outcomes of a systematic review of the application of LA in the context of early childhood education are described. Game-based learning analytics (GLA) is a sub-field of LA that focuses on the analysis of learning processes in educational games or interactive games. According to (Alonso-Fernández et al., 2019). GLA involves the collection, analysis and interpretation of data generated by user interactions while playing games, with the aim of understanding and improving the effectiveness of learning.

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Specifically, GLA has an important contribution to make in the development of more effective educational games, and in assisting teachers to design more enjoyable and rewarding learning experiences. GLA focuses on various elements related to game interaction, including the duration of the game, the level of difficulty of the game, the decisions that the player makes, the level of achievement achieved, and the response to different situations in the game (Cano et al., 2018). Early childhood education and care plays a very important role in the development of children. It includes cognitive, social, emotional and motor aspects, all of which are essential for the development of the child.

Learning through the use of image-based learning methods is one of the most effective ways of facilitating children's understanding of learning concepts. Images can be used to provide conceptual understanding, stimulate the imagination, and facilitate visual comprehension, which in turn supports the development of various aspects that are important to children (Ligorio et al., 2017). Image-based learning has the advantage of presenting concepts visually, helping children to better understand and recall information. In the context of GLA, images are used in educational games to understand children's learning patterns. The ways in which children interact with the pictorial elements in the game have been recorded by (Sung et al., 2017). This data can offer insights into the areas that children find more interesting based on their responses to specific visuals presented through the images.

GLA could be a useful tool in the optimisation of image-based learning methods, so that children can get the maximum advantage from the use of images in the learning process. Figure 2.5 shows the procedure that was followed during the implementation of the Game Learning Analytics.

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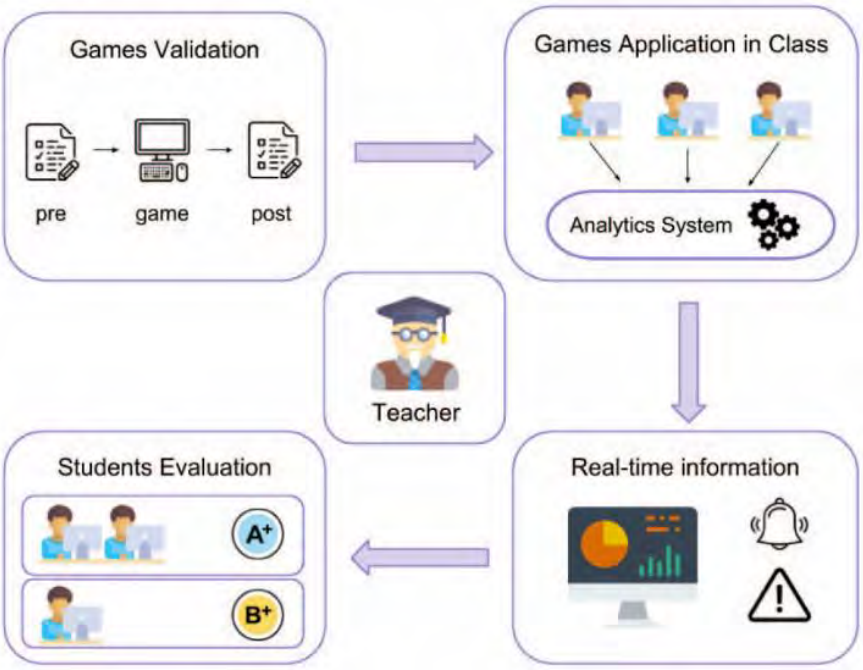


Figure 2.5. The GLA process involves the use of serious games for the validation of the game, its application in the classroom, the real-time collection of information and the evaluation of the students (Morata et al., 2019)

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Figure 2.5 shows that the GLA stage can assist game developers and teachers to increase the effectiveness of their game-based learning methods. Validation of games involves a pretesting and a post-testing step (Calderón & Ruiz, 2015). which allows the game to be validated to make sure that it has achieved certain standards, criteria or objectives that have been set previously. The implementation of the validated game in the classroom as part of the lesson is an excellent one to get immediate feedback from the children on the learning material (Hamari et al., 2016). Integrating the Game Learning Analytics (GLA) data into a dashboard or visualisation tool can provide the teacher with a comprehensive view of students' interactions with the game and their progress. These dashboards present the information in real time and help the teacher to understand patterns and provide insights (Perez-Colado et al., 2018). Performance

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assessments are conducted to determine student performance in the context of game-based learning using real-time information data.

The development of a game-based platform for the analysis of learning is an intelligent approach to addressing the research problem. This platform could provide a detailed and thorough understanding of how children learn and how children interact with materials through their play experiences.

2.8 Framework and Guidelines for The Education of Children 3-4 years old

This section describes the framework and guidelines for the education of children between the ages of 3 and 4 as an important framework for the development of an effective game-based learning analytics platform for children in their early stages of development. The section is divided into two subsections, with subsection 2.8.1 provides an explanation of the PERMATA curriculum, which is used as a framework for the education of children aged 3 to 4 years old in Malaysia. The Merdeka PAUD curriculum, which is used as a framework for the education of children aged 3 to 4 years in Indonesia, is explained in section 2.8.2.

2.8.1 The PERMATA Curriculum

The PERMATA curriculum is a framework for the national education system in Malaysia that focuses on the development of the potential of children through early

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childhood education (PERMATA, 2013). The following are some of the most important points of this curriculum:

A. The approach to learning
    1. The curriculum is based on the concept of play as the primary means of learning, with the most effective approach being through the interactive and fun activities.
    2. Through experimentation, children are given the chance to be free and to develop their intellectual abilities.
    3. Interaction with peers, teachers and parents is also supported. Collaboration with different individuals around them is important in helping children to develop socially and emotionally.

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B. Focus on the development of children
    1. Providing for the development of healthy skills and a positive personality, supporting children in the control of their emotions and helping them to develop a strong sense of themselves.
    2. Focuses on the development of all aspects of a child's personality, including emotional, social, spiritual, intellectual, physical and creative.
    3. All children are considered to have a unique potential that needs to be identified and appreciated through an individualized approach to education

The PERMATA curriculum highlights the importance of building a strong foundation for children's integrated development, not only academically, but also in their social, emotional and creative skill. Based on this, the Permata curriculum has

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developed six aspects of learning which focus on the growth and development of all children, as shown in Figure 2.6. These include the following six aspects.

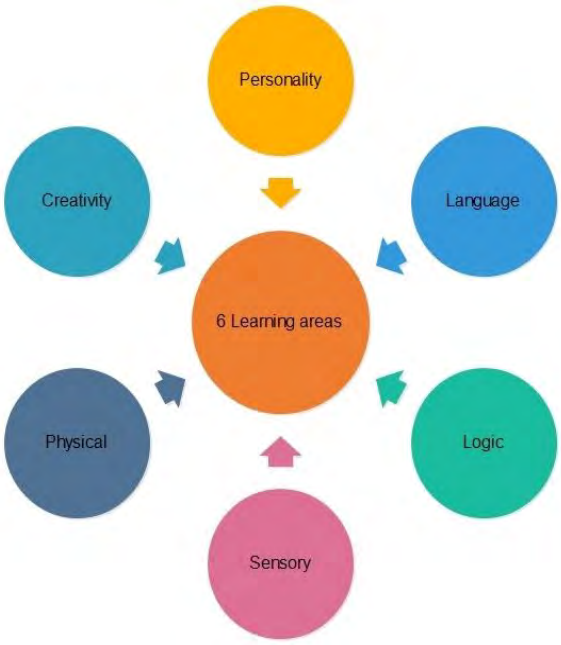


Figure 2.6. The PERMATA curriculum is based on six areas of learning for children

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1. Development of a strong and positive personality, including the children's social and emotional aspects, emotional management, self-confidence and ethics.
2. The development of language skills includes the mother tongue, the foreign language, the speaking skills, the listening skills, the reading skills and the writing skills.
3. The development of logical skills, critical thinking, problem-solving abilities, and the ability to identify relationships of cause and effect.
4. The development of children's five senses, including recognition, implementation and improvement of skills using children's senses such as seeing, hearing, smelling, touching and tasting.
5. Children's physical growth and development, including use of gross motor skills such as walking and running, and ability to use fine motor skills such as writing.

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6. Developing the creative expression and imagination of children, including through facilitating the development of their artistic skills, innovation and problem solving.

Through these areas of learning, the PERMATA curriculum provides a comprehensive foundation for children's development, ensuring that they have the opportunity for balanced growth and development in different aspects of life. This study focuses on logic development and creativity in 3 to 4 year age children, as these areas are important aspects of their lives, such as: development of thinking skills, cognitive growth, development of social skills, and preparation for further learning (Almeida et al., 2008; Bickham, 2017; Mumford & Gustafson, 1988). Good logical skills provide a strong framework for problem solving and sound decision making, thus contributing to their overall development (Fraassen, 2011).

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Designed for 3-4 year-olds to improve their creativity and logic. The programme focuses on a number of stages of learning that are essential for the development of the children. The following is an outline of the stages that should be in the learning process:

A) Development of the creativity

1. Able to draw, play music and perform body actions.
2. Able to generate new ideas.
3. Able to show great imagination.
4. Able to collect and select colours and textures of materials.
5. Able to participate when listening to stories or tales.
6. Able to generate ideas in a drawing form.

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B) Development of the Logic

1. Able to understand the shape of symbols.
2. Able to recognize differences and patterns.
3. Able to understand addition and measurement.
4. Able to count from 1 to 10 in Malay and English
5. Able to recognize and write numbers.
6. Able to understand many more shapes as well as their sizes.

Through this learning process the children achieve the expected goals in the development of creativity and logic in accordance with the educational framework for children of 3-4 years of age in the PERMATA curriculum.

2.8.2 The Merdeka PAUD Curriculum

The Merdeka Curriculum for PAUD is a curriculum designed for PAUD in Indonesia. The curriculum offers a more comprehensive and diverse approach to education, covering aspects that support the holistic development of the young children (Kebudayaan, 2020).

Here are some important aspects related to the Merdeka Curriculum for PAUD:

1. A holistic approach

   The holistic approach refers to the development of children in terms of cognitive, physical, social, emotional and spiritual aspects.

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2. Learning through practice and experience.

   Having fun and learning at the same time by using games and fun activities as the primary means of learning.

3. Participation of parents

   Parents should be involved in the education of their children from as early an age as possible.

4. Development of Various Aspects

   A focus on the development of children's creativity means paying attention to their creativity and their skills in the arts. It also means developing basic skills. These include counting, reading, writing and motor skills.

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5. Integration of technology

   The use of technology in the early childhood classroom with principles that support holistic development.

6. A holistic assessment

   This is a process-based assessment that is designed to determine the developmental progress of children through observation, data and documentation.

The Merdeka PAUD curriculum is designed to provide a comprehensive foundation for early childhood education by focusing on the individual needs of children and their holistic development. The curriculum places great importance on the

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development of creativity and logic in children. As such, the learning activities and methods offered are designed to stimulate and facilitate the development of these skills.

There are several stages of learning that are the main basis for the development of creativity and logic in children aged 3-4 years in the Merdeka PAUD Curriculum. The Stages that need to be considered in the development of logical creativity in the Merdeka PAUD Curriculum are as follows:

A. Development of the creativity

1. Exploration of imagination

   Children are given the opportunity to develop their imagination through play, creative activities and story-telling. Opportunities are provided for them to express creative ideas through various artistic and play-based activities.

2. The development of visual creativity

   Through painting, drawing, or other artistic media, children can develop their visual skills and enhance their creative expression. It is important to provide opportunities for children to explore different forms of art and encourage them to express themselves in a variety of ways.

3. Aesthetic Stimulation

   Introduce children to aesthetics and the appreciation of beauty in art and in the environment, with a view to the development of their own aesthetic sense.

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B. Development of the logic

1. Introduction to the skills of critical thinking

   Children are introduced to critical thinking skills in an effort to make logical conclusions.

2. Development of the ability to think systematically

   Stimulate children to think in a structured approach to solving problems by using organized steps.

3. Improvement of basic mathematical skills

   Presents the basics of mathematics through the introduction of the concept of numbers in a sequence.

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Through these stages in the development of creativity and logic in children aged 3 to 4. The children are given the opportunity to develop in a holistic approach that allows them to learn from experience.

2.9 Game-Based Learning Analytics Using Artificial Intelligence

This section provides an explanation of Artificial Intelligence (AI) and the role it plays in the analysis of game-based learning. The explanation is divided into several subsections. Machine learning, which provides an approach to analysing and optimising the learning process in the context of LA, is described in subsection 2.9.1. In subsection

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2.9.2 the classification model in LA is described, which is used for the grouping or classification of the learning data into certain labels.

2.9.1 The Machine Learning and Learning Analytics

Machine learning (ML) is a field of artificial intelligence (AI) that focuses on the development of algorithms and statistical models that enable platforms to learn from data in order to understand patterns, make predictions, or make decisions (Mahesh Batta, 2020). Figure 2.7 gives an overview of some of the ML algorithms that are commonly used.

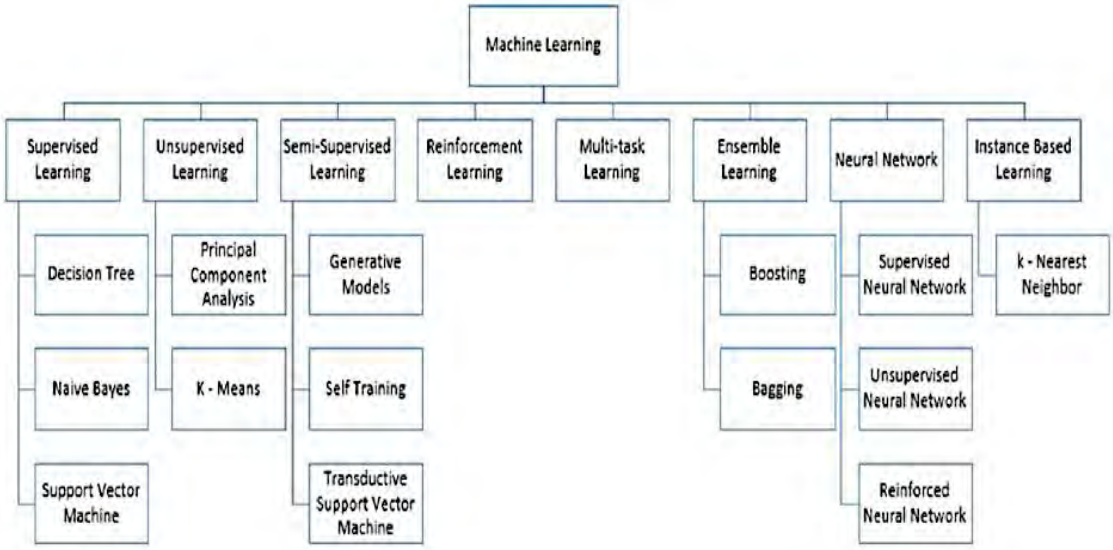


Figure 2.7. General algorithms for machine learning (Mahesh Batta, 2020)

According to (Mahesh Batta, 2020), each algorithm has a different set of strengths and weaknesses. The choice of the appropriate algorithm depends on a number of factors, including the types of data, the nature of the data, the performance

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of the model, the complexity of the model, the availability of training data and the availability of resources. According to (M. A. Chatti et al., 2012), LA and machine learning (ML) have a complementary and very strong relationship. In the context of LA, ML is used to analyse data that is generated from the learning interactions of students, from learning platforms, or from other learning-related data. The analysis produces information that is displayed in the form of a learning data visualisation (dashboard). This information is used to support decision making by stakeholders such as teachers or school administrators. Table 2.3 shows the articles in which machine learning has been applied in the context of LA.

Table 2.3

Methods applied to the ML and LA

Author	Title	Objective	Method
(Xing et al., 2015a)	Participation-based student final performance prediction model through interpretable Genetic Programming: Integrating learning analytics, educational data mining and theory	This study explores the development of usable prediction models by synthesising learning analytics approaches, educational data mining (EDM), and HCI theory. The prediction models are represented using data from the environment through collaborative geometry problem solving, specifically the Virtual Maths Team with GeoGebra (VMTwG).	Supervised Learning
(Sungkur et al., 2016)	TrueSight Learning - An innovative tool for Learning Analytics	The implementation of technology to enhance the effectiveness of learning and teaching, specifically in large student classes, in combination with traditional learning methods.	Supervised Learning

(continue)

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Table 2. 3 *(continue)*

Author	Title	Objective	Method
(Ada & Stansfield, 2017)	The Potential of Learning Analytics in Understanding Students' Engagement with Their Assessment Feedback	Presents the results obtained from the use of a prototype application to follow the engagement of students with their feedback.	Supervised Learning
(Pappas et al., 2017)	Fuzzy set analysis as a means to understand users of 21st-century learning systems: The case of mobile learning and reflections on learning analytics research	This paper briefly reviews the factors that have been shown to be important in the context of the implementation of mobile learning, and builds on complexity theory and configuration theory in order to explore the causal patterns of factors that stimulate the use of mobile learning.	Multi-task learning
(Hasan et al., 2020)	Predicting student performance in higher educational institutions using video learning analytics and data mining techniques	Prediction of the overall performance of students at the end of the semester through the use of video learning analytics and data mining techniques	Supervised Learning

From the table above, it can be explained that through the use of ML, LA is able to explore deeper insights from the data generated from the learning process. The relationship between ML and LA results in a powerful tool for understanding and enhancing the student learning experience (Siemens & Baker, 2012).

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2.9.2 The Learning Analytics Classification Model

Classification models in LA make use of machine learning techniques to analyse educational data and to understand the patterns that are contained in it. Classification models are trained on labelled data to learn the patterns and relationships between features and their corresponding labels. The success of a classification model depends on the quality of the data, on selecting suitable features and on applying algorithms as appropriate to the problem (Romero & Ventura, 2007).

According to (M. A. Chatti et al., 2012), classification models are one of the effective methods for the analysis of the data generated by the learning platforms in the context of LA. This method makes it possible to have a better understanding of the patterns that are hidden in the learning data. Classification models can be used for the analysis of the data generated by learning analytics platforms for the segmentation of students, the prediction of student performance, the personalisation of learning and the analysis of user interaction (Ihantola et al., 2015).

Some of the classification models that are commonly used in LA are Decision Tree, Naïve Bayes, Logistic Regression, Support Vector Machine, Random Forest, and K-Nearest Neighbours (KNN). The selection of these algorithm models depends on the nature of the data, the complexity of the problem and the specific objectives of the analysis to be achieved (Algarni, 2016; Mahesh Batta, 2020). Furthermore, in the context of LA, artificial neural networks can also be used for classifying models and are capable of dealing with classification problems with several classes or labels that are often presented in LA (Namoun & Alshanqiti, 2021).

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2.10 Chapter Summary

This section provides a summary of the literature review, which has provided a detailed explanation of learning analytics on the basis of the literature. The structure of the literature review, shown in Figure 2.1, clearly illustrates the results of the research from a systematic protocol aimed at identifying the main objectives and challenges in the field of learning analytics. Based on the scope of the research in the previous chapter, the development and improvement of teaching methods that focus on the use of educational games and children's interaction data to improve the teaching of creativity and logic development in children aged 3-4 years-olds. A game-based learning analytics platform is proposed as a valuable tool for the achievement of this goal. In addition, the literature review outlines the different stages of learning analytics in general, as well as its application in distributed learning environments and in early childhood education. The learning process is described in detail in a number of sub-sections, culminating in a critical review and analysis that is the basis for the case studies and solution recommendation.

This research approach of using game-based learning analytics for children aged between 3-4 years-old represents the step that is applied in this research in order to understand and improve the learning process at this age. Data is collected from children through educational games designed based on the framework and guidelines for the education of children aged 3-4 years-old described in the PERMATA curriculum and the Merdeka PAUD curriculum. Machine learning methods will be used in the data analysis process, in particular classification models, to evaluate the effectiveness of the educational games in the development of creativity and logic in children of 3-4 years-

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old. Based on the literature described, this will be the first step in the research objectives. The methodology to be used in this research study is explained in more detail in the next chapter.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

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This chapter provides an overview and explanation of the methodology used for the development of the game learning analytics platform. A developmental assessment of creativity and logic was carried out on children between the ages of 3-4 years-old. The discussion is divided into four phases of work. The first phase, the identification and description of the research problem, is described in section 3.2, while section 3.3 presents the second phase, the identification of the elements and attributes used in the educational game. The third phase involves evaluating the process of assessing Creativity and Logical Development. In the fourth phase, the development of a learning analytics platform that assesses the development of creativity and logic in children between the ages of 3 and 4 through games is presented in section 3.4. The third phase involves validating and evaluating the learning analytics platform by assessing the development of creativity and logic in children aged 3-4, as described in section 3.5.

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This chapter describes a four-phase process. Finally, section 3.6 summarises this chapter.

3.2 Preliminary Study Phase

A preliminary study was conducted to explore the methods developed for a game-based learning analytics platform aimed at assessing creativity and logic development in 3-4 year-olds. The investigation's various steps are described in the following subsections, as illustrated in Figure 3.1.

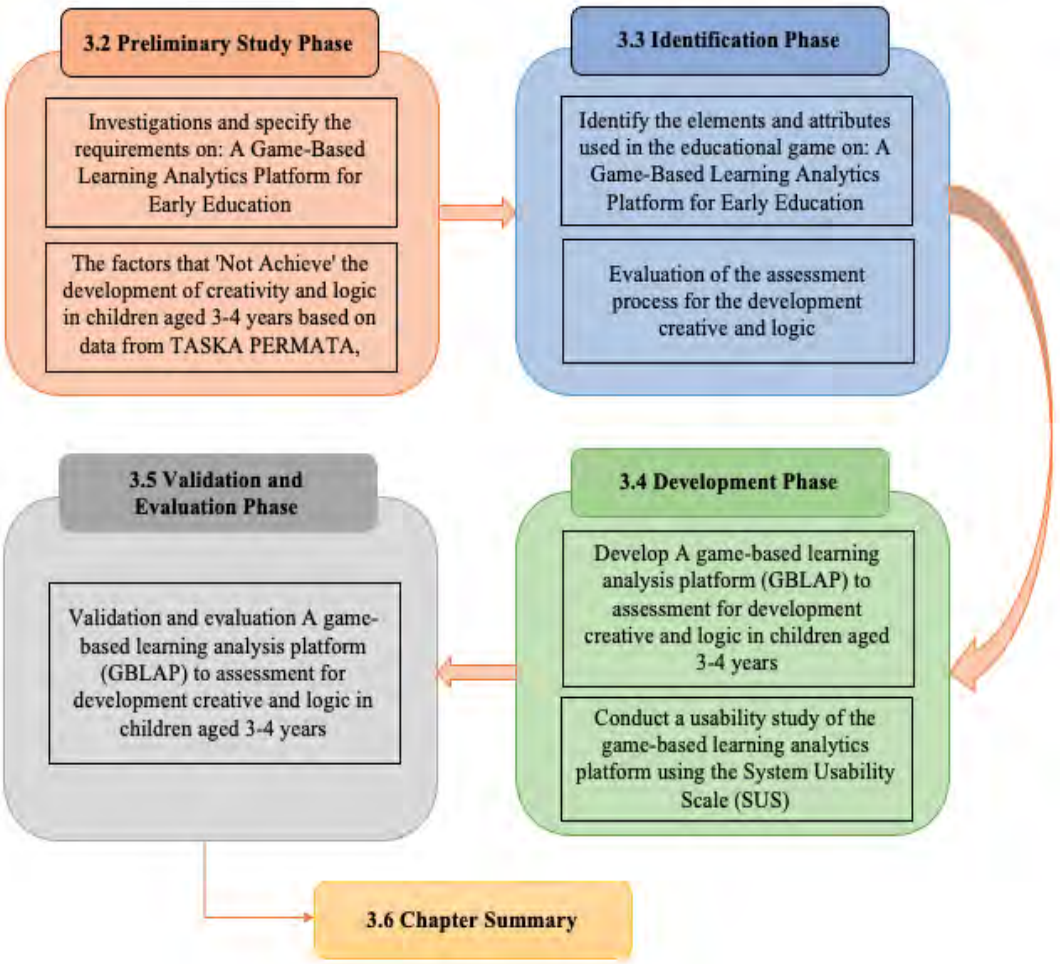


Figure 3.1. Research Methodology Phases

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3.2.1 Collecting Data on Developing Creative and Logic 3-4 year-old Children

This section describes the data collection process in relation to the development of creativity and logic in the case study. The scope of the research and the problems have been explained in chapter one. The development of creativity and logic in children between the ages of 3 and 4 is a crucial process, as it lays the foundations for their future development. This process lays the foundation for their future development. On the other hand, children who are not able to achieve or who do not understand the concept of learning or development will be left behind. The study involved the collection of data on the development of creativity and logic in children aged between 3 and 4 years from two institutions in Malaysia and Indonesia, namely Taska PERMATA UPSI and PAUD Manhajul Husna.

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Taska PERMATA UPSI is an early childhood education and care centre that provides services to children up to four years of age. It is located at The National Child Development Research Centre (NCDRC) at Universiti Pendidikan Sultan Idris (UPSI) in Malaysia. Children up to the age of four years are educated on the basis of the national standard curriculum in Malaysia, namely the PERMATA Negara Curriculum, which is explained in Chapter 2, Section 2.8.1.

Manhajul Husna PAUD is a private educational institution located in the village of South Alalak, Banjarmasin City, South Kalimantan Province, Indonesia. PAUD stands for 'Early Childhood Education' and is a centre for children between the ages of three to five years old. Children in this age group have access to education through playgroup programmes. In the state of Indonesia, a national standard curriculum called

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the Merdeka PAUD Curriculum has been designed to provide educational services for children aged three to five years. The curriculum is explained in Chapter Two, Section 2.8.2. Data on the development of creativity and logic in children between the ages of 3 and 4 years were collected from two different institutions. The information was in the form of child development reports and records of individual children's performance in learning.

3.2.2 Interviews and Observations About The Development Creative and Logic

In order to gain insights into the development of creativity and logic in children aged 3-4 years, this section describes the process of conducting interviews and observations. An important Some of the steps taken are as follows:

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3.2.2.1 Preparation

Preparing the aspects that children should achieve in the development of creativity and logic, based on the curriculum of the two institutions, for guidance or questions to teachers. The following aspects should be achieved:

a. The development of creativity in children between the ages of 3-4 years-old.
    1) The child can make doodles of different shapes, including straight lines, zigzags and curves.
    2) The child can choose objects they like. Examples are cars, fruit and animals.

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3) The child can draw two-dimensional shapes, such as squares, triangles, and circles.
4) The child can make draw shapes such as houses, cars, fish, and cats.
5) The child will also be able to colour the picture accurately to match the colours of the original.
6) The child can use musical instruments to skilfully create musical rhythms.

b. The development of logic for children between the ages of 3 and 4 years old.

1. The children can count from 1 to 10.
2. The children can match similar objects (example, socks, shoes).
3. Give cause and effect with guidance.
4. The children make easy decisions with reason by giving a logical reason.
5. Name the 4 basic colours.
6. Name the 3 basic shapes.
7. Know patterns and can shape them again.
8. Able to show mental representation using concrete objects (example: wild animal – tiger).
9. Be aware of the concept of time and time sequence (example: eat, shower, rest, get, ready to go home).
10. Use ICT more confidently (example: using an iPad without assistance and charging when the battery is exhausted).
11. Interest in asking questions about why and how things happen.
12. Make observations and conclusions with guidance.
13. Able to relate and use experience past and present learning in solving problems.

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3.2.2.2 Observation

An observational approach was used to study the natural activities of the children, noting how they behaved as well as what creative and logical activities they were involved in. In addition, references from a number of studies relating to technology in the context of children have been consulted.

According to (Neumann, 2018b; Papadakis & Kalogiannakis, 2017)in their research, children at this age have excellent literacy skills, such as reading, writing, listening and speaking. Interactive media can be employed as an attractive learning tool for children. Furthermore, pictures are an effective way of understanding children's representations of their learning process, as suggested by (Ligorio et al., 2017). With the help of images, teachers are able to know the circumstances of children that are happy and sad.

Applying the principles of technology is an important approach to educating children at this age. The use of technology is a valuable tool in educating children of this age group. Today's sophisticated technology, such as touch screens, can serve as an interactive medium for children aged 3 to 4 years, facilitating their learning process (Dostál, 2015; Verkhoturova et al., 2016). Nor Azah Abdul Aziz explains in her research described in Table 3.1 about the percentage of children's movements on the touchscreen.

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Table 3.1

The Percentage of gesture that can be used by children on a touch screen (Abdul Aziz et al., 2013)

Gesture	Age 3	Age 4
Tap	100%	100%
Drag/Slide	100%	100%
Free Rotate	91%	100%
Drag & Drop	100%	100%
Pinch	82%	100%
Flick	73%	100%
Spread	36%	100%

Based on the percentage of movement presented in the table above, this presents an opportunity for researchers to develop research in digital games that are popular among children, particularly those aged 3 to 4 years (Yilmaz, 2016).

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3.2.2.3 Interview

The aim of the interview approach was to gather in-depth information from teachers and stakeholders involved in the assessment of the development of creativity and logic in children between the ages of 3 and 4 years. Direct interviews provide researchers with the opportunity to connect with users and obtain information that may be difficult to understand through data analysis alone, as suggested by (Kourakli et al., 2017; Ziv et al., 2016). The researcher carried out face-to-face interviews with classroom teachers and obtained data from the database of each institution in order to gather the following

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information. Information on the factors that hinder the development of creativity and logic in children between the ages of 3 and 4 years old.

3.3 Identification Phase

The purpose of this phase is to identify the elements and attributes used in educational games. In this case study, the identification phase is crucial in the development of a game-based learning analytics platform (GBLAP) for assessing the development of creativity and logic in children aged 3-4 years. It is important to design the game features while considering the developmental needs of children and the research objectives to be achieved. Based on research (Siddoo et al., 2016) that provides relevant insights into effective approaches to teaching 3-4 year-olds, this approach takes into account the interests and needs of children at their early developmental stages. This approach takes into account the interests and needs of children at their early developmental stages, as shown in Table 3.2.

Table 3.2

Theme and Category of The Early Children Education and Care (Siddoo et al., 2016)

Sub Category	Category	Main Category
Learning Unit	Teaching Method	Suitability Game for Education Early Children
Cognitive Skill		
Activities		
Child Perception		
Learning Time	Awareness and Limitation	
Alternative Learning		
Learning Media		

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The table above shows that when designing or selecting educational games for children, it is important to take into account aspects such as engagement, interactive skills and a focus on learning. When designing or selecting educational games for children, it is important to consider the sub-categories of learning units, cognitive skills, activities, and children's perceptions. This includes a range of techniques used by teachers to deliver learning materials with learning time, learning alternatives, and learning media, as well as awareness and limitations in the learning process. By considering these factors, educational games can be tailored to support engaging and effective learning that meets the developmental needs of children.

Therefore, it is important to take into account that children aged 3-4 years are developing rapidly and have different levels of creativity and logic (Hinostroza et al., 2013). The identification phase involves identifying the elements and attributes used in educational games, which is described in the following subsections.

3.3.1 Pilot study measuring the development of creativity and logic in children through game use

In general, when developing games for educational purposes, it is important to have consideration for the limited time available for learning and to be sensitive to children's development. The use of colour, in addition to time, is also required to stimulate children's interest in the game. The developmental level of the child should also be taken into account when designing the game. The objectives of this pilot study are as follows:

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1. Investigate the potential of educational games in developing the creativity and logic of 3-4 year-old children.
2. Investigating the measurement of the ability of 3-4 year-old children to play educational games in developing their creativity and logic.

This sub-section outlines the process of selecting educational games for Android devices that are curriculum relevant and designed to develop creativity and logic. The selection process is based on the research conducted by Nor Azah Abul Aziz on children's interaction with tablet apps, specifically gestures and interface design (Aziz, 2013). When selecting games, it is important to consider the following criteria:

1. It has an educational category for pre-schoolers.
2. which is available free of charge.
3. Compatible with the Android operating system.
4. Available on the Google Play Store.
5. The content of creativity and logic development is in line with the Permata curriculum.
6. Possible to install on smartphones and tablets.

As part of the pilot study, observations were made of the children during their participation in the activities. The process of observation was carried out in the following step:

1. The children are asked to play a game that is in the form of an app.
2. The duration of each game is limited to a maximum of five minutes per child.
3. The scoring system for the game gives a score for each game from 1 to 3.

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4. The scoring process for the games is divided into two categories: games of form and games of number.

The assessment of children's abilities involves the completion of the game in both categories from the starting point of the game to the end of the game (Piotrowski & Meester, 2018). During the assessment process, the game will be divided into two categories as follows:

1. Creative category

The Torrance concept is a useful method for the assessment of creativity in children. It identifies several dimensions of creativity, including flexibility, fluency, originality and elaboration (Almeida et al., 2008; S. Yoon et al., 2017).

a. The concept of flexibility in this context refers to the ability of the children to experiment with various interactions within the game (Neumann, 2016; Price et al., 2015). In the given example, the success of the child in following the instructions of the lines provided in the game is demonstrated.
b. The fluency and originality of the children meant that they were able to complete each of the games and to create an image (Piotrowski & Meester, 2018). It is worth noting that the completion of the games was done by the children themselves.
c. Elaboration refers to the ability of the child to understand all the instructions in the game and to follow them (Piotrowski & Krcmar, 2017). In this case, the child responds to the game in a timely manner, without the assistance of the teacher.

2. Logic category

The theory of Howard Gardner provides a framework for the measurement of children's logical abilities. Children have an understanding of the sequence of numbers and the

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concept of numbers (Silveira, 2007). The research pilot study tests the children's skills through their participation in two games.

Scoring reports are an assessment of the children's ability to complete the game (C. H. Yoon, 2017). The length of time for the completion of each stage is the basis for the score (Siddoo et al., 2016). Each child will receive a score of 1, 2, or 3, based on a number of specific factors. The following is an explanation of the scores that are given:

1. A score of three (3) is awarded if the children successfully complete the game within 10 seconds.
2. A score of two (2) is awarded if the children successfully complete the game within 20 seconds.
3. A score of one (1) is awarded if the children successfully complete the game within 30 seconds.

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In this pilot study, educational games have been divided into two categories: creative games and logical games. There are different types of games in each of these categories. The games are designed so that they are played on a smartphone.

The researcher informs the teacher before the activity about the objectives and the steps to be taken in the pilot study, then the teacher gives instructions to the children on how to use or play each game. Children are then given the opportunity to play with the games on their own. The teacher is available to answer any questions that the children may have and to give them any guidance that they may need. This methodology was also used by (Yilmaz, 2016) in their research. The game takes approximately five minutes to complete, and all play sessions are recorded for behavioural pattern analysis. Following implementation, each child was interviewed to

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assess their cognitive performance in adapting to the game and their opinions about the game.

3.3.2 Game Design

In this section, we outline the process of creating an interactive game within a game-based learning analytics platform to assess the development of creativity and logic in children between the ages of three and four years. According to (Adams, 2013) in his Fundamentals of Game Design, a game is made up of a core mechanic, a user interface and a gameplay system. The game system is organised by the core mechanics. This is illustrated in Figure 3.2. The user interface and the gameplay system are important elements that need to be focused on in order to develop a game that can help children to achieve their developmental goals and abilities.

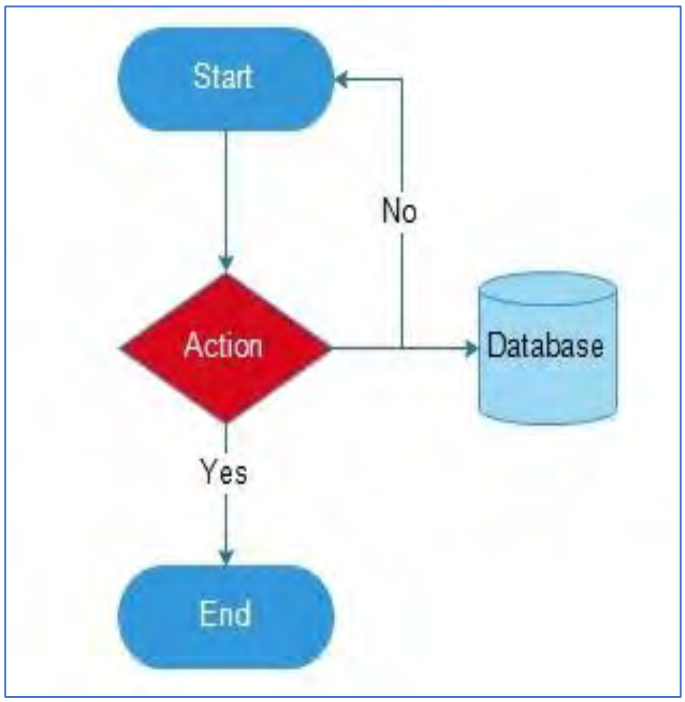


Figure 3.2. Core Mechanics for Game Design

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Therefore, designing a good user interface in a game is important not only to achieve learning goals but also to improve children's skills while playing. According to a study conducted by (Nand et al., 2019), one of the most attractive attributes in a game is 'having realistic graphics'. It has been suggested that incorporating realistic graphics into a game can enhance children's engagement and interest, as it creates a more authentic experience and visually more attractive to the user.

Furthermore, in a review study conducted by (Anugerah & Budiyanto, 2017) on the latest trends in educational games for children, it was highlighted that the use of visual imagery in game design can provide benefits to users, namely increasing excitement, facilitating understanding, and stimulating creativity. Therefore, an attractive and entertaining visual design in educational games for children has a great impact on their experience of the game. Considering this aspect of visual design, the development of games provides a more interesting game environment and helps to increase children's interest in the learning process, as well as creating a more meaningful and enjoyable play experience.

An important step in the visual design of interactive games, especially in the context of creative and logical games, is the coordination of colours, sounds and game features. The use of bright colours and special features in the design of interactive games has its own advantages. Bright colours can be categorised into two types, namely primary colours and secondary colours (Arbianingsih et al., 2018). The game material employs primary colours, namely red, yellow, blue, and green, for its objects or characters, respectively. This information is based on the research conducted by

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(Siddoo et al., 2016). The secondary colours are the colours that are used for the background in the game.

Then, audio instruments are part of the game's support for the provision of information in each game. The audio is divided into two categories: the first category is the audio music that is used for the background to make the game more interesting and to encourage the children to play the game. Second, is the audio used for the introduction, instructions in the game, as well as information on the child's achievements in the completion of all the challenges in the game.

The ADDIE model is used as a method for the production of educational games in the development process of the platform for the analysis of game-based learning. This model consists of Analysis, Design, Development, Implementation and Evaluation (Molenda, 2003). as shown in Figure 3.3.



Figure 3.3. ADDIE Framework (Molenda, 2003)

The stages in the ADDIE model are as follows:

1. Analysis

   This stage involves the needs, goals, and objectives of creative and logical learning. It also involves understanding the children and the learning environment.

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2. Design

   At this stage, the focus is on content planning, material organisation, game structure and user interaction. This design forms the basic framework for the game to play. Creating an assessment through the process of the game which is then analysed with the Learning Analytics Platform (LAP), it is one of the most important steps in this research.

3. Develop

   This stage involves creating the game based on the preliminary design. The development process includes programming, graphics creation, and feature implementation. Additionally, an assessment system is built which is connected to the game-based learning analytics platform through a database.

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4. Implement

   It is at this stage that the game is finalized and tested on teachers and children in order to receive feedback during the first phase of its development. Teachers and children from the PAUD Manhajul Husna were among the participants in this process.

5. Evaluate

   It is at this stage that the feedback from the implementation phase is obtained. As part of the assessment, the teachers were asked how satisfied they were with the support they gave to the children during the play.

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The assessment of the development of creativity and logic in children between the ages of 3 and 4 years is carried out with a structured and thorough planning. For the analysis process in the use of the platform on the final score or value is displayed as a result of the game. This has been also done by (Dzelzkaleja & Kapenieks, 2016)who explained the "colour code method" as an evaluation method of the learning process produced by children. The colours used in the game indicate different stages of the learning process: green for completed learning, yellow for learning in progress, and red for experiencing problems in the learning process.

Table 3.3

Score game on the basis of the time to completion

Time (Second)	Score (Star)
1 - 10	3
11 - 20	2
> 20	1

The table above shows that the rating is divided into three achievements: 3 stars for the value 'Good' with a completion time of 1-10 seconds, 2 stars for the value 'Moderate' with a completion time of 11-20 seconds, and 1 star for the value 'Low' with a completion time of more than 20 seconds. The scores are determined on the basis of the time it takes to complete each game. In the research, the games are divided into two categories of learning: creative learning and logical learning. There are four stages in each game that have to be completed, as shown in Figure 3.4.

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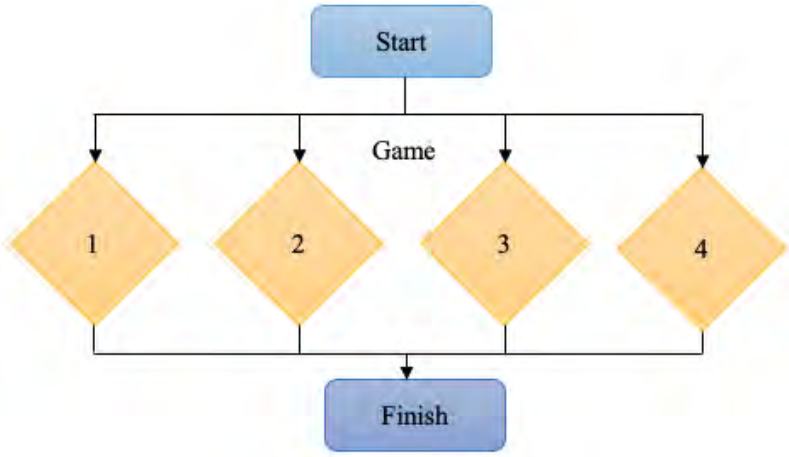


Figure 3.4. Scenario structure in games creative and logic

Assessment of the calculation process carried out in the assessment. In order to receive a score of 'Good', each game from 1 to 4 must be completed in less than 10 seconds. Each game from 1 to 4 must be completed in less than 20 seconds to receive a score of 'Moderate'. The score for the "Low" value is obtained by using a time of more than 20 seconds to complete each game. This technique was implemented by (Piotrowski & Meester, 2018) in the use of time as an assessment process for the measurement of children's abilities.

Table 3.4

Overall Performance Scoring Process

Children	Game (Time in Second)				Score				Total Score	Average Score	Overall Performance
	1	2	3	4	1	2	3	4			
1	10	10	10	10	3	3	3	3	12	3	GOOD
2	12	14	16	20	2	2	2	2	8	2	MODERATE
3	22	26	27	60	1	1	1	1	4	1	LOW

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Android applications are being used for the development of games for children because they provide a user-friendly interface that is easy to use and easy to navigate (Ma et al., 2014). In addition, according to a study conducted by (Sarkar, Goyal, Hicks, Sarkar, & Hazra, 2019), android also provides flexibility to researchers who use the Java IDE to develop Android-based applications.

3.4 Development Phase

This section describes the process of creating a game-based learning analytics platform to assess creativity and logic development in children aged 3 to 4 years in Malaysia and Indonesia. This section describes the process of creating a game-based learning analytics platform to assess creativity and logic development in children aged 3 to 4 years in Malaysia and Indonesia. The section is divided into several subsections, including Subsection 3.4.1 which outlines the design of the platform. Subsection 3.4.2 outlines the process of data analysis and modelling for classifying and predicting learning outcomes related to the development of creativity and logic in children aged 3-4 years. Subsection 3.4.3 details the software and hardware used for game development and the learning analytics platform. Finally, subsection 3.4.4 describes the usability study that evaluates the effectiveness and efficiency of the game-based learning analytics platform application (GBLAP) in assessing creativity and logic development using the System Usability Scale (SUS) method.

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3.4.1 The Design of A Game-Based Learning Analytics Platform for The Assessment of Creativity and Logic Development

The application of learning analytics in educational games facilitates direct score retrieval for teachers. Chapter 1 of the research problem section highlights the challenges teachers face in obtaining attention, assessing progress, and understanding the learning progress of each child. Children who receive a 'Not Achieved' grade or have not grasped the learning concept may fall behind and struggle with subsequent topics. In order to solve these problems, a learning analytics platform has been developed in this study in the assessment process that is carried out at each stage (C. H. Yoon, 2017). Figure 3.5 illustrates the flow chart for the entire process in GBLAP.

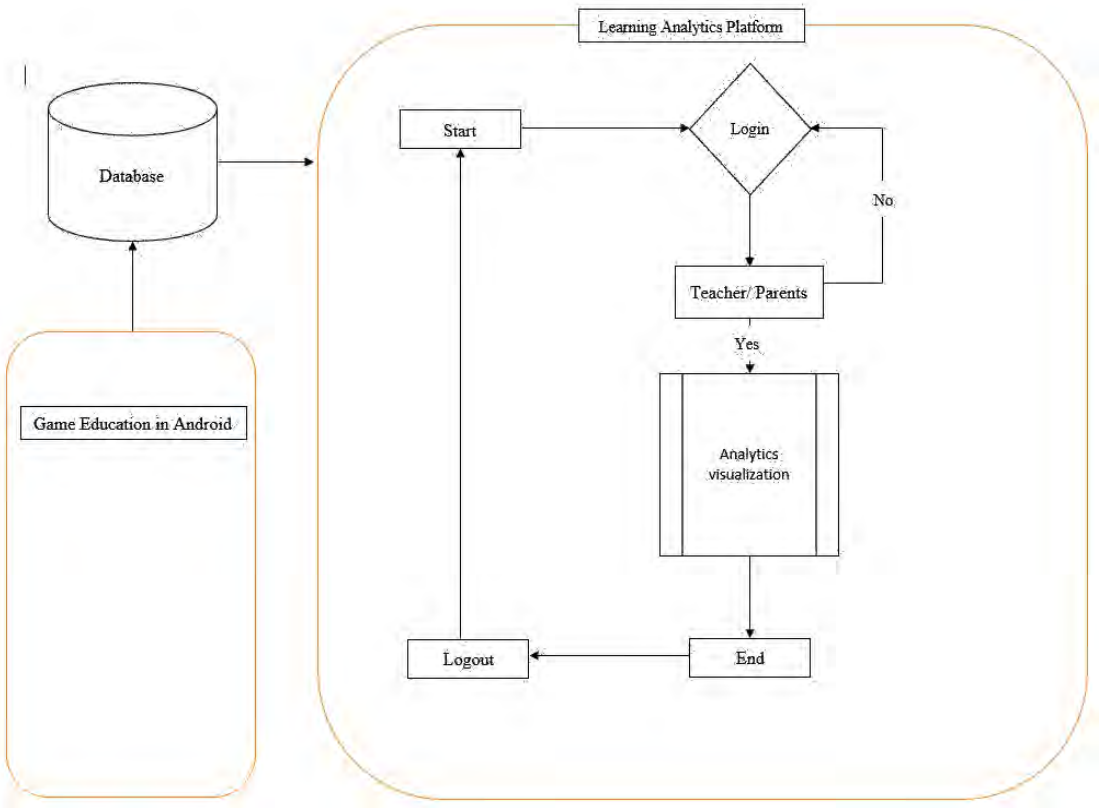


Figure 3.5. Flowchart for learning analytics platform

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Figure 3.5 shows that the data collection process involves educational games implemented in Android, with the game data then stored in a database. The firebase platform is used for data storage due to its convenience for Android-based application developers and efficient data management (Khawas & Shah, 2018). After completing the data storage process, the analysis process is carried out on the learning analytics platform. The learning analytics platform is a system designed to analyse and report on processes related to creative and logical learning. It also provides real-time visualisations of children's development for teachers and parents to monitor. The platform is accessible through a website, allowing users from various locations and devices to access it (Sulova, 2019).

3.4.2 The Process of Analysis and Modelling Data for The Classification and Prediction of Learning Outcomes Related to The Development of Creativity and Logic

This section outlines the process of analysing and modelling data to classify and predict outcomes related to creativity and logical thinking. The aim is to transform game data into insights that can be used to understand children's learning patterns, identify factors that affect learning outcomes, and make predictions about their creativity and logic development. Figure 3.6 illustrates the data analysis and modelling process.

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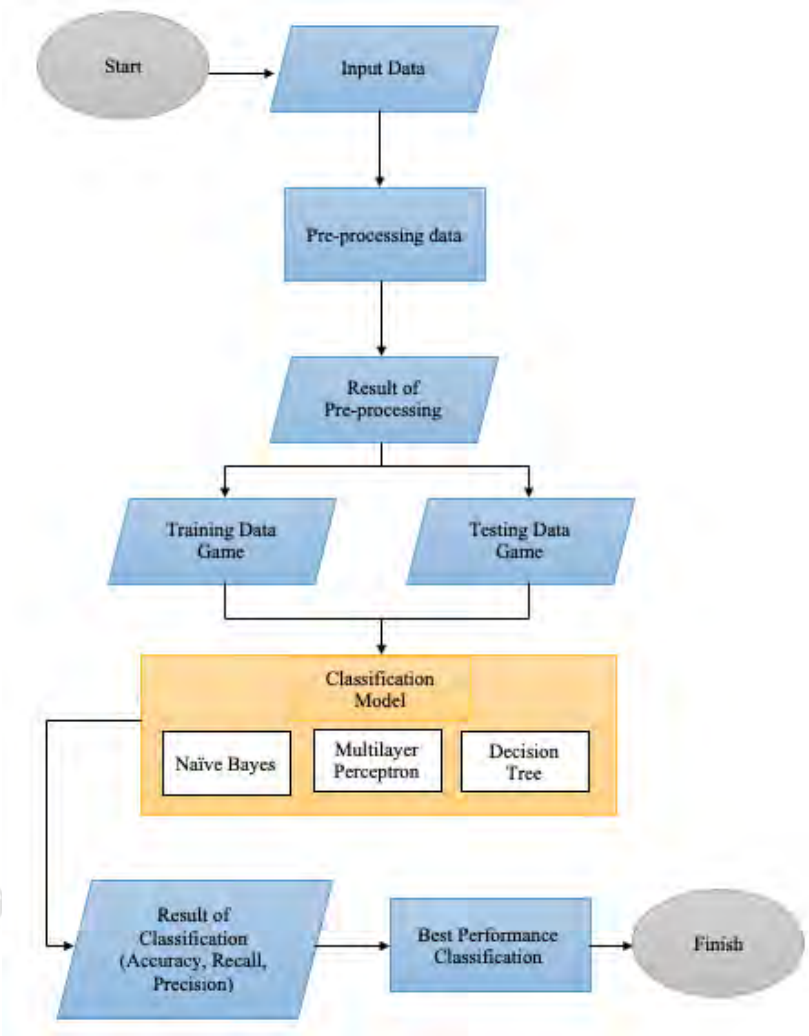


Figure 3.6. Flowchart analysis and modelling data for classification and prediction of learning outcomes related to the development of creativity and logic

Figure 3.6 illustrates the process of analysing and modelling data from creative games and logic games played by children. The process involves data input, pre-processing, classification using machine learning algorithms (Naïve Bayes, Multilayer Perceptron, and Decision Tree), and partitioning data into training and testing sets. The model's performance is then evaluated using accuracy, recall, and precision as benchmarks to compare the best performance of each classification algorithm. The data analysis and modelling process is carried out using the RapidMiner Studio 9.6000 platform. The process will be explained in subsections, as follows:

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3.4.2.1 Input Data

This section outlines the input data used for analysis. The data consists of information collected from sources related to children's games and their impact on creative and logical learning processes. Table 3.5 displays the variables used in the analysis process.

Table 3.5

Data set variables from a game-based learning analytics platform for the development creativity and logic in 3-4 year-old children

Attribute	Description	Value
userName	Username	-
Date	Game date and time	-
Game 1	Result of the first game	Milliseconds
Game 2	Result of the second game	Milliseconds
Game 3	Result of the third game	Milliseconds
Game 4	Result of the fourth game	Milliseconds
Result	Result of adding up the average of all games	Good, Moderate, Low

The dataset includes seven attributes: userName, date, Game 1, Game 2, Game 3, Game 4, and Result. The userName attribute identifies the children using the game. The date attribute indicates the time of the learning session. Game 1, Game 2, Game 3, and Game 4 represent the time taken to complete each game, measured in milliseconds. Finally, the result of each game is stored as either Good, Moderate, or Low. All of these variables are data generated by creative and logic games, which are stored in Firebase and connected in GBLAP for data analysis and modelling.

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3.4.2.2 Pre-processing data

Data pre-processing is a significant step in the data analysis process, involving a range of techniques to clean, organise and prepare raw data for further processing. The objective is to enhance data quality, reduce noise, and prepare the data for analysis and modelling. The dataset used in this study is the one described earlier. According to (Romero & Ventura, 2007), data pre-processing makes it possible to transform the original data into a form suitable for use by data mining algorithms. The steps for data pre-processing, as quoted from (Lee et al., 2000), are as follows:

1. Data cleaning involves identifying incomplete data and detecting invalid values within the dataset.
2. Data integration involves combining data from multiple sources into a unified dataset. In this case, data from creative and logic games are merged into a single dataset.
3. Dimensionality reduction involves reducing the number of less relevant features or variables.
4. Data transformation involves two processes: data normalisation and data encoding. Data normalisation equalises the scale or range of variables to have a uniform range of values, while data encoding converts data into a form that algorithms can process.
5. Outlier detection involves identifying and dealing with extreme values that may interfere with the analysis.
6. Feature selection involves selecting relevant variables for analysis or modelling.
7. Data splitting involves separating the data into a training set and a test set for model evaluation.

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The pre-processing of data is an important part of these steps in order to ensure that the data used in the analysis or modelling is of high quality. The application of these steps contributes to an increase in the accuracy and results of the analysis or modelling being performed.

3.4.2.3 Training and testing data

This stage describes the training and testing data used from the results of the data pre-processing described previously. In the data analysis or modelling process that is carried out in the machine learning method, the data set is divided into two data sets, namely the training data and the test data.

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Training data is a part of the dataset that is used to train the machine learning model. while testing data is another part of the dataset that is not used to train the model (Lee et al., 2000). In this study, we divided the data into a 70:30 ratio (70% training data; 30% testing data). This ratio provides a sufficient volume to train the model, allowing it to learn effectively from a manageable amount of data (Angeli et al., 2017). The division of training and testing data is crucial to prevent overfitting of data that was not used during training. The evaluation of model performance provided by testing data offers an objective assessment of how well the model performs on the unknown data.

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3.4.2.4 Evaluation data

Classification models are mathematical algorithms used in machine learning to categorise data based on given attributes (Caixinha & Nunes, 2017). The purpose of the classification model in this study is to identify patterns in the GBLAP data of creative and logical development and predict the corresponding label. Selecting an appropriate algorithm model is a crucial step in the process of machine learning analysis, particularly in classification models. This research discusses three commonly used algorithm models in the classification process of education data mining: Naïve Bayes, Multilayer Perceptron (MLP), and Decision Tree.

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3.4.2.4.1 Naïve Bayes

Naive Bayes is a suitable model for datasets with statistically independent features. Statistically independent features refer to variables in a dataset that do not have a strong relationship with each other (Kaur et al., 2015). Given the features in the data, naive Bayes calculates the probability of each class. and determines the most likely class based on that probability (Flach & Lachiche, 2004). To identify the probability, Naive Bayes uses the Bayes theorem method, which is expressed mathematically in the following equation.

$$P\ (H \mid X) = \frac{P\ (X \mid H)\ P(H)}{P(X)} \qquad (3.1)$$

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X = Data unknown class

H = The data hypothesis X is class specific

P (H | X) = The probability of hypothesis H based on condition x (posteriori prob.)

P (H) = The probability of hypothesis H (prior prob.)

P (X | H) = The probability of X under these conditions

P (X) = The probability of X

3.4.2.4.2 Multilayer Perceptron (MLP)

Multilayer perceptron (MLP) is an artificial neural network model that can learn complex patterns consisting of multiple layers. Each layer of the MLP calculates weights and biases to produce the final output of the network (Jeyanathan, 2018). Learning the MLP model is done using the backpropagation algorithm, which uses feedforward and backpropagation as computational stages, as shown in the formula presented in the following:

1. Steps on the feedforward as follows:

   Step 1: Input signal Xi (i = 1 to n) send to hidden unit

   Step 2: Hidden unit Zj (j = 1 to p) add them up and then calculate the net input

$$z_{in\ j} = V_{0j} + \sum_{i=1}^{n} X_i V_{ij} \qquad (3.2)$$

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$$Z_j = f(z_{in\,j})$$

$$y_{in\,k} = w_{0k} + \Sigma_{k=1}^{p} z_j w_{jk} \tag{3.3}$$

$$Y_K = f(y_{in\,k}) \tag{3.4}$$

2. Steps on backpropagation as follows:

Step 1: - Error correction

$$\delta_k = (t_k - y_k) f'(y_{in\,k}) \tag{3.5}$$

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- Send δ_k to *hidden layer backwards* and *weights*

$$\Delta w_{jk} = \propto \delta_k z_j \; ; \; \Delta w_{0k} = \propto \delta_k \tag{3.6}$$

Step 2: - *Hidden unit* are calculated *delta inputs* from *output units*

$$\delta_{in\,j} = \sum_{k=1}^{m} \delta_k w_{jk} \tag{3.7}$$

- Update *weights* and *error*

$$\delta_j = \delta_{in\,j} f'(z_{in\,j}) \tag{3.8}$$

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$$\Delta v_{ij} = \propto \delta_j x_i \; ; \; \Delta v_{0j} = \; \Delta \delta_j \tag{3.9}$$

3. Steps update *weights* and *error*

Step 1: - Update *output units* with *bias* and *weights*

$$w_{jk}(new) = w_{jk}(old) + \; \Delta w_{jk} \tag{3.10}$$

$$w_{0k}(new) = w_{0k}(old) + \; \Delta w_{0k} \tag{3.11}$$

- Update *hidden units* with *bias* and *weights*

$$v_{jk}(new) = v_{jk}(old) + \; \Delta v_{jk} \tag{3.12}$$

$$v_{0k}(new) = v_{0k}(old) + \; \Delta v_{0k} \tag{3.13}$$

Step 2: The condition will stop when a certain amount of time and actual output.

3.4.2.4.3 Decision Tree

This model facilitates comprehension by presenting decisions in a clear and concise manner. The decision tree utilises decision rules to map features from the dataset to the appropriate labels (Siknun & Sitanggang, 2016). The gain ratio of each attribute in the

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dataset is calculated to determine which attributes are best used in building decision trees. To construct a decision tree, an attribute is selected as the root and a branch is created for each value. The process involves dividing the cases into branches and repeating it for each branch. Decision tree is a machine learning algorithm that uses entropy to make decisions. Entropy measures the level of uncertainty or chaos in a system. In the context of decision tree, entropy is used to measure the homogeneity of a data set at a potential split point. The formula for entropy is as follows:

$$E(S) = \sum_{i=1}^{c} - p_i \, log_2 \, p_i \tag{3.14}$$

E(S) = Entropy of the data set S

c = the number of possible classes or labels

p_i = the proportion of the sample size in data set S that belong to the class

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3.4.2.5 Evaluation Data

The evaluation of data is performed by calculating the model's performance using an evaluation matrix, specifically accuracy, precision, and recall. In this study, the confusion matrix method was used to calculate the evaluation metrics results, as described in Table 3.6 by (Xu et al., 2020).

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Table 3.6

Confusion Matrix for Two-Class Classification (Xu et al., 2020)

f_{ij}		Prediction class (j)	
		Class = 1	Class = 0
Original Class (ι)	Class = 1	f_{11}	f_{12}
	Class = 0	f_{21}	f_{22}

The matrix displays the number of records or data from class ı that are predicted to class j. To determine the number of correctly predicted mapping data, add the values of f_11 and f_22 (f_11 + f_22) from the confusion matrix. To determine the number of incorrectly predicted mapping data, add the values of f_21 and f_12 (f_21 + f_12). When the number of correctly and incorrectly classified data is known, it is possible to calculate the accuracy of the prediction results. The accuracy, recall, and precision can be calculated using the following equation:

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$$Accuracy = \frac{Sum\ of\ the\ correctly\ predicted\ data}{Sum\ of\ the\ prediction\ made} = \frac{f_{11} + f_{22}}{f_{11} + f_{12} + f_{21} + f_{22}} \quad (3.15)$$

$$Recall = \frac{f_{11}}{(f_{11} + f_{21})} \quad (3.16)$$

$$Precision = \frac{f_{11}}{(f_{11} + f_{12})} \quad (3.17)$$

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3.4.3 Software and Hardware use for The development of GBLAP

Developing educational games and learning analytics platforms requires researchers to find the right combination of software and hardware for their development needs. The games are developed on a mobile basis and can later be uploaded to the Android Play Store, while the learning analytics platform is developed on a website basis. Minimal hardware specifications are necessary for developing games and platforms, as described in Table 3.7.

Table 3.7

Minimum hardware specification

No	Hardware	Description
1	Laptop	Intel® Core™ i5-7200 CPU @ 2.50GHz. 2.70 GHz NVIDIA GeForce 920MX 8 GB RAM 64-bit operation system, x-64 based processor Windows 10
2	Smartphone	8GB RAM 540x960 pixels Quad-core 1.2GHz Cortex-A53 Wi-Fi 802.11 b/g/n, hotspot Bluetooth 4.0, A2DP

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The educational game was developed using the UNITY Platform, which functions as a game engine and development tool. A game engine is a platform that enables developers to create interactive games and applications on various platforms,

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such as computers and cell phones. UNITY also supports various programming languages, including the C# language used for scripting game logic. Node.js programming is used for both the back-end and front-end processes in the development of a web-based learning analytics platform. This is because Node.js provides built-in modules that make Input/Output management easy. The platform is being developed with the aim of providing comprehensive analytics on student learning.

3.4.4 Usability Study of the GBLAP using the System Usability Scale (SUS)

A quantitative method has been carried out in this usability study, with the aim of evaluating the usability of a game-based learning analytics platform using the System Usability Scale (SUS). In this section, a step-by-step evaluation process of the game-based learning analytics platform will be presented. Ethical approval (see Appendix A) was obtained from the Human Research Ethics Committee, Sultan Idris Education University, for involving human subjects. This usability study has permission to conduct research at PAUD Manhajul Husna, South Kalimantan, Indonesia and the National Child Development Research Center (NCDRC). As before in Section 1.1, initially this study only targeted children at TASKA PERMATA UPSI, NCDRC, Malaysia. However, due to the Covid-19 pandemic there were restrictions while studying at TASKA PERMATA UPSI, children from PAUD Manhajul Husna, South Kalimantan, Indonesia also made restrictions to prevent the spread of the Covid-19 virus. The elements for the development of creativity and initial logic from the curriculum used (PERMATA) have been compared with the elements used by PAUD Manhajul Husna, South Kalimantan, Indonesia. It has been confirmed that the elements

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used in the PERMATA curriculum for assessing the development of creativity and logic in children aged 3-4 years is the same as the elements used in Indonesia.

3.4.4.1 Study Population

At the population study stage, it is necessary for decision making in the development of game-based learning analytics. There were two groups involved, consisting of 2 teachers, 10 parents and 10 children, from two different institutions: PAUD Manhajul Husna, South Kalimantan, Indonesia and TASKA PERMATA, NCDRC, UPSI, Malaysia. The children involved in this study were healthy boys and girls and were not included in the category of children with special needs. Teachers are asked to identify children with ‘Good’, "Moderate’, and ‘Low’ based on the achievement of the data they have in the development of their current creativity and logic.

3.4.4.2 Recruitment of Teachers

Prior to recruitment, permission letters to conduct research and teacher involvement in research were sent to each institution for approval to carry out a usability evaluation in their place. Once consent was obtained, teachers and classes of children aged 3-4 years were identified. Then a brief meeting (online/face to face) was held with the identified teachers to explain the purpose of the evaluation and the overall process to be carried out. Appropriate timing of sessions with children has also been discussed. Information about the study was included with the informed consent form to be given to teachers of

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children aged 3-4 years. The consent form for teachers is intended to obtain their consent to be involved in this usability evaluation process, as their feedback will also be collected at the end of the session. The teacher who has given consent will then identify the children in his class who will be involved in the usability evaluation process based on the child's developmental data. An example of a consent form for teachers can be seen in Appendix B.

3.4.4.3 Recruitment of Parents and Children

The parents of the identified children were then contacted or confirmed by the teacher/researcher to explain their child's involvement in the usability evaluation process. Meeting sessions are conducted online and are short so parents can see the whole process better. Then, research information was entered along with a consent form to be given to parents of children aged 3-4 years. There are two forms of consent for parents, one for their child to be involved in the research process with permission for them (photos and videos) of their child during the process and another for themselves, to be involved in the usability evaluation. Their feedback process on the learning analytics platform has also been collected. Parents can always choose not to be involved in the evaluation process, but simply give consent for their child to take part, or they can also refuse both forms of consent, as it is on a voluntary basis. An example of a consent form for parents is shown in Appendix C.

Children who had given consent from their parents were given a consent form (sample attached in Appendix D) during the evaluation process, before they started

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playing. If under any circumstances the child refuses to play, then the process will be terminated. The teacher will try to recruit a new child or if the same child under any circumstances changes his mind and wants to be involved another day, then the process will continue.

3.4.4.4 Game Play Sessions

In the evaluation stage used in this study an Android-based smartphone or tab has been used with a minimum layer size of 6.3 inches. Two smartphones/tablets have been used in each session. There are four game sessions that must be completed by one child with the teacher's supervision. The details of all sessions are in Table 3.8 session in the evaluation stage.

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Table 3.8

Session in The Evaluation Stage

Session	Announcements	Notes
1	Teacher teach the game to the children	In this first session, children have been taught by the teachers on how to play all the games. Approximate time taken were 10 minutes. However, in any circumstances, if the children refused to continue playing, the process will be stopped. We can either recruit new children, or if the children would like to continue playing in the next day or any other days (as long as it is within the evaluation process duration), then the process will be resumed. The activities have been recorded (video and photograph) throughout the session.

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Table 3.8 *(continue)*

Session	Announcements	Notes
2	Teachers accompanied children while playing the games	In this second session, children will play the games accompanied by the teachers. Approximate time taken were 10 minutes. This time, children were not taught by the teachers but teachers will be there to supervise the process. In case if the children have questions to ask, then the teachers can answer the questions. Same procedure in session 1 is applied, if the children refused to continue playing.
3	Teachers will observed children playing games from afar	In this third session, children will play the games alone while teachers will observe them from afar. Approximate time taken will be 10 minutes. This time, children will play the games all by themselves. However, in case if the children have questions to ask, then the teachers can answer the questions. Same procedure in session 1 is applied, if the children refused to continue playing.
4	Children will play the game without any help from teachers	In this fourth session, children will play the games alone without any help from teachers. This is like reinforcement exercise for the children. Approximate time taken will be 10 minutes. This time, children will play the games all by themselves. Same procedure in session 1 is applied, if the children refused to continue playing.

3.4.4.5 System Usability Scale (SUS)

The System Usability Scale (SUS) is an assessment method that was first developed by John Brooke in 1986 to measure user perceptions of the usability of a system or product (Brooke, 1986). SUS consists of 10 questions where participants are given a choice of

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a scale of 1 to 5 to answer based on how much they agree with each of the statements given, regarding the product or feature to be tested. The questions cover various aspects of system usability, such as complexity, ease of use, clarity of instructions, and user satisfaction. According to Lewis, James and Sauro, Jeff. (2018), SUS is a questionnaire that can be changed, where researchers can adopt and adapt to various conditions. For example, minor changes to the wording of items have been suggested by some researchers to suit their research scenarios. Finstad (2006) and Bangor et al. (2008) for example, recommends replacing "cumbersome" with "awkward" in Item 8, as shown in Table 3.9. Some researchers also replaced the word "website" or "product", or used the actual website or product name in the questionnaire items, but they found that these changes had no effect on the final score (Lewis & Sauro, 2018). In fact, there is research conducted by Lewis, James and Sauro, Jeff. (2018), who found that dropping items did not adversely affect scale reliability. All of this research has shown that the SUS is flexible enough to be used as a scale for assessing the usability of a system, prototype, or product, provided any changes or replacements made are consistent across items.

Table 3.9

The original SUS statements (Brooke, 1996) and the modified statements used in Finstad (2006) and Bangor et al. (2008)

Original SUS Statements	**Modified SUS Statements**
I think that I would like to use this system frequently	I think that I would like to use this product frequently
I found the system unnecessarily	I found the product unnecessarily

(continue)

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Table 3. 9 *(continue)*

Original SUS Statements	Modified SUS Statements
I thought the system was easy to use	I thought the product was easy to use
I think that I would need the support of a technical person to be able to use this system	I think that I would need the support of a technical person to be able to use this product
I found that the various functions in this system were well integrated	I found that the various functions in this product were well integrated
I thought that there was too much inconsistency in this system	I thought that there was too much inconsistency in this product
I would imaging that most people would learn to use this system very quickly	I would imaging that most people would learn to use this product very quickly
I found the system very cumbersome to use	I found the product very cumbersome to use
I felt very confident using the system	I felt very confident using the product
I needed to learn a lot of things before I could get going with this system	I needed to learn a lot of things before I could get going with this product

In this study, SUS was created in digital/online form (google form) to provide convenience to respondents. Teachers have provided their responses to two sets of SUS, the first SUS is for evaluation of learning analytics platforms, while the second SUS is for evaluation of creative and logic games. This is because, the teacher has been on the side of the children when they play the game, and therefore they can also provide

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feedback about the usefulness of the game based on the responses shown by the children while playing the game. An example of the SUS form for teachers can be seen in Appendix F.

As for parents, they were asked to provide their feedback about SUS regarding the learning analytics platform. Because the learning analytics platform was developed for parents to see the progress of their children based on the games being played in real-time. An example of the SUS form for parents can be seen in Appendix G. It takes less than 5 minutes for teachers and parents to respond to each series of SUS.

In addition, the children were part of SUS in feedback about the games they played at the end of the session, with the help of the teacher. SUS has made it easy for child contexts to provide feedback (An example of SUS for children can be seen in Appendix H). the teacher will ask questions to the children, the children will answer by choosing the character of the face given "Smiling face" for "YES" or "Frowning face" for "NO". It consists of six items that are asked to children, to get their responses about the games they have played as shown in Table 3.10 English and the Translated Items of SUS for Children. To make it easier for respondents in this study, the original English SUS question items were translated into Malay and the translated items were checked by an expert to ensure that there was no change in meaning. See Appendix E for the expert verification form.

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Table 3.10

English and the Translated Items of SUS for Children

No	English Items	Malay Items
Q1	I think I would like to play this (Logic/Creative) game regularly	Saya rasa saya ingin kerap bermain permainan (Logik/Kreatif) ini
Q2	I thought the (Logic/Creative) game was easy to play	Saya rasa permainan (Logik/Kreatif) ini mudah dimainkan
Q3	I thought I need adult support/help to play this (Logic/Creative) game	Saya rasa saya perlukan sokongan/bantuan orang dewasa untuk bermain permainan (Logik/Kreatif) ini
Q4	I learnt to use (Logic/Creative) game quickly	Saya belajar menggunakan permainan (Logik/Kreatif) dengan cepat
Q5	I felt very awkward playing this (Logic/Creative) game	Saya rasa sangat janggal (kekok) bermain permainan (Logik/Kreatif) ini
Q6	I felt very confident when playing this (Logic/Creative) game	Saya rasa sangat yakin semasa bermain permainan (Logik/Kreatif) ini

Although SUS for children contains only six items, items related to important elements of SUS, such as usability, ease of use, learnability, and satisfaction have been included, except for items related to efficiency, because these items are quite difficult to complete. or understood by children.

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3.4.4.6 Computing the System Usability Scale Score

The SUS is composed of ten statements, each having a five-point scale that ranges from Strongly Disagree to Strongly Agree. There are five positive items and five negative items, which alternate, as shown in Table 3.11. (Bangor et al., 2008).

Table 3.11

The Five Positive and Negative Items in SUS Used to Get the Feedback From Teachers and Parents (Bangor et al., 2008)

No	English Items	Malay Items	Types of Items
Q1	I think children would like to play this (logic/creative) game regularly	Saya rasa kanak-kanak ingin kerap bermain permainan (logik/kreatif) ini	Positive
Q2	I found the game (logic/creative) unnecessarily complex for children	Saya mendapati permainan (logik/kreatif) ini agak kompleks untuk kanak-kanak	Negative
Q3	I thought the (logic/creative) game was easy to play by children	Saya rasa permainan (logik/kreatif) ini mudah dimainkan oleh kanak-kanak	Positive
Q4	I thought children need adult support/help to play this (logic/creative) game	Saya rasa kanak-kanak memerlukan sokongan/bantuan orang dewasa untuk bermain permainan (logik/kreatif) ini	Negative
Q5	I found various functions in this (logic/creative) game were well integrated	Saya dapati pelbagai fungsi dalam permainan (logik/kreatif) ini digabungkan dengan baik	Positive
Q6	I found too many inconsistencies in this (logic/creative) game	Saya dapati terlalu banyak percanggahan di dalam permainan (logik/kreatif) ini	Negative

(continue)

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Table 3.11 *(continue)*

No	English Items	Malay Items	Types of Items
Q7	I found most children had learnt to use this (logic/creative) game quickly	Saya dapati kebanyakan kanak-kanak belajar menggunakan permainan (logik/kreatif) ini dengan cepat	Positive
Q8	I found children were very awkward playing this (logic/creative) game	Saya dapati kanak-kanak sangat janggal (kekok) bermain permainan (logik/kreatif) ini	Negative
Q9	I found children were very confident when playing this (logic/creative) game	Saya dapati kanak-kanak sangat yakin semasa bermain permainan (logik/kreatif) ini	Positive
Q10	I think children need to learn a lot of things before they can play this (logic/creative) game	Saya rasa kanak-kanak perlu belajar banyak perkara sebelum dapat bermain permainan (logik/kreatif) ini	Negative

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After the user gives an assessment of each statement, the SUS score is calculated using a predetermined formula. The first step in scoring SUS is to determine the contribution score of each item, which ranges from 0 to 4. For items with a positive tone, the contribution score is the scale chosen by the respondent minus 1. For items with a negative tone, the contribution score is 5 minus the scale chosen. To get the overall SUS score, the sum of the item score contributions is multiplied by 2.5 which results in a score that can range from 0 (very poor usability) to 100 (very good usability) in 2.5 point increments (Bangor et al., 2008). The average SUS score (x) is then calculated, using the following formula:

$$\overline{x} = \frac{\sum \mathrm{x}}{\mathrm{n}} \tag{3.18}$$

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$\overline{x}$ = Total score average

$\sum$ x = Total score SUS

n = Number respondents

However, for the results of the SUS score from childhood, the calculation is slightly different, because the number of positive and negative items is different, as shown in Table 3.12. In this case, there are four items that say positive and three items that say negative, so the number of items is six.

Table 3.12

The Positive and Negative Items in SUS used to get Feedback from Children

No.	English Items	Malay Items	Types of Items
Q1	I think I would like to play this (Logic/Creative) game regularly	Saya rasa saya ingin kerap bermain permainan (Logik/Kreatif) ini	Positive
Q2	I thought the (Logic/Creative) game was easy to play	Saya rasa permainan (Logik/Kreatif) ini mudah dimainkan	Positive
Q3	I thought I need adult support/help to play this (Logic/Creative) game	Saya rasa saya perlukan sokongan/bantuan orang dewasa untuk bermain permainan (Logik/Kreatif) ini	Negative
Q4	I learnt to use (Logic/Creative) game quickly	Saya belajar menggunakan permainan (Logik/Kreatif) dengan cepat	Positive
Q5	I felt very awkward playing this (Logic/Creative) game	Saya rasa sangat janggal (kekok) bermain permainan (Logik/Kreatif) ini	Negative
Q6	I felt very confident when playing this (Logic/Creative) game	Saya rasa sangat yakin semasa bermain permainan (Logik/Kreatif) ini	Positive

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Because less than ten items are used, the maximum score contribution is adjusted to four multiplied by the number of items used (4 x 6), which is then equivalent to 24, not 40. So, to get a multiple of this SUS, serratus is divided by twenty four (100/24), which will result in a new multiplier of 4.166 instead of 2.5 (Lewis & Sauro, 2018).

3.4.4.7 Categorizing the System based on the System Usability Scale Score

For the final process of reporting the evaluation using the System Usability Scale is to determine the average SUS score category. After the average SUS score is calculated, the score will be referred to the SUS score category introduced by Aaron Bangor, Philip Kortum, and James Miller., (2008) to find out whether the system is in an acceptable category or not, as shown in Figure 3.7. A system is said to be feasible if it has a minimum SUS score of 70. Then followed by a good system, which is between a SUS score of 70 and 80. And for a system that can be categorized as very good, it will have a SUS score above 85. For a system with a score SUS below 70 will be considered as a system that needs attention and must be repaired (Bangor et al., 2008).

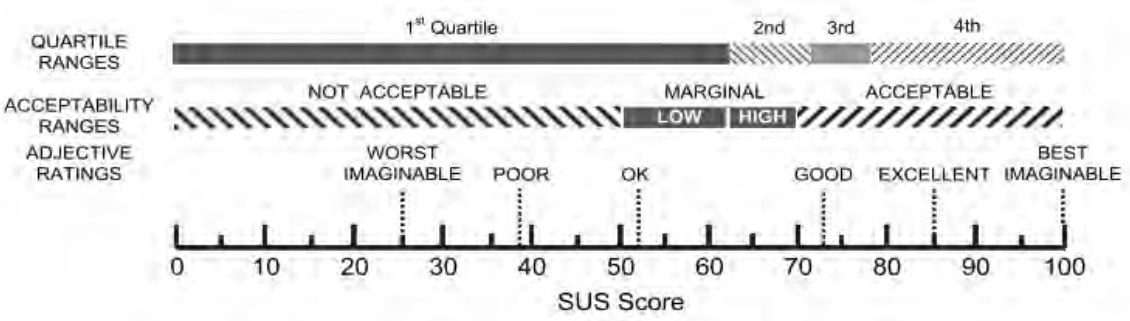


Figure 3.7. The SUS score category (Bangor et al., 2008)

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Acceptable SUS scores can be summarized as shown in Table 3.13. In this regard, Aaron Bngor, Philip Kortum, and James Miller (2008) have referred ratings to 'Acceptability Ranges' and 'Adjective Ratings', where 'Acceptability Ranges' refers to a more general term to categorize the average SUS score, whereas 'Adjective Ratings' refers to a more detailed category of 'Acceptability Ranges' based on the average SUS score.

Table 3.13

The acceptable SUS score with reference to the 'Acceptability Ranges' and 'Adjective Rating'

	Score	**The Score Category**
Acceptability Ranges	a) 0 – 50	a) Not Acceptable
	b) 50 – 64	b) Marginal Low
	c) 64 – 70	c) Marginal High
	d) 70 – 100	d) Acceptable
Adjective Rating	a) 0 – 25	a) Worst Imaginable
	b) 25 – 39	b) Poor
	c) 39 – 53	c) Ok
	d) 53 – 74	d) Good
	e) 74 – 85	e) Excellent
	f) 85 - 100	f) Best Imaginable

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3.5 Validation and Evaluation Phase

The validation and evaluation phase is crucial in the development of GBLAP for assessing creativity and logic development in 3-4-year-old children. Effectiveness and compatibility of developed platform with the requirements of users are important. The purpose of validation and evaluation is to ensure that the developed platform not only meets the user's needs, but also performs well technically and provides the expected added value.

3.5.1 Validation Process

Validation involves two processes: validation of learning materials and validation of learning media. Experts in their respective fields carry out the validation process by testing the feasibility and effectiveness of the learning media based on validation with material and media experts (Kristanto et al., 2019). The validation information in this study is presented in the following:

1. Learning materials validation

   This validation is concerned with assessing the suitability and accuracy of the learning materials applied in GBLAP. The assessment process is carried out by education or subject matter experts in GBLAP. They evaluate the learning materials to ensure accuracy, relevance, and appropriateness for children's needs and level of understanding. The goal is to make a positive contribution to achieving learning objectives.

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2. Learning media validation

   This validation involves assessing the feasibility and effectiveness of learning media used in the delivery of GBLAP learning materials. Experts in graphic design or related fields evaluate learning media, such as visual presentations and animations, to ensure they support learning objectives and improve user understanding. It is important to make sure that the media used is not only eye-catching, but also effective in conveying information and supporting the learning process.

3.5.2 Evaluation Process

The evaluation process involves completing a questionnaire that is distributed to experts. For this study, two experts were involved: one learning material expert and one learning media expert from Indonesia. The validation process was conducted during the Covid-19 pandemic. The questionnaire assesses usability aspects, specifically question elements, to ensure that the system is suitable for the developed learning materials (Munaiseche & Liando, 2016). The questionnaire is sent through 'Google Form'. Technical abbreviations of the questionnaire will be divided into 2 questionnaires, namely:

1. Learning material expert

The questionnaire for learning material experts contains 12 questions from 4 aspects. Questions asked to the expert are shown in Table 3.14

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Table 3.14

Questionnaire for learning material experts

Variable	Sub Variable	Indicator
Learning Material Validation	Learning	The suitability of the presented learning material
		The clarity of the material presented
		The simplicity with which learning materials can be understood
	Content	The accuracy of the content of the learning material
		The correct procedure for learning materials
		The suitability of learning materials with the curriculum
		The presented material can enhance children's knowledge.
	Presentation	The simplicity of the language used in the presentation of learning materials
		The suitability of learning materials with children's basic skills
		The suitability of the materials to the learning objectives
	Effectiveness	The presented learning materials are effective for learning purposes.
		The effectiveness of media in learning material delivery based on users

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2. Learning media expert

The questionnaire for experts in learning media comprises 15 questions across 5 aspects. Table 3.15 displays the questions provided to the expert

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Table 3.15

Questionnaire for learning media experts

Variable	Sub Variable	Indicator
Learning Media Validation	Interface	The suitability of the theme used
		The attractiveness of the characters used
		The attractiveness of the animation used
		The attractiveness of colour
		The suitability of the design colour with the layout
		The attractiveness of the images used
		The suitability of the image for the layout
	Font size	The clarity of the font or letters to read
		The suitability of the font size used
		The suitability of the font colour used
	Audio	The suitability of the background music used
		The attractiveness of the background music used
	Instruction	The clarity of instructions for the use of GBLAP media
	Comfortable	The simplicity of using GBLAP media
		The simplicity of the language used in GBLAP media

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To assess the questionnaire, a Likert scale with five alternative answers was used, following the approach of (Pescaroli et al., 2020). The results are presented in table 3.16.

Table 3.16

Likert scale measurement

Criteria	Score
Very Good	4
Good	3
Not Good	2
Very Not Good	1
None	0

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The application of this rating scale enables the acquisition of quantitative data that can assist in the identification of areas requiring greater attention in the development of the game-based learning analytics platform. The maximum score is 4, which indicates very good performance, while the minimum score is 0, which indicates that the given variable is not effective in the evaluation indicator. This approach enables the identification of the strengths and weaknesses of Learning materials and media, thereby facilitating the design of appropriate interventions to support the development of the platform.

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After validation by experts, the calculation process was carried out using the descriptive percentage method as described by Siedlecki (Siedlecki, 2020). The equation used is the following:

$$PSP = \frac{\sum score\ of\ all\ aspects}{\max \sum score\ of\ all\ aspects\ x\ N}\ x\ 100\% \qquad (3.19)$$

PSP = Total percentage

After completing this process, the percentage value can be categorised based on the validation criteria. This categorisation facilitates a clearer understanding of the results, as shown in Table 3.17.

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Table 3.17

Category percentage of validation results

Percentage	Category
85% - 100%	Perfect
50% - 84%	Valid
25% - 49%	Not Valid
0 – 24%	Not Recommended

The table shows that categories are based on percentage results. Results between 85 and 100% are classified as 'Perfect'. Results between 50 and 84% are classified as 'Valid', indicating that minor improvements are necessary. Results between 25 and 49%

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are classified as 'Not Valid', indicating that comprehensive improvements in learning materials or media are necessary. Meanwhile, if the percentage falls between 0 and 24, the system is categorized as 'Not Recommended' and should not be used.

3.6 Chapter Summary

This chapter presents the research methodology used to achieve the research objectives. The methodology is divided into four phases, each corresponding to one research objective. The first phase, the preliminary study, identifies and describes the research problem. The second phase, identification, identifies the elements and attributes used in educational games. The evaluation process for creativity and logic development was also assessed during this phase. The development of a game-based learning analytics platform (GBLAP) to assess the development of creativity and logic in children aged 3-4 years was the focus of the third phase. Finally, the fourth phase involved the validation and evaluation of the GBLAP for assessing the development of creativity and logic in children aged 3-4 years. Additionally, chapter 4 provides a detailed description of the research methodology, results, and discussion.

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CHAPTER 4

RESULT AND DISCUSSION

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4.1 Introduction

This chapter presents the results and discussion related to the phases of the methodology. All phases are related to the research objectives, particularly in the context of developing a game-based learning analytics platform for the process of creativity and logic development in children aged 3 to 4 years old. The achievement of children in creativity and logic development is highlighted from two institutions. The Taska PERMATA checklist from NCDRC, Malaysia and achievement data from PAUD Manhajul Husna, Indonesia revealed that the majority of children did not achieve the expected level of creativity and logic development. The report also discusses the use of specific elements and attributes in educational games to collect data from children for analysis in GBLAP. Machine learning was applied to model and learn

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patterns from GBLAP data related to creative and logical development, with the aim of predicting the corresponding class or label.

This discussion is divided into several sections. Section 4.2 discusses the selection of achievements related to children's creativity and logic development. Section 4.3 covers the elements and attributes used for the game that aids in the development of children's creativity and logic. Section 4.4 describes the creativity and logic game 'A Day at The Zoo Game'. Finally, Section 4.5 discusses scaling the learning model based on the results of 'A Day at The Zoo Game' Section 4.6 covers the classification and prediction of learning achievements in creativity and logic through data modelling. Section 4.7 presents the results of a usability study of GBLAP using the System Usability Scale (SUS). Section 4.8 focuses on the validation and evaluation of GBLAP. Finally, in Section 4.9, a summary of the chapter is provided.

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4.2 Selection of the achievements of the development of creative and logic of the children

The data collection process for the development of creativity and logic in this case study involved various approaches, as described in Chapter One's research scope and problem. The approach included conducting interviews and direct observations with classroom teachers from two institutions: Taska PERMATA UPSI and Manhajul Husna PAUD. The interview questions covered the learning methods employed and the challenges encountered in developing creativity and logic. The observations focused on the interactions between children during creative activities, their problem-solving skills in logic, and their responses to learning materials.

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As explained in the previous chapter in section 3.2.2, the items in the developmental stages of creativity and logic can be seen in the database stored in each institution with the authorisation. Table 4.1 displays the six developmental milestones for creativity, which were obtained from the PAUD Manhajul Husna database in Indonesia.

Table 4.1

Items of the creativity development that are not achieved by 3-4 years old children from PAUD Manhajul Husna (Indonesia)

No.	Items in the Creative developmental checklist that are not achieved by children age 4 years old	Total Children Achieved	Total Children Not Achieved	Percentage Children Not Achieved (%)
1.	The child can make doodles of different shapes, including straight lines, zigzags and curves.	137	0	0
2.	The child can choose objects they like. Examples are cars, fruit and animals.	137	0	0
3.	The child can draw two-dimensional shapes, such as squares, triangles, and circles.	78	59	43
4.	The child can make draw shapes such as houses, cars, fish, and cats.	49	88	64
5.	The child will also be able to colour the picture accurately to match the colours of the original.	89	48	35
6.	The child can use musical instruments to skilfully create musical rhythms.	119	18	13

Table 4.1 shows that 137 children from the PAUD Manhajul Husna database in Indonesia were involved in the process of creative development. Item 1, which involves

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children making scribbles with various shapes, straight lines, zig-zags, and curves, was found to be difficult for children aged 3 to 4 years. Similarly, item 2, which involves children choosing drawing objects that match their preferences, was also difficult for the same number of children. Item 3 involves creating two-dimensional shapes, such as squares, triangles, and circles. Out of a total of 78 children, 59 did not achieve this task. Item 4 involves drawing shapes such as houses, mounds, fish, and cats. Out of a total of 49 children, 88 did not achieve this task. Item 5 involves accurately colouring the image on the object to resemble the original. 89 children achieved this, while 48 did not. Item 6 involves skilfully creating musical rhythms using musical instruments. 119 children achieved this, while 18 did not. The percentage of children who did not achieve was 43% for item 3, 64% for item 4, 35% for item 5, and 13% for item 6. For items 1 and 2, all children achieved the expected level. To achieve the items in Logical Development, data was obtained from the NCDC database. The NCDC database serves as the central repository for such data. Table 4.2 displays the 13 items of early developmental achievement in math and logic that were obtained from the NCDC database in Malaysia.

Table 4.2

Items of the early mathematics and logic development that are not achieved by 4 years old children from NCDC database

No	Items in the logic developmental checklist that are not achieved by children age 4 years old	Total Children Achieved	Total Children Not Achieved	Percentage Children Not Achieved (%)
1.	Can count from 1 to 10	27813	4366	13.57
2.	Can match similar objects (example: socks, shoes)	27813	0	0.00

(continue)

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Table 4.2 *(continue)*

No	Items in the logic developmental checklist that are not achieved by children age 4 years old	Total Children Achieved	Total Children Not Achieved	Percentage Children Not Achieved (%)
3.	Give cause and effect with guidance	17083	10730	38.58
4.	Make easy decisions with reason by giving a logical reason.	7750	20063	72.14
5.	Name the 4 basic colors.	11859	15954	57.36
6.	Name the 3 basic shapes.	10663	17150	61.66
7.	Know patterns and can shape them again.	7669	20144	72.43
8.	Able to show mental representation using concrete objects (example: wild animal – tiger).	5271	22542	81.05
9.	Be aware of the concept of time and time sequence (example: eat, shower, rest, get ready to go home).	10538	17275	62.11
10.	Use ICT more confidently (example: using an ipad without assistance and charging when the battery is exhausted).	8636	19177	68.95
11.	Interest in asking questions about why and how things happen	8877	18936	68.08
12.	Make observations and conclusions with guidance.	7245	20568	73.95
13.	Able to relate and use experience past and present learning in solving problems	6290	21523	77.38

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Table 4.2 displays data from the NCDC database in Malaysia on 27,000 children in the early stages of mathematical and logical development. For item 1, counting from 1 to 10, 27,813 children accomplished this task while 4,366 did not. Item 2 required matching similar objects, which was achieved by all 27,813 children. Item 3 provided cause-and-effect guidance, indicating that out of a total of 27,813 children, 17,083 achieved the desired outcome while 10,730 did not. Section 4 provides objective reasons to facilitate decision-making. It reports that out of a total of 27,813 children, 7,750 achieved the desired outcome while 20,063 did not. Section 5 lists the four primary colours and reports that out of a total of 27,813 children, 11,859 achieved the desired outcome while 15,954 did not. Section 6 mentions the three basic shapes and reports that out of a total of 27,813 children, 10,663 achieved them while 17,150 did not. Item 7 requires pattern recognition and manipulation. 7,669 children achieved this skill, while 20,144 did not. Item 8 involves the ability to mentally represent concrete objects, such as wild animals like tigers. 5,271 children achieved this skill, while 22,542 did not.

Item 9 is the concept of time and time sequences such as eating, bathing and resting with a total of 10538 children achieved and a total of 17275 children not achieved. Item 10 is the ability to use ICT more confidently with a total of 8636 children achieved and a total of 19177 children not achieved. Item 11 is interested in asking questions about why and how with a total of 8877 children achieved and a total of 18936 children not achieved. Item 12 is about making observations and conclusions with guidance with a total of 7245 children reached and a total of 20568 children not reached. Item 13 requires the ability to link and apply past and present learning experiences to problem-solving, with 6290 children achieving it and 21523 children not achieving it.

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The percentages of children who did not achieve each item are as follows: 13.57% for item 1, 0% for item 2, 38.58% for item 3, 72.14% for item 4, 57.36% for item 5, 61.66% for item 6, 72.43% for item 7, 81.05% for item 8, 62.11% for item 9, 68.95% for item 10, 68.08% for item 11, 73.95% for item 12, and 77.38% for item 13. 13.57% for item 1, 0% for item 2, 38.58% for item 3, 72.14% for item 4, 57.36% for item 5, 61.66% for item 6, 72.43% for item 7, 81.05% for item 8, 62.11% for item 9, 68.95% for item 10, 68.08% for item 11, 73.95% for item 12, and 77.38% for item 13.

Based on interviews and observations from the database of tables of two institutions, items 3 and 4 are suitable criteria for the development of creativity in the game, based on interviews with teachers. For logical development, items 5, 6, 7 and 8 are suitable criteria for game development, as reported by teachers. Although there are other criteria with a higher percentage of not being achieved, these are the most relevant for the purpose of the study.

4.3 The selects elements and attributes used in games to develop creative and logic

At this stage, the selection of attributes and elements that support the development of creativity and logic in children aged 3 to 4 years. As explained in the previous section based on several items that have been obtained from the database in 2 institutions. That based on the process in this case there are only a few items that can be applied to the game. Such as items 3 and 4 based on the database of PAUD Manhajul Husna, namely the process of drawing in two-dimensional form, and making a picture shaped like a

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house, car and others. These items are the basis for the creative learning process that will be applied in the game. In terms of logical development, items 5, 6, 7 and 8 are items that form the basis of the learning process. These results are based on the database obtained from NCDC UPSI.

In the context of educational game development, the process of identifying game elements and attributes was carried out using pilot study steps for game analysis. The pilot study step is a commonly used research approach to collect initial data and identify elements that can improve the game's quality. The process is explained in the following subsections.

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4.3.1 Pilot study result on game analysis for the development of creativity and logic

In this pilot study, the purposive sampling method was used to identify samples with specific characteristics. The selection of a sample of children based on their performance in creativity and logic development learning from the NCDRC database during the period January to July is a specific approach and in line with the research focus. Ten children, consisting of 6 boys and 4 girls, came from the PERMATA NCDRC Taska class, UPSI. at the age of 3 years.

The game selection process for the pilot study is divided into two categories: one for creativity development and the other for logic development. The games are selected based on the PERMATA NEGARA curriculum, which serves as the

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framework for developing creativity and logic in 3-year-old children. This study focuses on adapting the game selection to the learning framework. The selection of games is based on specific criteria as explained in section 3.3.1. A pilot study for the creativity development process includes two games to be played by children. The games are the for following:

1) Drawing for kids learning game for toddlers age 3

This is a game of drawing using animation in the form of two-dimensional characters. The game consists of the following components:

(a) Have enjoyable sound effects.

(b) An outline guide for the pre-writing skills is available.

(c) Have information about movement for pre-writing skills.

(d) Have colouring pencils.

(e) Create an image or character of an animal.

2) Kids-draw animals with step

This game is designed to be a simple game to help children learn to draw. The game includes the following components:

(a) Music sounds available.

(b) A guideline for pre-writing skills is available.

(c) Create an image or representation of an animal.

As for the pilot study of the logic development process, there are two games that the children are playing. The games are the following:

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1) Super numbers

This game is designed to help children learn about number concepts and number writing skills. The game includes the following components:

(a) The sound effects are enjoyable.

(b) Have a moving display

(c) A line guide for pre-writing skills is available.

(d) Have movement information for pre-writing skills.

(e) Write numbers by selecting

(f) The number display is assigned a character.

2) Numbers puzzles for toddlers

This game is designed to help children recognized the concept of numbers and develop their ability to match objects. The game includes the following components:

(a) Having a voice.

(b) A character is displayed on the number.

As explained in section 3.3.1, the purpose of this pilot study was to investigate children's ability to play educational games for their creativity and logic development. Furthermore, it became a benchmark in the process of assessing the development of creativity and logic.

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4.3.1.1 Creative and logic development skills of children aged 3-4 playing educational games

Investigating the impact of educational games on the creativity and logic development of children aged 3 to 4 years is crucial. The study aimed to determine the extent to which educational games can positively impact children's development. The pilot study involved direct observation of children's skills and responses to assess the effectiveness of the games. The assessment of skills was divided into three categories according to (Nikolova & Georgiev, 2017), namely:

1. Able (A): the children can do everything without the help of the teacher.
2. In progress (IP): children in the process of learning or assisted by teacher guidance.
3. Not Able (NA): children do not have the ability and are not in the learning process, or do not carry out the action even with the teacher's guidance.

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The observation process was conducted with two children, accompanied by their teachers, over five days. The results of the direct observation are presented in Figure 4.1



Figure 4.1. Observation of children's play activities

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Through this process, the abilities and skills of the children can be observed while they play, under the supervision of the teacher. This allows for an assessment of the children's interaction with the game, their level of engagement, and how they overcome any challenges that may arise. The observation results indicate that children are capable of performing tasks without teacher direction, as shown in Figure 4.2 and classified under category A.



Figure 4.2. Able (A): the children can do everything without the help of the teacher

4.3.1.2 The ability to develop creativity and logic in 3-4 year olds through educational games

Investigating the measurement of 3-year-olds' ability to play educational games for creativity and logic development involves a series of steps to understand the extent to which children master skills through play. The assessment of children's abilities for creative development is based on Flexibility, Fluency, Originality, and Elaboration, as explained in the previous chapter (section 3.3.1). Regarding the development of logic,

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Howard Gardner's theory serves as the standard for assessment. Children should have a good understanding of the concept of numbers.

Based on this assessment, the children's ability to play in the context of creativity and logic development was analysed. It notes that in the observation, there were five children whose ability in the learning process with the game required assistance from the teacher. The pilot study is currently in progress and is included in the 'IP' category, as shown in Figure 4.3.



Figure 4.3. In progress (IP): Children learn by doing or under the guidance of a teacher

The figure 4.3 shows that the children are supported in the game by the teacher's instructions in the context of creativity and logic development. Some children had difficulties in completing all the activities in the game. Especially in the logical development games, namely in the Super Numbers game. However, children were able to solve all the problems in other games without assistance from the teacher.

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4.3.2 Game creative and logic in children aged 3-4 years: 'A Day at the Zoo Game'

After identifying the elements and attributes used for educational games in children aged 3 to 4 years, data on children's achievements in creativity and logic development were collected from two institutions. The learning element used in creativity games was drawing two-dimensional shapes in several stages to create an animated character in the form of an animal. To aid in the development of children's basic logic skills, the logic game introduces the use of four primary colours (red, yellow, green, and blue) and three basic shapes. The objective is to help children recognise patterns and solve puzzles that will eventually form a complete picture. Additionally, the game recommends the use of concrete objects, such as animals, to assist children in developing mental representations. This concept is related to that investigated by (Dağal et al., 2015), who used the colour-number-shape method as a learning medium for children with no prior knowledge of English in order to improve their English proficiency.

Therefore, it is important to develop educational games that can enhance creativity and logic. The Game-Based Learning Analytics Platform (GBLAP) uses educational games as the main medium. As described in Chapter 3 of the research methodology, interactive games have been developed in GBLAP to assess the development of creativity and logic in 3-4-year-old children. Section 3.3.2 explains the methodological steps used in the development of the game

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4.3.2.1 Analysis: A Day at the Zoo Game

The analysis process at this stage is based on the data collection process related to the development of creativity and logic in this case study, which involves various approaches. Educational games, as learning media, are beneficial for children's development in the context of creativity and logic. It is important to consider the active involvement of children. Through games, they can learn while playing, making learning more enjoyable and interesting for them (Morata et al., 2019). Consideration of elements such as narrative, characters, and game mechanics is crucial in creating effective educational games for children.

The involvement of narratives in educational games can be key to stimulating the imagination and supporting children's creative and logical development. An important element that can enrich the narrative in educational games is the mission, which can provide challenges and goals for children and be related to the learning concepts to be conveyed (J. Baker et al., 2017). According to tables 4.1 and 4.2, the game narratives are linked to the learning concepts or skills found in the children's achievement data in the databases of both institutions.

The characters used in educational games are cartoon-like animal characters, which are the choice to attract children's attention. This was also done by (Arbianingsih et al., 2018) in her research which showed that interesting characters such as those with bright colours, cartoon-like characters and animals are effective in attracting children's attention in games (Arbianingsih et al., 2018). Furthermore, it is important to consider incorporating popular characters that appeal to children in order to increase their

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engagement (Istiono & Waworuntu, 2021). For instance, animal characters such as cats, fish, tigers, elephants, rabbits, frogs, butterflies, and frogs have been found to be particularly appealing to children (Nainggolan et al., 2019).

The game mechanic supporting the learning objectives is a challenge that aligns with the research goals. When children successfully complete the game challenges, they receive a score or reward to increase motivation. As explained in section 3.3.2, the reward for success in the game is a star, which symbolises achievement or reward.

4.3.2.2 Design: A Day at the Zoo Game

At this stage, the educational game's concept and design are based on the analysis results. As previously explained, the game is in 2D and comprises four parts, each with a score based on the time taken to complete it. Refer to Table 3.3 in Chapter 3 for more information. The assessment score is presented using a star rating system: 'Good' receives 3 stars, 'Moderate' receives 2 stars, and 'Low' receives 1 star. Please refer to Table 4.3 for details.

Table 4.3

The information about scoring is taken from the game

No	Average Score	Symbol (Star)	Overall Performance
1.	3 (Three)	★★★	GOOD
2.	2 (Two)	★★	MODERATE
3.	1 (One)	★	LOW

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Additionally, the game features and assets described in the previous section are used. The game features include animal characters that are popular among children, such as fish, cats, ducks, elephants, frogs, butterflies, rabbits, mice, lions, penguins, and sea squirts. Additionally, shape characters, such as squares, circles, triangles, and rectangles, are used for logic games. Table 4.4 shows the additional assets used in games, including creative and logic attributes. The assets were obtained from both self-made sources and search platforms such as Google and institutional websites.

Table 4.4

Creativity and logic attributes and assets in games

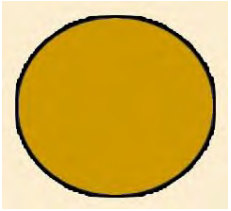
No	Assets Material	Description
1.		NCDRC Logo
2.		UPSI Logo
3.		Welcome screen
4.		Login screen

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Table 4.4 *(continue)*

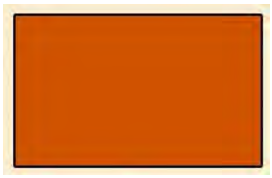
No	Assets Material	Description
5.		Play menu screen
6.		Screen loading (Shape game)
7.		Wallpaper screen (shape game)
8.		Circle shape
9.		Square shape

(continue)

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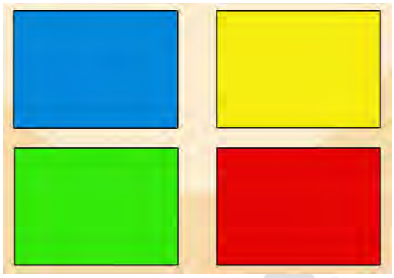
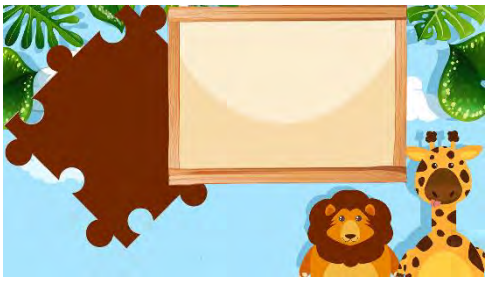
No	Assets Material	Description
10.		Triangle shape
11.		Rectangle shape
12.		Screen loading (Colour game)
13.		Wallpaper screen (Colour game)
14.		Butterfly (Blue)
15.		Frog (Green)

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Table 4.4 *(continue)*

No	Assets Material	Description
16.		Ladybird (Red)
17.		Duck (Yellow)
18.		Color
19.		Screen loading (Puzzle game)
20.		Wallpaper screen (Puzzle game)
21.		Elephant

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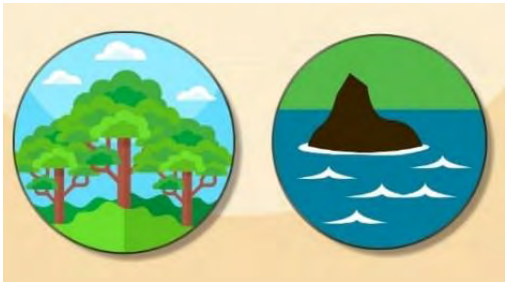
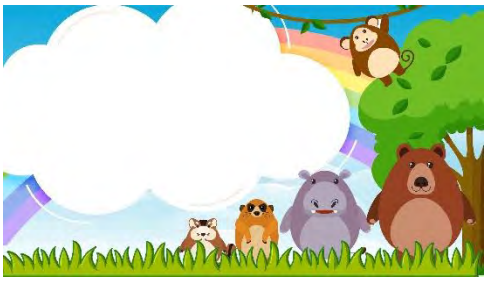
No	Assets Material	Description
22.		Lion
23.		Rabbit
24.		Mouse
25.		Screen loading (Animal home game)
26.		Wallpaper screen (Animal home game)
27.		Penguin

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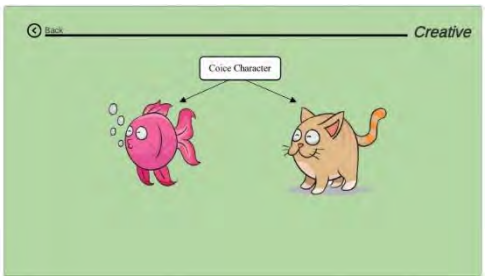
No	Assets Material	Description
28.		Seal
29.		Lion
30.		Elephant
31.		Animal home (Jungle and Sea)
32.		Wallpaper screen (Result game)
33.		Star

(continue)

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Table 4.4 *(continue)*

No	Assets Material	Description
34.		Home button
35.		Play menu screen (Creative game)
36.		Fish
37.		Cat
38.		Colour pencil

Audio is a support for the game in the form of information about each game. Two types of audio are used: background music and game audio. Background music makes the game more engaging and encourages children to play, while game audio provides instructions, introductions, and information on children's achievements in completing challenges.

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The games are categorised into two groups: creative games and basic logic games for children aged 3-4 years. Each game comprises four parts, as illustrated in Figure 3.4. Creative games involve following a shape pattern, with each part of the pattern becoming increasingly difficult. The objective of the game is to follow the line pattern by dragging until the pattern is complete. The first part is 'shape', which involves matching the shape of the image object with the target image. The second part is 'colour', which requires choosing the same colour as the animal object image. The third part is 'puzzle', which involves arranging scattered images. The fourth and final part is 'animal home', which requires choosing where the animal lives in the object section. Regarding the basic logic game, there are four parts to it. For the first and second parts, the game rules dictate that the player must 'click' one of the pictures in the target column. Regarding the third and fourth sections, the game rules require the user to 'drag' the image from the object column to the target column.

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4.3.2.3 Development: A Day at the Zoo Game

The educational game's development is based on a pre-existing design. Important considerations for development include narrative, characters, and game mechanics that encourage user participation and learning. The UNITY platform was used for game development, as explained in section 3.5. The game was developed for Android. Thus, the creative and logical game is designed to display the final score upon completion. The game flowchart, illustrated in Figure 4.4, was developed to ensure a clear and logical progression.

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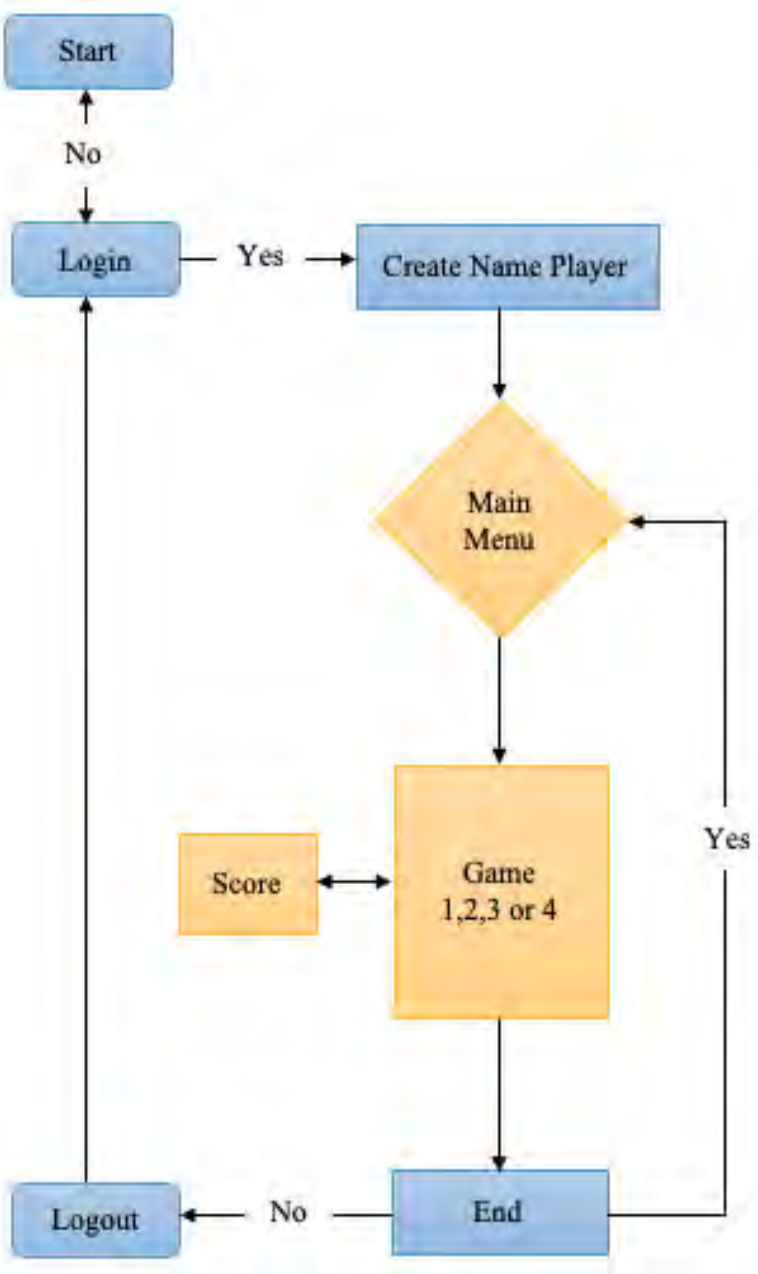


Figure 4.4. Flowchart for game creative and logic

The game begins with a login process that manages user access rights and ensures the privacy of user data by limiting access to the account owner only. The login process is illustrated in Figure 4.5. The account creation process used in the game is the same as that used in GBLAP. Users can use their active Google accounts, such as Gmail

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and Yahoo, to access their accounts. Inactive accounts will be rejected during the registration process.

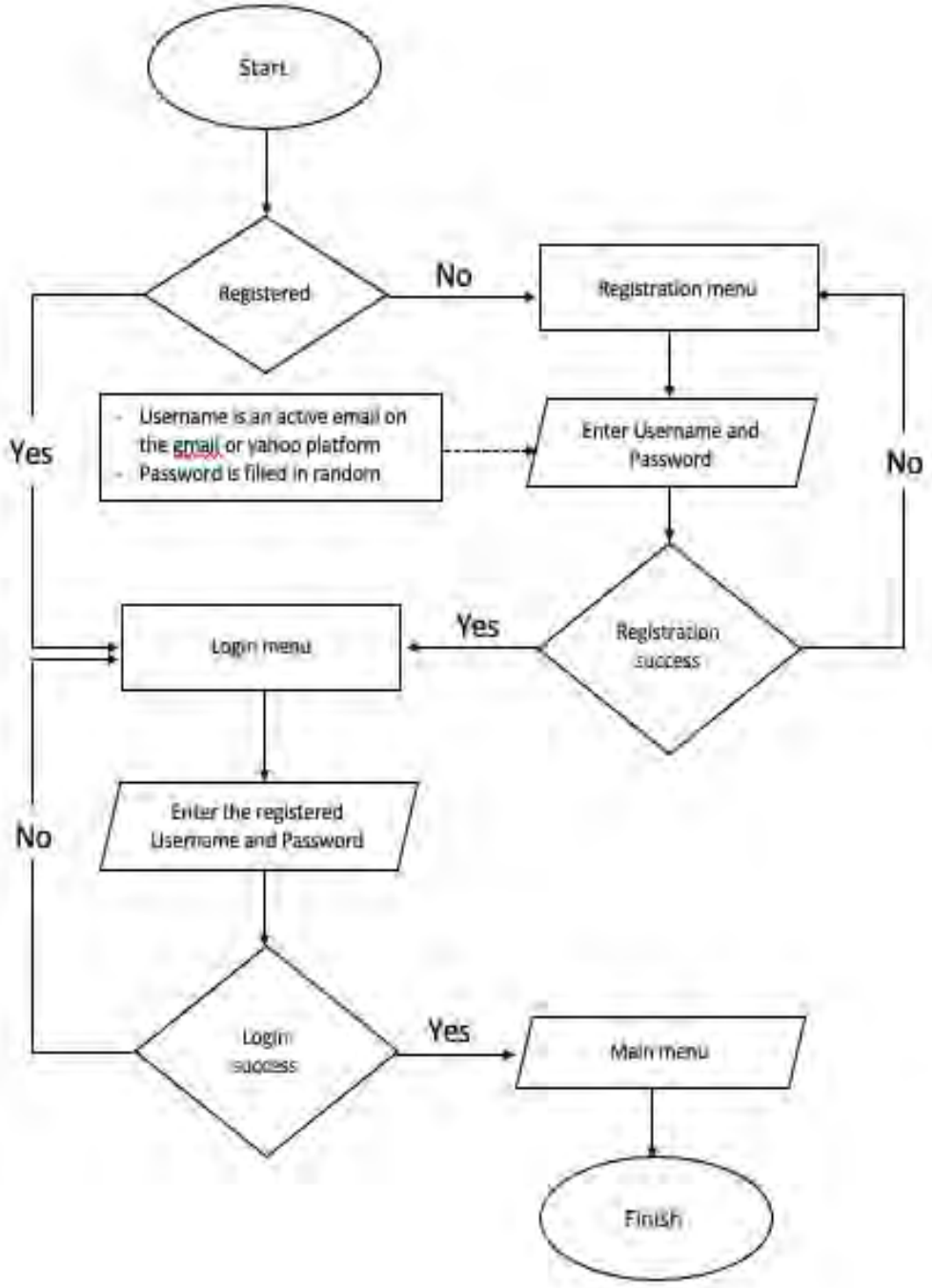


Figure 4.5. Flowchart for game login

The process of the registration and login that will have to be carried out by the users who will appear in the game on the Android, as shown in Figure 4.6.

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Figure 4.6. Screen login and register game

After a successful login, the account owner can register the name of the children who will be playing the game in the 'Create Name Player' menu. Once a name has been successfully created, the screen will switch to the 'Welcome Screen' and 'Main Menu' of the game. The main menu will display four games for children to choose from. At the end of each game, a score will be generated as a reward and stored in the game database. After completing the fourth game, the user has the option to continue playing instead of exiting the game. The game storyboard is designed to facilitate the development of educational games, as shown in Figure 4.7.



Figure 4.7. Example of Storyboard created for ‘Welcome Screen’ and ‘Game Menu’

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The learning elements integrate the design of creative and logical game concepts that have been selected through the analysis process in the previous section. In creative games, children follow a pattern, such as drawing a shape until the end of the game to form an animal they have chosen beforehand. See Figure 4.8 for the steps taken.

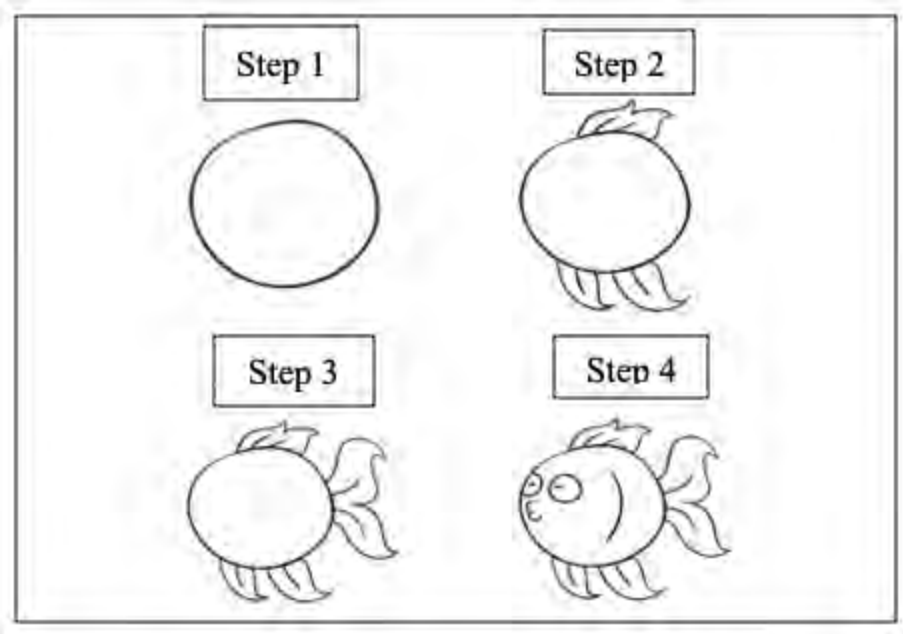


Figure 4.8. The process of the game is on display in the creative games section

Figure 4.8 shows the step-by-step process for creating a fish shape. In the first step, the children will form a circle. Then, in the second step, they will create a zigzag line to form the fish fin. The third step involves creating another zigzag line to form the fish tail. Finally, in the fourth step, the children will add the eyes and gills by making a small circle and a curved line.

As for the logic game, the concepts used in the game are shape recognition, colour recognition, puzzles and animal houses. The game is divided into several sections, as shown in Figure 4.9.

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Figure 4.9. The logic games are based on a play process that revolves around shapes, colours, puzzles and the homes of the animals

At the end of the game, the score will be displayed. The score is generated based on the time spent playing, as described in the previous section (Chapter 3: Methodology). The obtained score will be stored in the Firebase database, which is connected to UNITY and the Learning Analytics Platform. The results are shown in Figure 4.10.

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Figure 4.10. Result of game creative and logic

Developing an educational game for 3 to 4-year-olds that focuses on creativity and logic development involves specific elements and outcomes. The storyboard provides a basis for developing outcomes or features in the context of a game-based learning analytics platform (GBLAP) for game development interfaces. These include the selection of interesting characters, interactive learning modes, child-friendly interface design, difficulty level adjustment, and learning track records as data

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collection of children's activities and achievements during play. Figure 4.11 illustrates these features in the creativity game. The interface of the Logic game is shown in Figure 4.12.

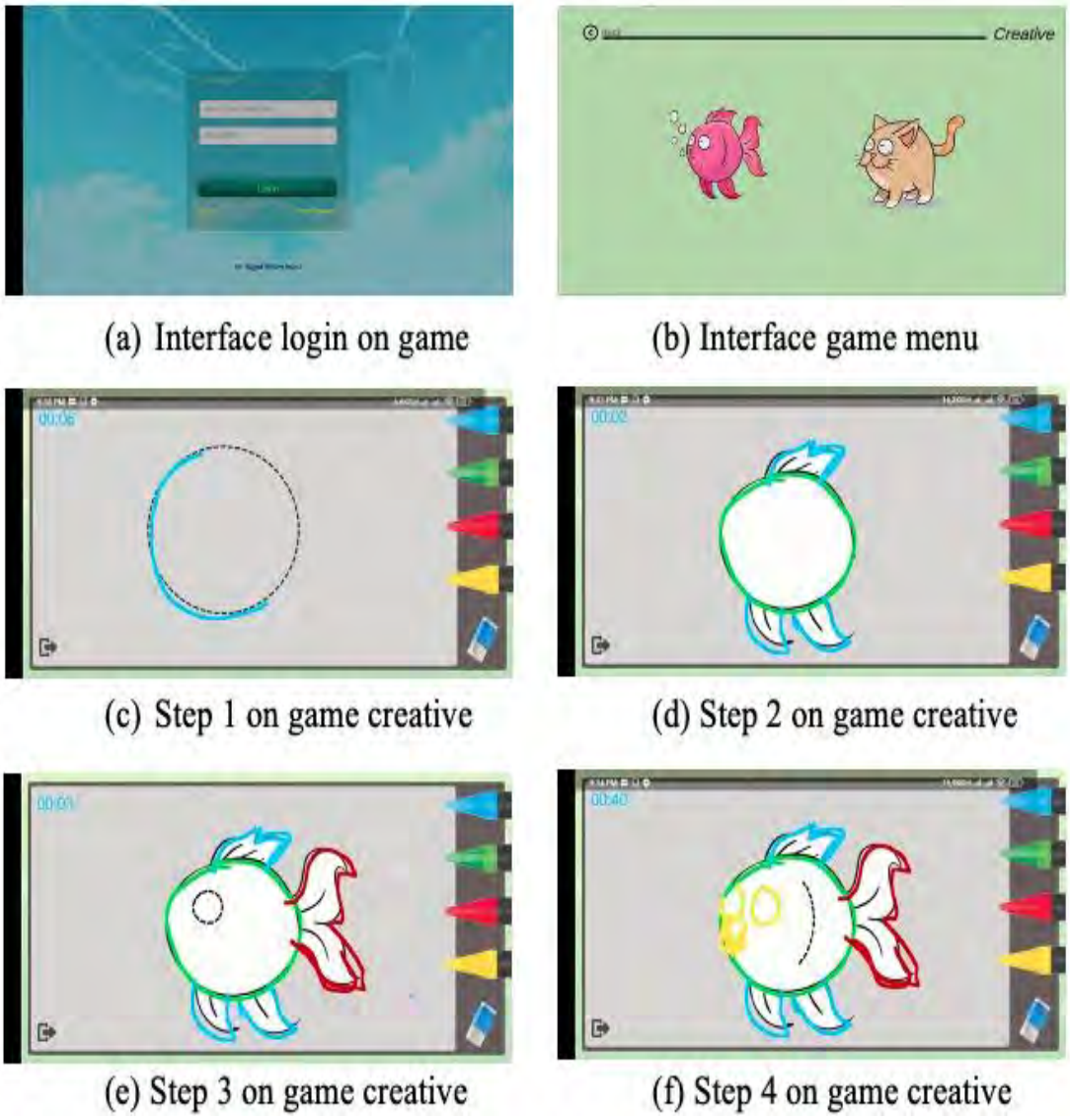


Figure 4.11. Interface for the game creative (login, game menu, step 1 to 4)

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(a) Interface login

(b) Interface game menu

(c) Let's learn about shape

(d) Let's learn about colour

(e) Let's learn about puzzle

(f) Let's learn about animal home

Figure 4.12. Interface for the game logic (login, game menu, let's learn about shape, colour, puzzle, and animal home)

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4.3.2.4 Implementation 'A Day at the Zoo Game'

At this stage, the games that have been developed will be implemented involving 10 children and 2 teachers. The implementation was carried out in the Manhajul Husna PAUD class, South Kalimantan, Indonesia. As explained in the previous section on study population, section 3.6.1. The stages of game implementation are carried out using a tablet or smartphone with a minimum layer size of 6.3 inches. The session stages that will be carried out during implementation are shown in Table 4.5. Before the session begins the researcher first introduces the game that will be implemented to the teacher.

Table 4.5

Session stages during the implementation of games creative and logic

Session	Announcements	Notes
1	Teacher teach the game to the children	In this first session, children have been taught by the teachers on how to play all the games. Approximate time taken were 10 minutes. However, in any circumstances, if the children refused to continue playing, the process will be stopped. We can either recruit new children, or if the children would like to continue playing in the next day or any other days (as long as it is within the evaluation process duration), then the process will be resumed. The activities have been recorded (video and photograph) throughout the session.

(continue)

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Table 4.5 *(continue)*

Session	Announcements	Notes
2	Teachers accompanied children while playing the games	In this second session, children will play the games accompanied by the teachers. Approximate time taken were 10 minutes. This time, children were not taught by the teachers but teachers will be there to supervise the process. In case if the children have questions to ask, then the teachers can answer the questions. Same procedure in session 1 is applied, if the children refused to continue playing.

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4.3.2.5 Evaluation 'A Day at the Zoo Game'

At this stage, an evaluation of the games that have been implemented for children and teachers in two places, namely the Manhajul Husna PAUD class. This evaluation stage is carried out to get a level of satisfaction that gets feedback from the teacher who is a stakeholder in the learning process for creative and logical development. From the implementation results, it can be concluded that for creative games the results are 50:50 percent, while for logic games the results are 100%. As shown in Figure 4.13 Diagram of satisfaction with educational games.

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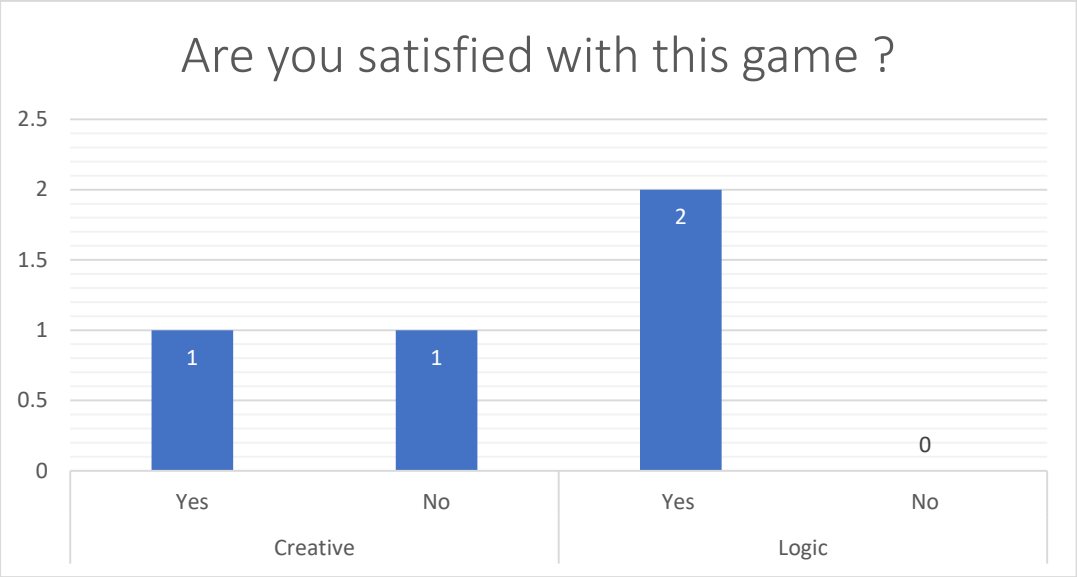


Figure 4.13. Diagram of satisfaction with educational games

4.4 Game-based Learning Analytics Platform Interfaces and Visualization

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The learning analytics platform is a very important element in the development of game-based learning analytics, because the visual analytics provided by the learning analytics platform has the potential to describe a child's learning process in "real-time" while playing games. Visual analysis is the process of combining all learning data from games developed on the Android system, in addition to conventional teaching and learning methods so that teachers can have information about children's performance easily while playing games. Coupled with the current conditions during the Covid-19 pandemic, which required learning that was previously carried out face-to-face, to be transferred to online learning which is done from home only. This visual information is designed in the form of a dashboard, where several visualizations are combined to provide clear information about individual children's learning. The dashboard was developed in the form of a website-based feature, where the website makes it easier for

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parents to monitor their child's creative and logical development. The development of this learning analytics platform, according to the flowchart shown in Figure 3.3 section 3.4.1, Chapter 3. As mentioned in Chapter 3, when the game process is complete, the data will be stored in the database, and the learning analytics platform will carry out the analysis and visualization process. For the process of analysis and visualization, it is necessary to design data entity relationships as shown in Figure 4.14. So that the algorithm will get the appropriate data from the database to display on the dashboard.

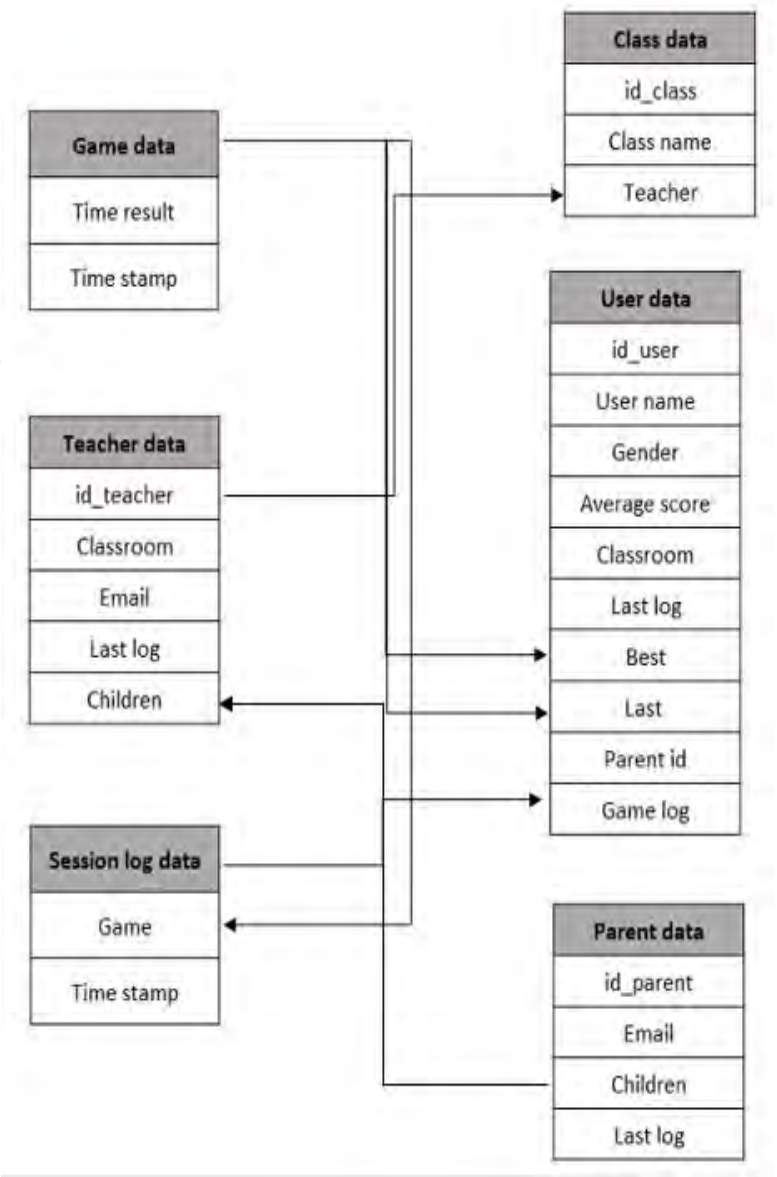


Figure 4.14. Data entity relationship design

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a) **Table Name** : Game Data

Description : Table for user game time

Table 4.6

Design game data table

Column Name	Description	Data Type	Remarks
TIME RESULT	Game result	UINT 64	Millisecond
TIME STAMP	Epoch time	UINT 64	Millisecond

b) **Table Name** : Session Log Data

Description : Table for user session data

Table 4.7

Design session log data table

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Column Name	Description	Data Type	Remarks
GAME	All game data	Array	
TIME STAMP	Epoch time	UINT 64	Millisecond

c) **Table Name** : User data

Description : Table for user registration

Table 4.8

Design user data table

Column Name	Description	Data Type	Remarks
ID	ID user	String	
User name	User name	String	
Gender	Gender	Uint 8	
Average score	Average score	Float	

(continue)

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Table 4.8 *(continue)*

Column Name	Description	Data Type	Remarks
Classroom	Class user	Uint 8	
Last log	Last time login	Uint 64	Millisecond
Best	Best time game	Array	
Last	Last time game	Array	
Parent id	Id user parent	String	
Game log	All session game	Array	

d) **Table Name** : Class data

Description : Table for user classroom

Table 4.9

Design class data table

Column Name	Description	Data Type	Remarks
Id_class	Class id	Uint 8	
Class name	Name class	String	
Teacher	Teacher id	String	

e) **Table Name** : Parent data

Description : Table for user parent

Table 4.10

Design parent data table

Column Name	Description	Data Type	Remarks
Id_parent	Parent id	String	
Email	Email parent	Email	
Children	Children id	Array string	
Last log	Last parent login	Uint 64	

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f) **Table Name** : Teacher data

Description : Table for user teacher

Table 4.11

Design teacher data table

Column Name	Description	Data Type	Remarks
Id_teacher	Teacher id	String	
Class	Class teacher	Uint 8	
Email	Email teacher	Email	
Last log	Last teacher	Uint 64	
Children	Children id	Array string	

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For data storage that is synchronized with the learning analytics platform in the form of a website-based application, the back end and front-end processes are carried out in the Node.js programming, as shown in the script below.

```
async function displayUserData(dataId){
   var dataSnap = await getDoc(doc(db, 'Users', dataId));
   var userData = dataSnap.data();
   var recordedAvg = userData.average;
   var parent = await sendGet('/user', {id : userData.parentId});
   var parentName = 'Unknown';
   var classIdx = userData.childrenClass.toString();
   var classRoom = await getDoc(doc(db, 'Classroom', classIdx));
   var classData = classRoom.data();
   var teacherName = "None";
   var bestState = [false, false, false, false];
   $('#tabs').hide('slide',{}, 100, ()=>{});
   var usrElm = $(await getPage('/page/user_data'));
   if(parent){
      if(parent.displayName){
         parentName = parent.displayName;
      } else if(parent.email){
```

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```
            parentName = parent.email;
        }
    }
    if(classData.teacher){
        var teacherData = await sendGet('/user', {id : classData.teacher});
        if(teacherData) teacherName = teacherData.displayName;
    }
    $(usrElm).find('#user_info_teacher').children().last().text(teacherName);
    $(usrElm).find('#user_info_parent').children().last().text(parentName);
    $(usrElm).find('#user_name').text(toTitleCase(userData.userName));
    $(usrElm).find('#user_info_gender').addClass(userData.gender > 0? 'fa-venus':'fa-mars');
    $(usrElm).find('#user_login').text("Last Logged : " + formatDate(new Date(userData.lastLogged *
1000)));
    $(usrElm).find('#user_info_class').children('label').eq(1).text(classRoom.data().name);
    $(usrElm).find('button[name="back"]').on('click', evt => {
        $(usrElm).hide('slide',{},100, () => {
            $(usrElm).remove();
        })
        $('#tabs').show('slide',{}, 100, ()=>{});
    });
    if(userData.best && userData.best.length == 4){
        if(userData.best[0]){
            bestState[0] = true;
            $(usrElm).find('.info_region').eq(2).find('.info_item').eq(0).children().text(new
Date(clamp(userData.best[0].timeResult)).toISOString().substr(14, 5));
        }
        if(userData.best[1]){
            bestState[1] = true;
            $(usrElm).find('.info_region').eq(2).find('.info_item').eq(1).children().text(new
Date(clamp(userData.best[1].timeResult)).toISOString().substr(14, 5));
        }
        if(userData.best[2]){
            bestState[2] = true;
            $(usrElm).find('.info_region').eq(2).find('.info_item').eq(2).children().text(new
Date(clamp(userData.best[2].timeResult)).toISOString().substr(14, 5));
        }
        if(userData.best[3]){
            bestState[3] = true;
            $(usrElm).find('.info_region').eq(2).find('.info_item').eq(3).children().text(new
Date(clamp(userData.best[3].timeResult)).toISOString().substr(14, 5));
        }
    }
    $('#tabs').parent().append($(usrElm));
    $.get('/logs',{id:dataId}, res => {
        var column = [
            ['x'],
            ['Shapes'],
            ['Colour'],
            ['Puzzle'],
            ["Animal's home"]
```

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```
];
var parts = [
    [['x'],
    ['Shapes']],
    [['x'],
    ['Colour']],
    [['x'],
    ['Puzzle']],
    [['x'],
    ["Animal's home"]]
]
var sessions = [
    ['Low'],
    ['Moderate'],
    ['Good']
];
var gameTotals = [
    0,0,0,0
]
var totalGame = 0;
var totalSession = 0;
var completed = 0;
var totalTime = 0;
var totalIndex = 0;

res.forEach((element, idx) => {
    column[0].push(idx + 1);
    var sessionSum = 0;
    var sessionPoint = 0;
    var failed = false;
    for(var i = 0; i < 4; i++){
        var val = 60000 * 5;
        var point = 0;
        if(element.game[i] != null){
            val = element.game[i].timeResult;
            totalGame++;
            totalTime += val;
            if(bestState[i] && element.game[i].timeStamp == userData.best[i].timeStamp) {
                var bElm = $(usrElm).find('.info_region').eq(2).find('.info_item').eq(i).children();
                var txt = $(bElm).text();
                $(bElm).text(txt + '(' + (idx + 1) + nth(idx + 1) + ' session)');
            }
            point = CalculatePoint(val/1000);
        } else{
            failed = true;
        }

        if(val < 1){
            val = 1;
        }
```

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```
            column[i + 1].push(clamp(val));
            parts[i][0].push(idx + 1);
            parts[i][1].push(point);
            sessionSum += val/1000;
            sessionPoint += point;
            gameTotals[i] += point;
        }

        var sessionAvg = sessionPoint/4;
        var sessionIdx = Math.round(sessionAvg);

        totalIndex += sessionIdx;

        if(sessionIdx < 1){
            sessionIdx = 1;
        }
        sessions[sessionIdx - 1].push(1);

        totalSession++;
        if(!failed){
            completed++;
        }
    });

    var graph = c3.generate({
        bindto : '#user_graph',
        data : {
            x : 'x',
            columns : column,
            colors : bar_color
        },
        axis : {
            x : {
                label : {
                    text : 'Session index number',
                    position : 'inner-center'
                }
            },
            y : {
                label : {
                    text : 'Time in mm:ss',
                    position : 'outer-middle'
                },
                tick : {
                    format : d3.timeFormat("%M:%S")
                }
            }
        }
    });
```

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```
c3.generate({
    bindto : '#point_stacks_shape',
    data : {
        x : 'x',
        columns : parts[0],
        type : 'bar',
        legend : {show : false},
        colors : bar_color
    },
    bar : {
        width : 12
    },
    axis : {
        y : {
            tick : {
                values : [0, 1, 2, 3, 4]
            }
        }
    }
});
c3.generate({
    bindto : '#point_stacks_color',
    data : {
        x : 'x',
        columns : parts[1],
        type : 'bar',
        legend : {show : false},
        colors : bar_color
    },
    bar : {
        width : 12
    },
    axis : {
        y : {
            tick : {
                values : [0, 1, 2, 3, 4]
            }
        }
    }
});
c3.generate({
    bindto : '#point_stacks_puzzl',
    data : {
        x : 'x',
        columns : parts[2],
        type : 'bar',
        legend : {show : false},
        colors : bar_color
    },
```

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```
    bar : {
        width : 12
    },
    axis : {
        y : {
            tick : {
                values : [0, 1, 2, 3, 4]
            }
        }
    }
});
c3.generate({
    bindto : '#point_stacks_homes',
    data : {
        x : 'x',
        columns : parts[3],
        type : 'bar',
        legend : {show : false},
        colors : bar_color
    },
    bar : {
        width : 12
    },
    axis : {
        y : {
            tick : {
                values : [0, 1, 2, 3, 4]
            }
        }
    }
})

var sums = c3.generate({
    bindto : '#session_chart',
    data : {
        columns : sessions,
        type : 'donut',
        colors : pie_color
    },
    donut: {
        title: "Session Data"
    },
    legend : {
        position : 'right'
    }
})

var statParent = $('#stats_header').parent();
var avgIdx = Math.round(totalIndex / totalSession);
var pointIndex = [0,0,0,0];
```

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```
        for(var p = 0; p < pointIndex.length; p++){
            pointIndex[p] = gameTotals[p] / (column[0].length - 1);
            var roundedIdx = Math.round(pointIndex[p]);


$(usrElm).find('.info_region').eq(1).find('.info_item').eq(p).children().text(literalPoints[roundedIdx]);
        }

        $('#user_average_point').children().last().text(literalPoints[avgIdx]);
        $(statParent).children().eq(1).children().text(totalGame);
        $(statParent).children().eq(2).children().text(totalSession);
        $(statParent).children().eq(3).children().text(completed);
        $(statParent).children().eq(4).children().text(millisToMinutesAndSeconds(totalTime));

        if(avgIdx != recordedAvg){
            setDoc(doc(db, 'Users', dataId), {average: avgIdx}, {merge : true});
        }
    });
}
```

The learning analytics platform users are divided into three main users: (1) Admin, (2) Teachers and (3) Parents. This learning analytics platform is attached to creative and logical games that can be used to assess the creative and logical development of 3–4-year-olds. The learning analytics platform is designed in such a way that teachers can only see the progress and achievements of children in their classes, while parents can only see their children's performance as shown in Figure 4.15.

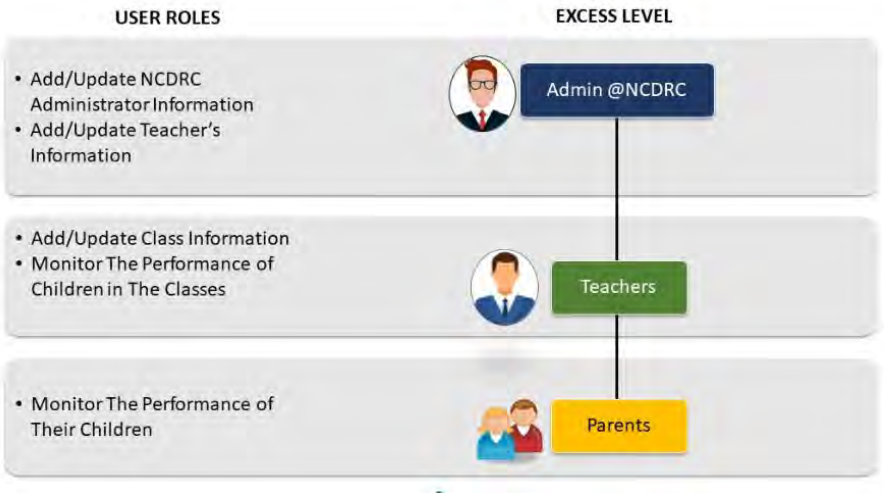


Figure 4.15. User excess level for the learning analytics platform

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4.4.1 Platform interface

As shown in Figure 4.15. The platform is designed for three main users, each user has an interface tailor-made for them according to the level, which will be explained further in this section. Figure 4.16.

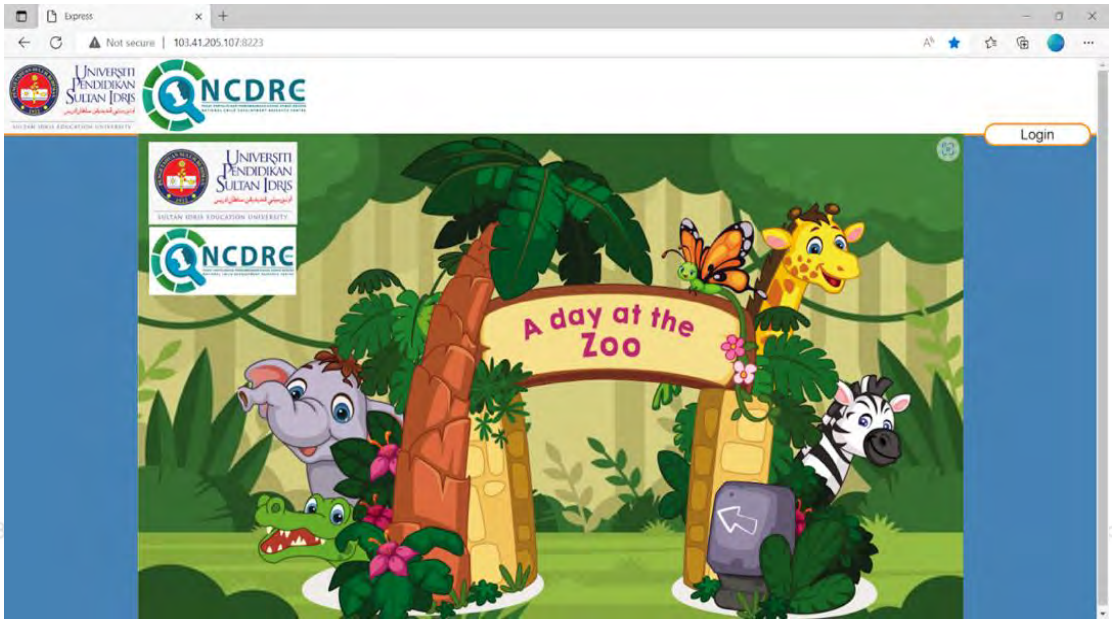


Figure 4.16. Interface for learning analytics platform

For the use of the admin serves as the person responsible for managing and operating everything related to the platform. The interface for Admin is shown in Figures 4.17 and 4.18. For this interface, there are two menus; (1) User Management, and (2) classrooms. The user management menu is used to select a user role, either as teacher or admin. This menu can be accessed by the admin master in NCDRC. Meanwhile, the class menu is useful for adding classes, and entering or moving teacher and child names.

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Figure 4.17. Interface for user management menu

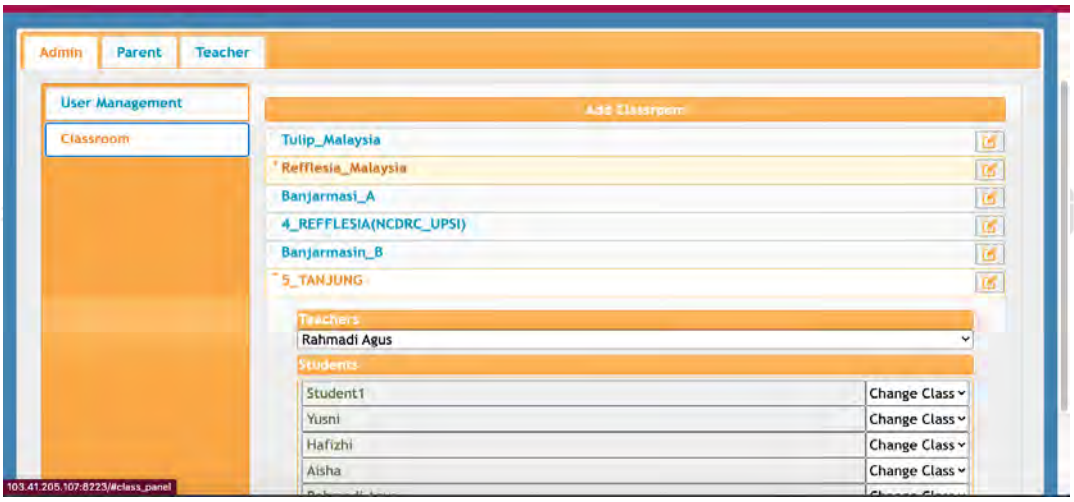


Figure 4.18. Interface for classroom

4.4.1.1 Interface for Teacher

As mentioned in the previous section, this section shows the interface used by the teacher. In this interface the teacher can only see the progress and achievements of their students in class. In the current version, the admin will assign students to each class, so the teacher will automatically see a list of their students in the class. As seen in Figure

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4.19. Apart from that, the teacher can see the overall performance of each student by clicking the 'Calculate Score Chart' button. In addition, the teacher can click on the name of each student to see in more detail the child's appearance in each game, as shown in Figure 4.20. Guidelines for teachers to register and gain access to this platform are provided in the guidelines as provided in APPENDIX I.

The dashboard that is displayed visualizes the presentation of the child's performance in the game. This visualization aims to make it easier for parents or teachers to monitor children's development, in visualization there are several attributes to facilitate monitoring. Attributes are described in Table 4.12. Additionally, these descriptions are included in the manual and the dashboard itself as a reference for teachers.

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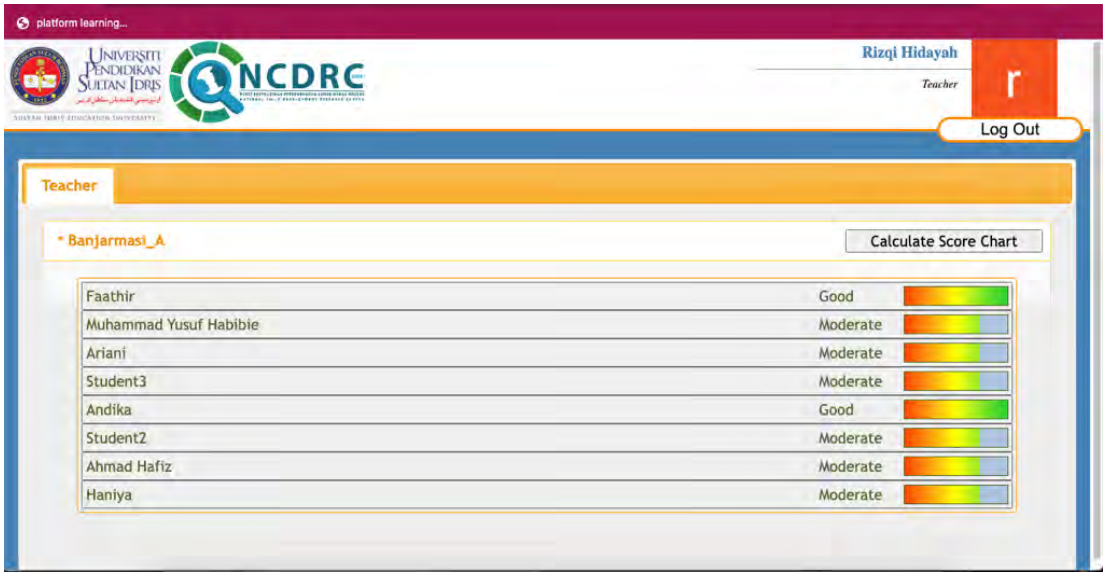


Figure 4.19. Teacher interface for one class

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(a)



(b)

Figure 4.20. (a)-(b) Teacher's dashboard to see detail performance of each child

Table 4.12

Description of each attribute for each children's performance visualization

No	Performance Attributes	Description
1.	Total Average Index	Overall performance of the children based on the average score. For all the games. If average score is 3, then it is GOOD, average score 2, then MODERATE, if the score is 1, then it is LOW.

(continue)

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Table 4.12 *(continue)*

No	Performance Attributes	Description
2.	Game Average	Shows performance of children in each game
3.	Best Time	Record the best time for each children in completing the games for various sessions.
4.	Statistic	Shows total game, total sessions, completed sessions, and total play time.
5.	Main Graph	Shows all time results per game (mm:ss)
6.	Cumulative Graph	Shows calculated results per game
7.	Sessions Data Chart	Shows average results per games sessions (total time in a session / 4)
8.	Last Logged	Shows last play date

4.4.1.2 Interface for Parent

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The interface for parents is a dashboard that provides information for their child's development. As explained in the previous section. To access a parent's account, they must log in with the account that was registered with the “A DAY AT THE ZOO” game account on Android. Guidelines for parents to register and gain access to the platform are also provided in the guidelines as provided in Appendix J. The dashboard display for parents is shown in Figure 4.21, which shows the parent account for registering more than one child. As for the visualization for the overall appearance in each game for their children, the display is similar to that shown to the teacher.

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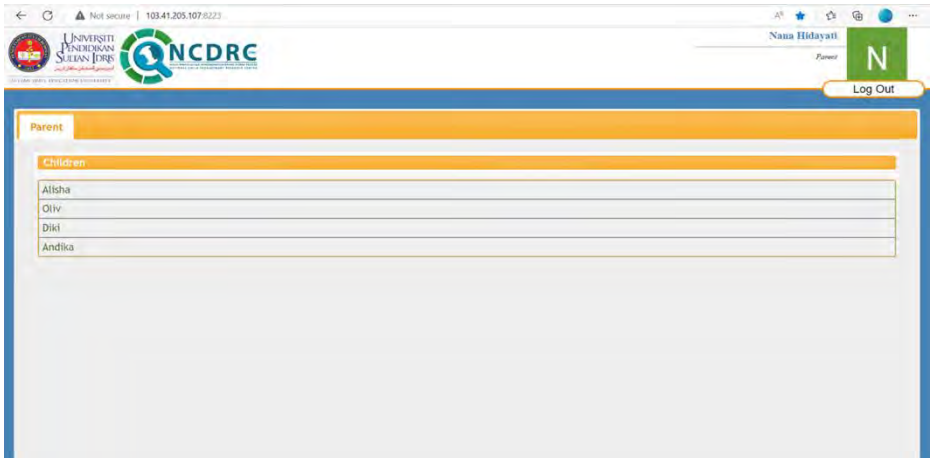


Figure 4.21. Parent's dashboard to see detail performance of their children

4.5 Measuring the 'A Day at the Zoo game' learning model

At this stage, the game is played by children aged 3-4 years old, as explained in section 3.6.1 of chapter 3, the children are specially selected by the teacher by looking at the developmental achievements of creativity and logic. The children play the teacher-installed game on the smartphone mentioned in section 3.5. The teacher will ask the child's parents to send an email to register for the game so that the children can play it and the data can be stored in their own name. The stages of the game are conducted for one day only, allowing 2 children to participate, each accompanied by a teacher. The children perform the logic game in four sessions, the same for the creative game. The game sessions are described in section 3.6.4. A study by Sara Price et al. (2015) and the Technology and Play (TAP) research institute at the University of Sheffield and the University of Edinburgh found that the maximum amount of time children aged three to four can concentrate on games on tablets or smartphones is 10 minutes. (Marsh et al., 2015; Price et al., 2015). As can be seen from Table 4.13.

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Table 4.13

Playing activities children do each day

	Session			
	1	**2**	**3**	**4**
Description	Teacher teach the game to the children	Teachers accompanied children while playing the games	Teachers will observed children playing games from afar	Children will play the game without any help from teachers
Max Time (minutes)	10	10	10	10
Respondent (child)	2	2	2	2

The researcher made time arrangements with the TASKA PERMATA class, NCDRC, UPSI MALAYSIA as mentioned earlier. The case study was conducted in the TASKA PERMATA class, but due to Covid 19 conditions at the time of the research, which required the class to be closed and online, the researcher conducted a case study at PAUD Manjul Husna Indonesia. This means that the researcher conducted the research at PAUD Manhajul Husna in Indonesia. With the COVID procedures in place, the researcher can conduct research in the classroom. As shown in Figure 4.22.

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(A) (B)

Figure 4.22. Data collection (A) for session 1 and 2 "Teachers teach and accompanied children while playing the game", (B) for session 3 and 4 "Teachers will observed children playing game from afar and children will play the game without any help from teachers"

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4.5.1 Measurement of game-based learning analytics model for creativity development

The researcher carried out an experiment in order to collect the necessary data for the validation of the game as an assessment tool. This experiment involved 20 children: 10 children from the classes TASKA PERMATA, REFFLESIA and TULIP and 10 children from the classes PAUD Manhajul Husna, PAUD A and PAUD B, aged between 3 and 4 years, as well as 2 teachers. As mentioned, these children were selected following a process carried out by the teachers based on the results of their creative development. The stages described in Table 4.13 were used in the measurement process. The experiment was carried out in two rooms. Each room consisted of one teacher and one child.

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Once this is done, the smartphone criteria are explained in section 3.5 and the children are given a smartphone with a game installed. The game they have to play is a creativity game, which is the subject of section 4.3. The children are first instructed to complete the test and then, depending on the session, to play the game. The game is shown in Figure 4.23.

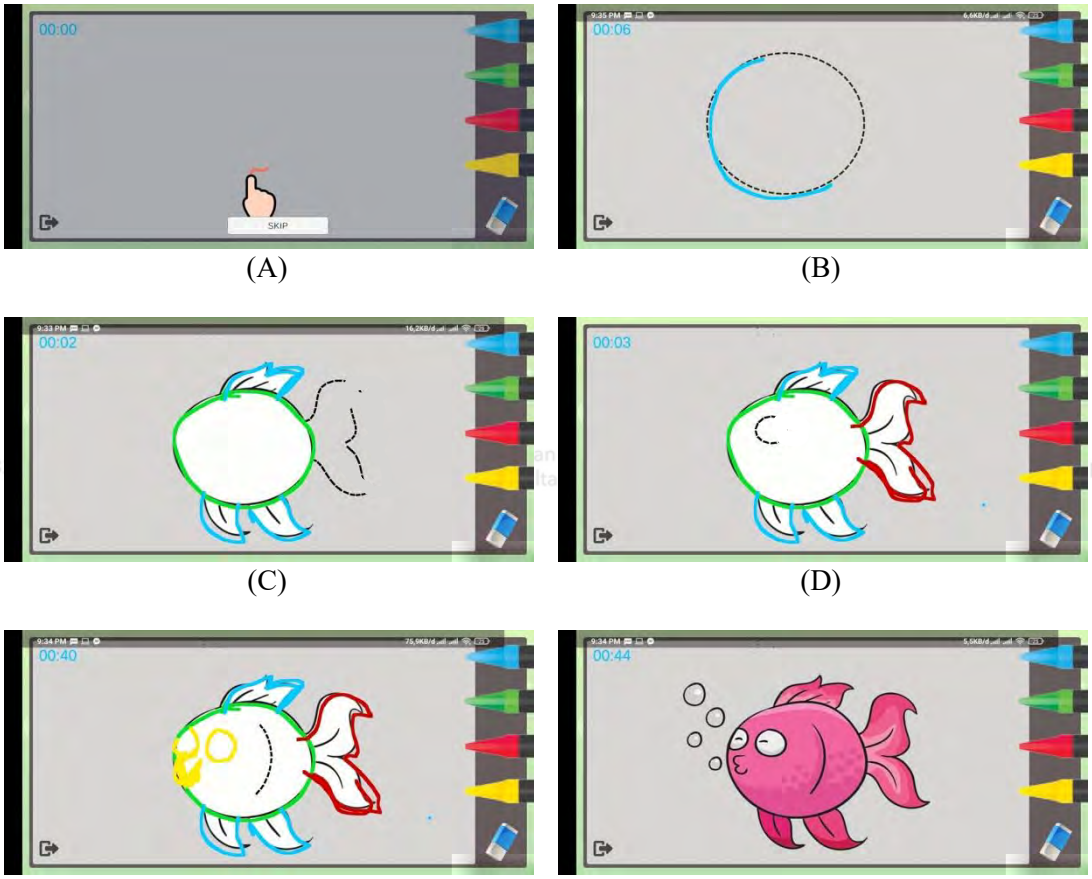


Figure 4.23. The stages of the game of creativity that the children will be playing 'Fish'

For the creativity game, the children have to start from the beginning, with the 'screen gestures' stage shown in Figure A. Once the children have understood the game instructions, the teacher moves on to the next stage by pressing the 'skip' button available in the game. Then, in the first game, the children make a circle by following

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the line on the screen with the coloured pens provided, as shown in figure B. Then, in the second game, the children make a zigzag line by following the line, which will be the shape of the fin on the fish, as shown in figure C. Then, in the third game, the children make a zigzag and curved line by following the line, which will be the shape of the tail on the fish, as shown in figure D. Then, in the fourth game, the children make curved lines and small circles by following the lines, which will become the shape of the gills and eyes on the fish, as shown in Figure E. When all the games have been played, the image will become a perfect fish shape in 2D drawing, as shown in Figure F. As described in Chapter 3, Section 3.3.2, at the end of the game, the score is displayed from the game results obtained from the processing time, which is described in Table 3.3 and Table 4.3. Therefore, at the end of the game, a summary of the game results is displayed on a separate screen, as shown in Figure 4.24. To return to the beginning of the game, press the 'Next' button.

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Figure 4.24. Summary of creativity game results

After each child has played the game, the results are stored in the database. As can be seen from the data in Table 4.14 for the results of 20 children in the first session.

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Table 4.14

Creativity game data from the first session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 1	3.525	3.954	8.837	6.361	Good
Child 2	Sessions 1	1.686	1.337	7.927	2.507	Good
Child 3	Sessions 1	2.575	4.033	18.411	22.001	Moderate
Child 4	Sessions 1	9.519	41.607	11.604	23.881	Moderate
Child 5	Sessions 1	3.792	3.001	7.938	4.063	Good
Child 6	Sessions 1	10.778	6.418	11.604	4.517	Good
Child 7	Sessions 1	4.872	5.903	7.285	3.606	Good
Child 8	Sessions 1	4.819	2.942	10.405	21.824	Good
Child 9	Sessions 1	1.081	1.555	10.116	1.717	Good
Child 10	Sessions 1	2.775	1.376	7.563	10.204	Good
Child 11	Sessions 1	13.049	9.075	59.182	9.245	Moderate
Child 12	Sessions 1	5.769	2.026	22.931	27.762	Moderate
Child 13	Sessions 1	1.659	1.823	18.046	4.555	Good
Child 14	Sessions 1	5.893	6.361	13.363	12.119	Good
Child 15	Sessions 1	6.653	5.236	10.730	8.577	Good
Child 16	Sessions 1	1.276	1.109	8.071	2.410	Good
Child 17	Sessions 1	9.361	14.829	26.230	23.881	Moderate
Child 18	Sessions 1	7.535	7.581	11.451	7.497	Good
Child 19	Sessions 1	10.402	8.669	12.888	10.048	Good
Child 20	Sessions 1	13.254	6.061	14.704	14.675	Moderate

The data above shows that for the achievement results in the first session with 'Teacher teaches the game to the children'. A total of 70% (14 out of 20 children) achieved 'Good', while 30% (6 out of 20 children) achieved 'Moderate'. No child achieved 'low'. After the end of the first session, the second session continued with 'Teachers accompanied children while playing the games'. As in the previous session,

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the data were stored in the game database, see Table 4.15 for the results of the 20 children in the second session.

Table 4.15

Creativity game data from the second session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 2	4.648	Not Played	Not Played	Not Played	Low
Child 2	Sessions 2	13.139	2.049	10.186	18.655	Good
Child 3	Sessions 2	3.126	Not Played	Not Played	Not Played	Low
Child 4	Sessions 2	8.792	8.890	51.961	3.122	Good
Child 5	Sessions 2	1.785	1.066	6.886	2.759	Good
Child 6	Sessions 2	3.893	3.659	7.845	2.818	Good
Child 7	Sessions 2	2.801	2.326	5.915	3.345	Good
Child 8	Sessions 2	6.920	2.666	12.372	5.143	Good
Child 9	Sessions 2	0.781	214.748	4.990	2.083	Good
Child 10	Sessions 2	1.890	1.848	29.426	25.928	Moderate
Child 11	Sessions 2	6.301	3.377	9.635	4.095	Good
Child 12	Sessions 2	1.660	0.642	13.538	2.499	Good
Child 13	Sessions 2	6.841	2.491	Not Played	Not Played	Moderate
Child 14	Sessions 2	3.218	9.137	Not Played	Not Played	Moderate
Child 15	Sessions 2	9.430	7.138	7.604	4.483	Good
Child 16	Sessions 2	9.094	8.944	13.373	5.755	Good
Child 17	Sessions 2	13.431	14.222	25.129	13.306	Moderate
Child 18	Sessions 2	10.088	11.112	22.924	9.686	Moderate
Child 19	Sessions 2	6.903	5.028	11.195	5.896	Good
Child 20	Sessions 2	15.197	16.898	23.943	13.438	Moderate

The data results above show that 60% (12 out of 20 children) achieved 'Good', 30% (6 out of 20 children) achieved 'Moderate', while 10% (2 out of 20 children)

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achieved 'Low'. This is different from the first session where there were 2 children who stopped playing in the first game. There were also 2 children who stopped playing in the second game. However, they could finish the first and second games with a "Good" time under 10 seconds.

The third session, 'Teachers will observed children playing games from afar', continued after the second session ended. As in the previous sessions, the data were stored in the game database. The results for the 20 children in the third session are shown in Table 4.16.

Table 4.16

Creativity game data from the third session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 3	2.474	Not Played	Not Played	Not Played	Low
Child 2	Sessions 3	12.895	10.702	22.642	11.486	Moderate
Child 3	Sessions 3	6.941	Not Played	Not Played	Not Played	Low
Child 4	Sessions 3	9.213	9.016	22.141	7.325	Good
Child 5	Sessions 3	1.001	1.017	6.660	1.375	Good
Child 6	Sessions 3	1.351	1.334	5.869	1.616	Good
Child 7	Sessions 3	0.962	1.815	7.213	4.239	Good
Child 8	Sessions 3	1.035	Not Played	Not Played	Not Played	Low
Child 9	Sessions 3	2.435	7.064	10.959	Not Played	Moderate
Child 10	Sessions 3	24.381	13.903	86.299	10.091	Moderate
Child 11	Sessions 3	2.738	8.674	Not Played	Not Played	Moderate
Child 12	Sessions 3	4.099	4.462	6.732	4.717	Good
Child 13	Sessions 3	05.08	2.502	Not Played	Not Played	Moderate
Child 14	Sessions 3	9.894	10.442	17.365	2.040	Good
Child 15	Sessions 3	11.903	12.079	15.073	7.694	Moderate
Child 16	Sessions 3	12.564	13.705	9.854	5.476	Good
Child 17	Sessions 3	11.454	13.712	19.665	12.512	Moderate
Child 18	Sessions 3	6.603	22.003	30.514	15.497	Moderate
Child 19	Sessions 3	11.529	8.944	16.564	10.448	Good
Child 20	Sessions 3	26.849	28.861	Not Played	Not Played	Low

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The data above show that 40% (8 out of 20 children) achieved 'Good' results, 40% (8 out of 20 children) achieved 'Moderate' results and 20% (4 out of 20 children) achieved 'Low' results. The absence of the teacher beside them but the teacher remaining visible from a distance, as in the first and second sessions, changed these results. However, the children were able to achieve "good" results in the first and second games despite not playing in the third and fourth games.

The fourth session continued after the third session ended with 'Children will play the game without any help from teachers'. The data was stored in the game database as in the previous sessions. Table 4.17 shows the results for 20 children in the fourth session.

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Table 4.17

Creativity game data from the fourth session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 4	4.323	11.399	11.041	Not Played	Moderate
Child 2	Sessions 4	9.799	11.013	Not Played	Not Played	Low
Child 3	Sessions 4	1.813	0.811	Not Played	Not Played	Moderate
Child 4	Sessions 4	6.222	40.537	Not Played	Not Played	Low
Child 5	Sessions 4	0.667	0,619	5.758	1.711	Good
Child 6	Sessions 4	7.444	Not Played	Not Played	Not Played	Low
Child 7	Sessions 4	6.684	11.22	19.325	6.686	Good
Child 8	Sessions 4	2.577	2.143	9.733	6.575	Good
Child 9	Sessions 4	1.712	0.985	6.547	11.18	Good
Child 10	Sessions 4	9.213	9.016	22.141	7.325	Good
Child 11	Sessions 4	1.391	0.907	7.911	2.425	Good
Child 12	Sessions 4	9.047	9.051	27.704	Not Played	Moderate
Child 13	Sessions 4	2.473	2.763	31.151	2.407	Good

(continue)

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Table 4.17 *(continue)*

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 14	Sessions 4	2.984	10.487	9.313	8.370	Good
Child 15	Sessions 4	2.809	13.431	10.697	9.185	Good
Child 16	Sessions 4	14.564	10.012	12.780	11.820	Moderate
Child 17	Sessions 4	15.839	12.919	21.141	Not Played	Low
Child 18	Sessions 4	18.605	24.591	22.46	17.597	Moderate
Child 19	Sessions 4	14.621	13.522	13.859	12.545	Moderate
Child 20	Sessions 4	12.711	11.133	Not Played	Not Played	Low

The data above shows that 45% (9 out of 20 children) achieved 'Good', 30% (6 out of 20 children) achieved 'Moderate' and 25% (5 out of 20 children) achieved 'Low'. This result is an increase in the 'Good' performance from the third session where there were 9 children who achieved this. This result is the best performance of all sessions where the children are able to play well in developing their creativity. This is because in this fourth session the children played alone, without teacher supervision and support, as in the first, second and third sessions. Although there were still some children who did not finish the game, in the first and second games they were able to finish in less than 10 seconds. These results have become a benchmark for the teachers in developing their creativity.

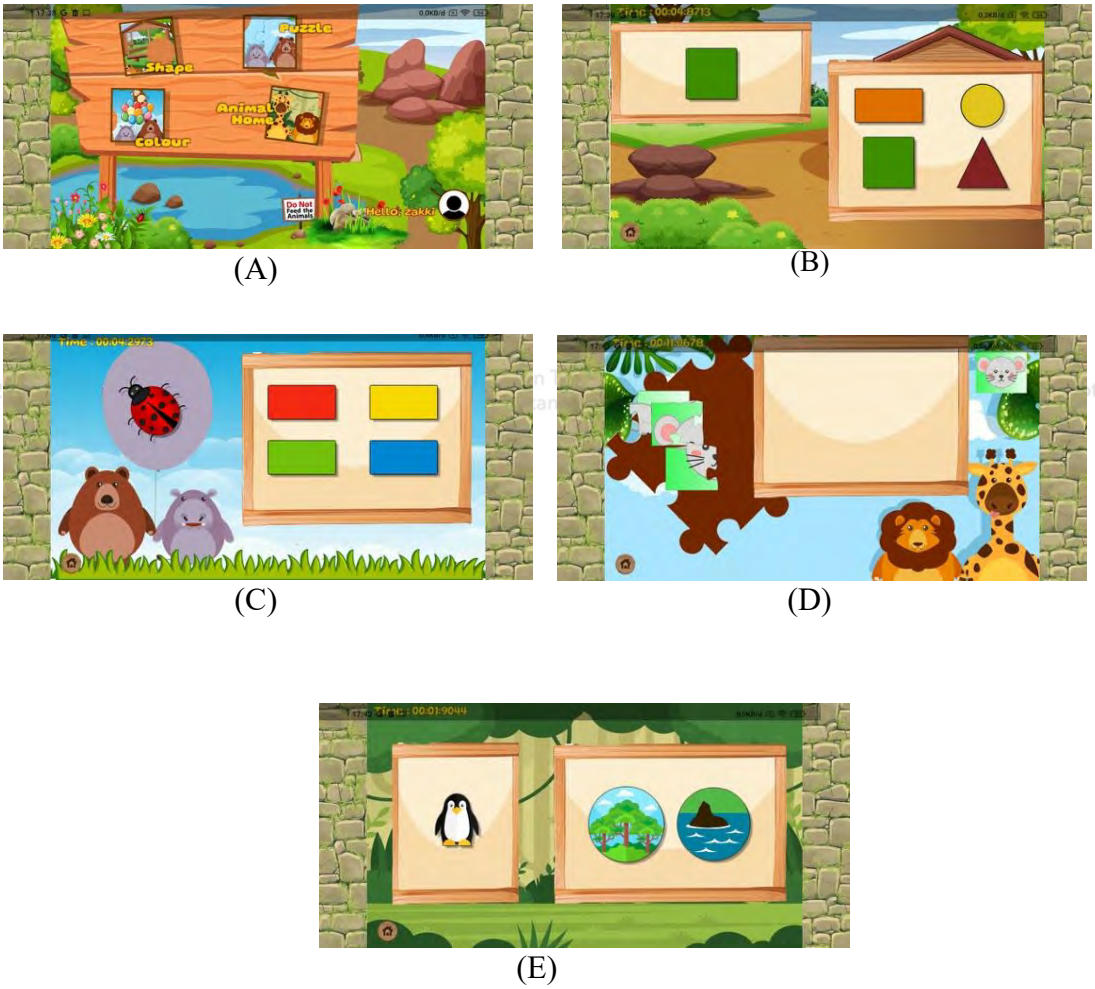
4.5.2 Measurement of game-based learning analytics model for logic development

Experiments are carried out in the same way as for measuring the development of creativity, in order to measure the development of children's logic. This experiment involved 20 children: 10 children from TASKA PERMATA, REFFLESIA and TULIP

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classes and 10 children from PAUD Manhajul Husna, PAUD A and PAUD B classes, aged between 3 and 4 years, and 2 teachers. The children who are working on their logic are different from the children who are working on their creativity. The steps in the logic development experiment are the same as the steps in the creativity experiment, namely by installing games on a smartphone. For the game shown in Figure 4.25, the game played to develop logic is a game specifically designed to develop logic, as explained in Section 4.3.



(A) (B)

(C) (D)

(E)

Figure 4.25. The stages of the logic game children will play

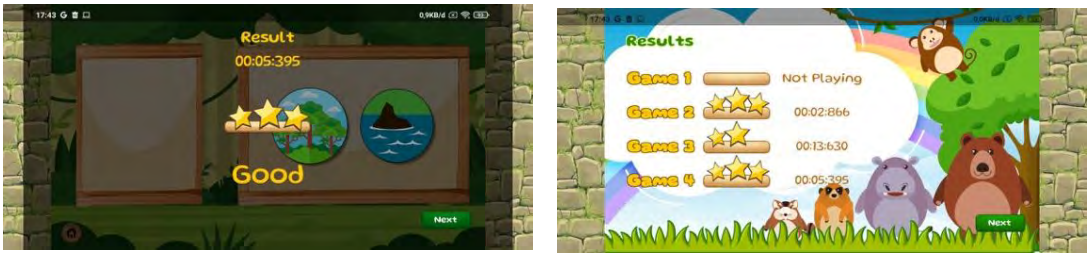
For the logic game, the children had to start from the beginning with a game consisting of 4 games, namely Shape, Colour, Puzzle and Animal Home, as shown in Figure A.

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Once the children understood all the games, they were ready to play the games in a given session. The first game was the Shape game. In this game, the similarity of the object picture with the target picture is selected, as shown in Figure B. After the first game was completed, the second game was the Colour game. In this game the child had to choose the colour of the object picture and match it, as shown in figure C. After completion of the second game, the third game is a puzzle game. The child must place the picture in the space provided on the right-hand side of the screen, as shown in Figure D. The fourth game is played when the third game has been completed. The fourth game is the Animal Home game. The child needs to select the animal's home on the object picture by swiping to the right, as shown in Figure E. When all the games have been completed, the score in each game will be displayed at the end of the game, as shown in Figure 4.26.

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(A) (B)

Figure 4.26. Logic game results (A) results for each game and (B) results for all games

The child can start the game again by pressing the 'Next' button at the bottom right. All scores from the game are stored in the game database and can be analysed in the same way as in the creativity game. As shown in Table 4.18 for the first session with a total of 20 children.

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Table 4.18

Logic game data from the first session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 1	2.878	3.218	13.645	8.526	Good
Child 2	Sessions 1	1.724	1.383	15.421	4.268	Good
Child 3	Sessions 1	1.582	1.492	16.438	2.258	Good
Child 4	Sessions 1	1.841	1.517	10.563	3.775	Good
Child 5	Sessions 1	1.542	1.124	15.439	2.809	Good
Child 6	Sessions 1	3.393	12.950	29.402	6.193	Moderate
Child 7	Sessions 1	1.565	1.699	31.176	5.684	Good
Child 8	Sessions 1	1.884	1.285	19.107	2.610	Good
Child 9	Sessions 1	2.282	1.208	17.679	2.042	Good
Child 10	Sessions 1	1.027	1.316	12.846	2.533	Good
Child 11	Sessions 1	2.648	2.296	19.030	4.476	Good
Child 12	Sessions 1	2.448	2.422	27.611	3.249	Good
Child 13	Sessions 1	12.732	14.113	45.716	12.293	Moderate
Child 14	Sessions 1	10.748	3.729	30.291	5.022	Good
Child 15	Sessions 1	8.786	3.975	51.737	12.836	Moderate
Child 16	Sessions 1	11.601	9.462	60.347	11.425	Moderate
Child 17	Sessions 1	3.199	5.679	Not Played	Not Played	Moderate
Child 18	Sessions 1	3.642	3.066	19.26	4.777	Good
Child 19	Sessions 1	3.483	2.949	31.499	5.237	Good
Child 20	Sessions 1	5.654	9.221	Not Played	Not Played	Moderate

The data above shows that for the achievement results in the first session with 'Teacher teach the game to the children', 70% of the children achieved 70% (14 out of 20 children) achieved 'Good' results, 30% (6 out of 20 children) achieved 'Moderate' results. Even though 2 children did not complete the third and fourth games, they

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completed the game in less than 10 seconds in the first and second games with a "good" score.

The second session, 'Teachers accompanied children while playing the games', continued after the end of the first session. As in the previous session, data were stored in the game database, see Table 4.19 for the 20 children's second session results.

Table 4.19

Logic game data from the second session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 2	1.384	1.334	13.084	4.218	Good
Child 2	Sessions 2	1.593	3.076	13.715	4.535	Good
Child 3	Sessions 2	1.317	1.534	16.806	2.700	Good
Child 4	Sessions 2	2.950	3.536	31.235	4.775	Moderate
Child 5	Sessions 2	1.815	0.975	Not Played	Not Played	Moderate
Child 6	Sessions 2	4.608	2.567	10.795	6.161	Good
Child 7	Sessions 2	1.699	1.558	32.251	3.518	Good
Child 8	Sessions 2	2.391	1.901	20.669	3.286	Good
Child 9	Sessions 2	1.284	1.150	15.722	1.941	Good
Child 10	Sessions 2	1.384	1.458	18.578	3.009	Good
Child 11	Sessions 2	Not Played	Not Played	Not Played	5.611	Low
Child 12	Sessions 2	1.863	2.415	18.036	3.566	Good
Child 13	Sessions 2	Not Played	Not Played	33.014	8.597	Low
Child 14	Sessions 2	2.363	1.890	29.514	2.625	Good
Child 15	Sessions 2	2.410	1.780	78.340	6.568	Good
Child 16	Sessions 2	6.348	4.777	44.451	10.166	Moderate
Child 17	Sessions 2	Not Played	1.470	35.657	8.380	Moderate
Child 18	Sessions 2	1.721	1.520	13.547	3.373	Good
Child 19	Sessions 2	1.755	2.510	23.907	3.758	Good
Child 20	Sessions 2	Not Played	Not Played	41.813	4.184	Low

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The data results above show that 65% (13 out of 20 children) achieved 'Good', 20% (4 out of 20 children) achieved 'Moderate' and 15% (3 out of 20 children) achieved 'Low'. In this second session many games were not played by some children. For example, the third and fourth games were not played by child 5. Child 11 missed games one, two and three. Child 13 did not play the first and second games. Child 17 did not play the first game and child 20 did not play the first and second games. However, all these children were able to complete the game with 'Good'. The third game took more than 10 seconds to complete.

The third session, 'Teachers will observe children playing games from afar', continued after the second session ended. Results were stored in a game database as in each previous session. The results for the 20 children in the third session are shown in Table 4.20.

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Table 4.20

Logic game data from the third session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 3	1.441	1.468	16.315	8.095	Good
Child 2	Sessions 3	1.842	1.869	17.296	4.210	Good
Child 3	Sessions 3	1.292	1.541	15.189	4.104	Good
Child 4	Sessions 3	1.184	3.702	15.481	9.361	Good
Child 5	Sessions 3	Not Played	Not Played	14.170	3.560	Low
Child 6	Sessions 3	3.935	3.506	17.873	6.493	Good
Child 7	Sessions 3	1.390	2.208	21.398	3.751	Good
Child 8	Sessions 3	2.134	1.351	17.872	2.277	Good
Child 9	Sessions 3	Not Played	Not Played	19.190	4.476	Low
Child 10	Sessions 3	2.944	2.250	15.923	3.451	Good

(continue)

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Table 4.20 *(continue)*

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 11	Sessions 3	1.671	3.291	15.844	4.426	Good
Child 12	Sessions 3	1.738	6.727	19.084	3.757	Good
Child 13	Sessions 3	Not Played	Not Played	Not Played	6.993	Low
Child 14	Sessions 3	1.612	2.159	26.61	3.190	Good
Child 15	Sessions 3	2.322	1.896	55.621	6.588	Good
Child 16	Sessions 3	5.642	3.937	32.717	10.493	Moderate
Child 17	Sessions 3	1.813	0.811	Not Played	Not Played	Moderate
Child 18	Sessions 3	Not Played	1.596	15.786	5.327	Moderate
Child 19	Sessions 3	1.846	1.345	24.534	3.549	Good
Child 20	Sessions 3	2.739	3.676	34.191	5.545	Good

The data results above show that 70% (14 out of 20 children) achieved 'Good' results, 15% (3 out of 20 children) achieved 'Moderate' results and 15% (3 out of 20 children) achieved 'Low' results. There were some games that the children did not play in this third session. However, they were able to complete each game with a 'Good'. The time they took to complete each game was around 10 seconds. The fourth session continued after the third session ended with: 'Children will play the game without any help from teachers'. The data was stored in the game database as in the previous sessions. Table 4.21 shows the results for 20 children in the fourth session.

Table 4.21

Logic game data from the fourth session

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 1	Sessions 4	8.770	2.852	13.455	5.233	Good
Child 2	Sessions 4	1.492	1.383	12.073	3.417	Good
Child 3	Sessions 4	1.792	2.218	17.423	3.350	Good

(continue)

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Table 4.21 *(continue)*

UserName	Date	Time (Milliseconds)				Result
		Game 1	Game 2	Game 3	Game 4	
Child 4	Sessions 4	2.792	6.551	10.462	6.553	Good
Child 5	Sessions 4	2.400	1.866	11.337	1.425	Good
Child 6	Sessions 4	9.261	11.871	30.858	18.504	Moderate
Child 7	Sessions 4	2.626	1.990	33.547	5.735	Moderate
Child 8	Sessions 4	5.842	5.319	19.391	8.177	Good
Child 9	Sessions 4	0.926	1.366	13.472	1.933	Good
Child 10	Sessions 4	1.890	1.848	29.426	25.928	Moderate
Child 11	Sessions 4	1.695	1.787	16.871	3.570	Good
Child 12	Sessions 4	2.440	1.454	18.885	3.241	Good
Child 13	Sessions 4	14.609	5.659	24.384	10.428	Moderate
Child 14	Sessions 4	2.838	1.275	29.121	2.429	Good
Child 15	Sessions 4	Not Played	Not Played	Not Played	6.919	Low
Child 16	Sessions 4	3.090	5.647	32.007	9.327	Good
Child 17	Sessions 4	Not Played	Not Played	38.572	5.671	Low
Child 19	Sessions 4	1.712	1.311	20.512	2.797	Good
Child 20	Sessions 4	2.180	1.963	17.774	4.268	Good

The data results above show that 74% (14 out of 19 children) achieved 'Good' results, 21% (4 out of 19 children) achieved 'Moderate' results and 11% (2 out of 19 children) achieved 'Low' results. In this fourth session only, a few children did not play the games, one child did not play the first, second, third and fourth games, namely child 18. However, as in the first and second sessions, the child scored 'Good' in the previous session. This is an excellent achievement in the child's logical development, given that the third and fourth sessions were entirely self-generated.

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4.6 Classification and prediction of learning achievements in the areas of creative and logic through data modelling

In this stage, a classification model is defined to apply machine learning algorithms to classify or predict the educational data obtained from the LAP process in developing creativity and logic, applied to children aged 3-4. Classification of children's level of progress in a development on the basis of tests that have been carried out. This has been done by Xing Wali (2015) in his research in a learning analytics approach, educational data mining, to explore the development of more predictive models for collaborative problem solving in geometry with the Virtual Math Team with Geogebra (VMTwG) (Xing et al., 2015b). Supervised learning is used as a machine learning technique to perform model classification using data from the development of creativity and logic, where the data has been labelled for the association process between the input data and the output data. As shown in Figure 4.28 Supervised Learning Workflow.

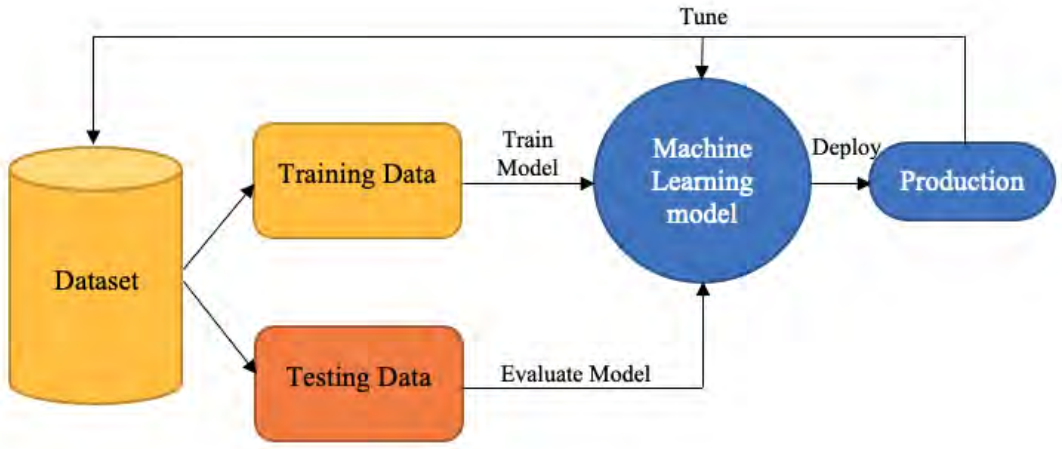


Figure 4.27. Supervised learning workflow (Mahesh Batta, 2020)

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In the modelling stage, two types of datasets are needed from the pre-processed data, namely training data and testing data. Training data is the dataset used to build the model in machine learning, while testing data is used to calculate the performance value of the model formed by comparing the actual data label and the data label from the model classification. To form training data and testing data, as explained in chapter 3 section 3.4.2.3 The division of datasets uses the deterministic / holdout method popularized by Barber and Lyon in 1997, namely by determining the division ratio of the two datasets themselves (Barber & Lyon, 1997). The machine learning models used for classification in this research include Naïve Bayes (NB), Multilayer Perceptron (MLP) and Decision Tree (C4.5).

Each algorithm has its advantages and disadvantages. Naive Bayes classification has been shown to be very accurate and fast when applied to large databases. It has an accuracy of over 80% for breast cancer data (Saritas & Yasar, 2019). The Multilayer Perceptron has a relatively low mean squared error (MSE) value in the classification performance of the breast thermogram (Jeyanathan, 2018). On the other hand, according to Raheela Asif and friends (2017), in their research, the decision tree provides good performance results in grouping the academic performance of students with an accuracy of almost 70 % (Asif et al., 2017). In addition, the Decision Tree is the most accurate classification algorithm with different types of datasets (Charbuty & Abdulazeez, 2021). Classification performance is a production output in the context of machine learning. It refers to the ability of the model to make accurate and precise predictions based on the given data. Classification performance evaluation is important to assess how well the model can classify previously unseen data. Accuracy, precision and recall are the metrics used to evaluate classification performance. The classification

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modelling process is performed using the RapidMiner software, as described in Chapter 3, Section 3.4.2.3.

4.6.1 Data and modelling classification

4.6.1.1 Dataset

The data used in this study consisted of the results of Creative-Game and Logic-Game of 20 children from NCDRC, UPSI, Malaysia and 20 children from Manhajul Husna Preschool, Banjarmasin, Indonesia. This study used data from two games, creative and logic, with 4 sessions conducted with the children as described in Chapter 3 Section 3.6.4 Play sessions. The data set consists of variables related to the children's creativity and logic development scores, as shown in Table 4.22. UserName is the name of the child playing the game, Category is the type of developmental material in the game, namely creativity and logic, Session is the stages that the child performs while playing the game, Game 1 is the score obtained from the first game in both creativity and logic development, Game 2 is the score obtained from the second game in both creativity and logic development, Game 3 is the score obtained from the third game in both creative and logical development, Game 4 is the score obtained from the fourth game in both creative and logical development, and Result is the score of the child's performance in the game in both creative and logical development.

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Table 4.22

Variable of the dataset

Variable	Description
UserName	Name
Category	Creativity, Logic
Sessions	Sessions 1, Sessions 2, Sessions 3, Sessions 4
Game 1	Score
Game 2	Score
Game 3	Score
Game 4	Score
Result	Good, Moderate, Low

Table 4.23 shows the datasets generated from the creativity development games. Data were collected from 10 children from Taska PERMATA, NCDRC, UPSI, Malaysia and 10 children from PAUD Manhajul Husna, Banjarmasin, Indonesia, while the data sets generated from the games for logic development are shown in Table 4.24. Data were also collected from 10 children from Taska PERMATA, NCDRC, UPSI, Malaysia and 10 children from PAUD Manhajul Husna, Banjarmasin, Indonesia.

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Table 4.23

Dataset from creativity development games

UserName	Category	Sessions	Game 1	Game 2	Game 3	Game 4	Result
Child 1	Creativity	Sessions 1	3	3	3	3	Good
Child 2	Creativity	Sessions 1	3	3	3	3	Good
Child 3	Creativity	Sessions 1	3	3	2	1	Moderate
Child 4	Creativity	Sessions 1	3	1	2	1	Moderate
Child 5	Creativity	Sessions 1	3	3	3	3	Good
Child 6	Creativity	Sessions 1	3	3	2	3	Good
Child 7	Creativity	Sessions 1	3	3	3	3	Good
Child 8	Creativity	Sessions 1	3	3	3	1	Good
Child 9	Creativity	Sessions 1	3	3	3	3	Good
Child 10	Creativity	Sessions 1	3	3	3	3	Good

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Table 4.23 *(continue)*

UserName	Category	Sessions	Game 1	Game 2	Game 3	Game 4	Result
Child 11	Creativity	Sessions 1	2	3	1	3	Moderate
Child 12	Creativity	Sessions 1	3	3	1	1	Moderate
Child 13	Creativity	Sessions 1	3	3	2	3	Good
Child 14	Creativity	Sessions 1	3	3	2	2	Good
Child 15	Creativity	Sessions 1	3	3	3	3	Good
Child 16	Creativity	Sessions 1	3	3	3	3	Good
Child 17	Creativity	Sessions 1	3	2	1	1	Moderate
Child 18	Creativity	Sessions 1	3	3	2	3	Good
Child 19	Creativity	Sessions 1	3	3	2	3	Good
Child 20	Creativity	Sessions 1	2	3	2	2	Moderate
Child 1	Creativity	Sessions 2	3	Not Played	Not Played	Not Played	Low
Child 2	Creativity	Sessions 2	2	3	3	2	Good
Child 3	Creativity	Sessions 2	3	Not Played	Not Played	Not Played	Low
Child 4	Creativity	Sessions 2	3	3	1	3	Good
Child 5	Creativity	Sessions 2	3	3	3	3	Good
Child 6	Creativity	Sessions 2	3	3	3	3	Good
Child 7	Creativity	Sessions 2	3	3	3	3	Good
Child 8	Creativity	Sessions 2	3	3	2	3	Good
Child 9	Creativity	Sessions 2	3	1	3	3	Good
Child 10	Creativity	Sessions 2	3	3	1	1	Moderate
Child 11	Creativity	Sessions 2	3	3	3	3	Good
Child 12	Creativity	Sessions 2	3	3	2	3	Good
Child 13	Creativity	Sessions 2	3	3	Not Played	Not Played	Moderate
Child 14	Creativity	Sessions 2	3	3	Not Played	Not Played	Moderate
Child 15	Creativity	Sessions 2	3	3	3	3	Good
Child 16	Creativity	Sessions 2	3	3	2	3	Good
Child 17	Creativity	Sessions 2	2	2	1	2	Moderate
Child 18	Creativity	Sessions 2	3	2	1	3	Moderate
Child 19	Creativity	Sessions 2	3	3	2	3	Good
Child 20	Creativity	Sessions 2	2	2	1	2	Moderate
Child 1	Creativity	Sessions 3	3	Not Played	Not Played	Not Played	Low

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Table 4. 23 *(continue)*

UserName	Category	Sessions	Game 1	Game 2	Game 3	Game 4	Result
Child 2	Creativity	Sessions 3	2	3	1	2	Moderate
Child 3	Creativity	Sessions 3	3	Not Played	Not Played	Not Played	Low
Child 4	Creativity	Sessions 3	3	3	1	3	Good
…	…	…	…	…	…	…	…
Child 20	Creativity	Sessions 4	2	2	Not Played	Not Played	Low

Table 4. 24

Dataset form logic development games

UserName	Category	Sessions	Game 1	Game 2	Game 3	Game 4	Result
Child 1	Logic	Sessions 1	3	3	2	3	Good
Child 2	Logic	Sessions 1	3	3	2	3	Good
Child 3	Logic	Sessions 1	3	3	2	3	Good
Child 4	Logic	Sessions 1	3	3	2	3	Good
Child 5	Logic	Sessions 1	3	3	2	3	Good
Child 6	Logic	Sessions 1	3	2	1	3	Moderate
Child 7	Logic	Sessions 1	3	3	1	3	Good
Child 8	Logic	Sessions 1	3	3	2	3	Good
Child 9	Logic	Sessions 1	3	3	2	3	Good
Child 10	Logic	Sessions 1	3	3	2	3	Good
Child 11	Logic	Sessions 1	3	3	2	3	Good
Child 12	Logic	Sessions 1	3	3	1	3	Good
Child 13	Logic	Sessions 1	2	2	1	2	Moderate
Child 14	Logic	Sessions 1	3	3	1	3	Good
Child 15	Logic	Sessions 1	3	3	1	2	Moderate
Child 16	Logic	Sessions 1	2	3	1	2	Moderate
Child 17	Logic	Sessions 1	3	3	Not Played	Not Played	Moderate
Child 18	Logic	Sessions 1	3	3	2	3	Good

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Table 4.24 *(continue)*

UserName	Category	Sessions	Game 1	Game 2	Game 3	Game 4	Result
Child 19	Logic	Sessions 1	3	3	1	3	Good
Child 20	Logic	Sessions 1	3	3	Not Played	Not Played	Moderate
Child 1	Logic	Sessions 2	3	3	2	3	Good
Child 2	Logic	Sessions 2	3	3	2	3	Good
Child 3	Logic	Sessions 2	3	3	2	3	Good
Child 4	Logic	Sessions 2	3	3	1	3	Moderate
Child 5	Logic	Sessions 2	3	3	Not Played	Not Played	Moderate
Child 6	Logic	Sessions 2	3	3	2	3	Good
Child 7	Logic	Sessions 2	3	3	1	3	Good
Child 8	Logic	Sessions 2	3	3	1	3	Good
Child 9	Logic	Sessions 2	3	3	2	3	Good
Child 10	Logic	Sessions 2	3	3	2	3	Good
Child 11	Logic	Sessions 2	Not Played	Not Played	Not Played	3	Low
Child 12	Logic	Sessions 2	3	3	2	3	Good
Child 13	Logic	Sessions 2	Not Played	Not Played	1	3	Low
Child 14	Logic	Sessions 2	3	3	1	3	Good
Child 15	Logic	Sessions 2	3	3	1	3	Good
Child 16	Logic	Sessions 2	3	3	1	3	Moderate
Child 17	Logic	Sessions 2	Not Played	3	1	3	Moderate
Child 18	Logic	Sessions 2	3	3	2	3	Good
Child 19	Logic	Sessions 2	3	3	1	3	Good
Child 20	Logic	Sessions 2	Not Played	Not Played	1	3	Low
Child 1	Logic	Sessions 3	3	3	2	3	Good
Child 2	Logic	Sessions 3	3	3	2	3	Good
Child 3	Logic	Sessions 3	3	3	2	3	Good
Child 4	Logic	Sessions 3	3	3	2	3	Good
…	…	…	…	…	…	…	…
Child 20	Logic	Sessions 4	3	3	2	3	Good

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4.6.1.2 Training and Testing Data

In this research, the supervised learning model is applied as one of the machine learning paradigms to be modelled. The machine learning task is to learn a function that maps inputs to outputs based on examples of input-output pairs. Supervised machine learning algorithms are algorithms that require external assistance to infer a function from labelled training data consisting of a set of training examples. The input data is divided into training and testing data. The training dataset has output variables that need to be classified in the machine learning model. In this research, the Naive Bayes, Decision Tree and Multilayer Perceptron algorithms are compared to learn from new data, namely 3-4 year old children's creativity and logic development data. The aim is to obtain the performance of classification models that use multiple approaches to find solutions to problems with limited datasets.

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Once the dataset has been acquired, data pre-processing must take place, cleaning or preparing the raw data into a format better suited for the classification process. As shown in Table 4.25 and Figure 4.28, the dataset used in this study has 159 records, 6 regular attributes and 2 special attributes. Where the UserName variable is the Id attribute, the Category variable is the regular attribute, the Sessions variable is the regular attribute, the Game 1 variable is the regular attribute, the Game 2 variable is the regular attribute, the Game 3 variable is the regular attribute, the Game 4 variable is the regular attribute, and the Result variable is the label. There are also no missing data in the data statistics

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Table 4.25

Pre-processing the childhood creative and logic development dataset

Attributes	Variable	Description	Type
Id	UserName	Name	Polynominal
Regular	Category	Creativity, Logic	Polynominal
Regular	Sessions	Sessions 1, Sessions 2, Sessions 3, Sessions 4	Polynominal
Regular	Game 1	Score	Integer
Regular	Game 2	Score	Integer
Regular	Game 3	Score	Integer
Regular	Game 4	Score	Integer
Label	Result	Good, Moderate, Low	Polynominal

Row No.	UserName	Result	Category	Sessions	Game 1	Game 2	Game 3	Game 4
1	Child 1	Good	Creativity	Sessions 1	3	3	3	3
2	Child 2	Good	Creativity	Sessions 1	3	3	3	3
3	Child 3	Moderate	Creativity	Sessions 1	3	3	2	1
4	Child 4	Moderate	Creativity	Sessions 1	3	1	2	1
5	Child 5	Good	Creativity	Sessions 1	3	3	3	3
6	Child 6	Good	Creativity	Sessions 1	3	3	2	3
7	Child 7	Good	Creativity	Sessions 1	3	3	3	3
8	Child 8	Good	Creativity	Sessions 1	3	3	3	1
9	Child 9	Good	Creativity	Sessions 1	3	3	3	3
10	Child 10	Good	Creativity	Sessions 1	3	3	3	3
11	Child 11	Moderate	Creativity	Sessions 1	2	3	1	3
12	Child 12	Moderate	Creativity	Sessions 1	3	3	1	1
13	Child 13	Good	Creativity	Sessions 1	3	3	2	3
14	Child 14	Good	Creativity	Sessions 1	3	3	2	2
15	Child 15	Good	Creativity	Sessions 1	3	3	3	3
16	Child 16	Good	Creativity	Sessions 1	3	3	3	3

ExampleSet (159 examples, 2 special attributes, 6 regular attributes)

Figure 4.28. Pre-processing dataset on RapidMiner

After the data pre-processing is completed, the division of datasets, namely training and testing, is carried out using the deterministic / holdout method by

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determining the ratio of training data and testing data. In this study, the data ratio is set at 70:30, which is 70 percent for training data and 30 percent for testing data. This was also done by (Vrigazova, 2021) in his research determining the split of the ratio of training data and testing data to perform classification models, it was found that the split of the 70:30 ratio was the best ratio based on the accuracy results of the existing academic literature by expanding ways to speed up fitting and making predictions with logistic regression and decision tree classifiers. In this study, the split data was used in RapidMiner as a split ratio with values of 0.7 and 0.3, as shown in Figure 4.29.

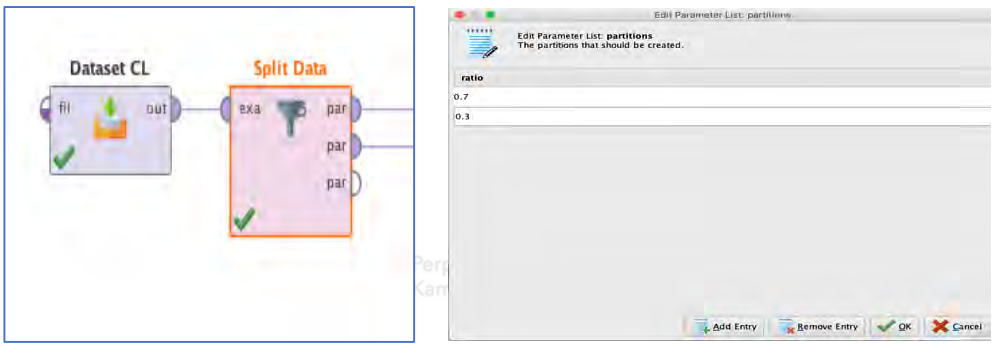


Figure 4.29. Splitting ratio training and testing dataset

4.6.1.3 Modelling Classification

At this stage, the classification algorithm is tested on the dataset described in the previous section. The algorithms used in this research are Naive Bayes, Multilayer Perceptron and Decision Tree. In this section, each sub-section will be explained. Sub-subsection 4.6.1.3.1 is a sub-section that explains the modelling process using the Naive Bayes algorithm. The modelling process using the Multilayer Perceptron (MLP) algorithm is explained in Sub-subsection 4.6.1.3.2. Finally, the modelling process using the decision tree algorithm is explained in Sub-subsection 4.6.1.3.3.

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4.6.1.3.1 Naïve Bayes Algorithm

The data evaluation process uses the Naïve Bayes classification algorithm to classify data generated by the Learning Analytics Platform (LAP) for the creative and logical development of children aged 3-4 years, as described in Chapter 3, Section 3.4.2.4. As explained earlier, this research uses a dataset of 159 records. The dataset is processed using the Naïve Bayes algorithm, in which learning is more focused on estimating probabilities by requiring data that is labelled as information. It is known that the data is in the form of labels, with the results categorised into two parts, namely creative and logical. For the creative category, the 'good' value is 43, the 'moderate' value is 26 and the 'low' value is 11. For the logical category, the 'good' value is 54, the 'moderate' value is 17 and the 'low' value is 8. As shown in Table 4.26

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Table 4.26

Calculating probability prior using LAP result development creativity and logic dataset

	Classification			Probability Prior (Percentage)		
	Creative	**Logic**	**Overall**	**Creative**	**Logic**	**Overall**
Good	43	54	97	53,75	68,35	61,01
Moderate	26	17	43	32,50	21,52	27,04
Low	11	8	19	13,75	10,13	11,95
All Data	80	79	159	100	100	100

From the table above, we know that there is no significant difference in the distribution of classes in the dataset. This means that each creative development or logical development has a chance to reach the maximum value in the creative and logical development of children at the age of 3-4 years.

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The next step is to calculate the conditional posterior probability of X (P(X|Good), (P(X|Moderate) and (P(X|Low). The posterior probability calculations are performed on the same set of data. The tests are performed on 6 indicators, namely 1) Category, 2) Sessions, 3) Game 1, 4) Game 2, 5) Game 3 and 6) Game 4. Table 4.27 shows the description of each calculation result.

Table 4.27

Conditional probability posterior

Attribute	Parameter	Values	Classification			Probability Posterior		
			P (Good)	P (Moderate)	P (Low)	P (Good)	P (Moderate)	P (Low)
Category	Creativity	80	43	26	11	0,4433	0,6047	0,5789
	Logic	79	54	17	8	0,5567	0,3953	0,4211
Sessions	Sessions 1	40	28	12	-	0,2887	0,2791	0,0000
	Sessions 2	40	25	10	5	0,2577	0,2326	0,2632
	Sessions 3	40	22	11	7	0,2268	0,2558	0,3684
	Sessions 4	39	22	10	7	0,2268	0,2326	0,3684
Game 1	Not Played	10	-	2	8	0,0000	0,0465	0,4211
	3	129	94	27	8	0,9691	0,6279	0,4211
	2	18	3	13	2	0,0309	0,3023	0,1053
	1	2	-	1	1	0,0000	0,0233	0,0526
Game 2	Not Played	14	-	-	14	0,0000	0,0000	0,7368
	3	121	93	28	-	0,9588	0,6512	0,0000
	2	18	3	12	3	0,0309	0,2791	0,1579
	1	6	1	3	2	0,0103	0,0698	0,1053
Game 3	Not Played	22	-	9	13	0,0000	0,2093	0,6842
	3	27	27	-	-	0,2784	0,0000	0,0000
	2	61	49	10	2	0,5052	0,2326	0,1053
	1	49	21	24	4	0,2165	0,5581	0,2105
Game 4	Not Played	23	-	12	11	0,0000	0,2791	0,5789
	3	113	93	12	8	0,9588	0,2791	0,4211
	2	16	3	13	-	0,0309	0,3023	0,0000
	1	7	1	6	-	0,0103	0,1395	0,0000

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Based on the information in the table above, there is variation in the posterior predictions, suggesting that the predictions of creative and logical development are significantly different for each child. In addition, there is an interesting attribute where Sessions has a session parameter of 3, which is considered to be a highly productive indicator. As for the games that the children choose, the attribute Game 1 has a parameter value of 3, and this is prioritised in the naive bayes model.

In the next step, calculations are performed with software that is intended to determine the test results obtained with the probability data already available. The tests in this study use the RapidMiner software explained in the previous chapter, with the distribution of the data ratio described in the previous section, namely 70:30. This is done to determine the classification performed by Naïve Bayes and 3 important things, namely accuracy, precision and recall. These three things are considered as important as the value of the test accuracy measure, as shown in Figure 4.30.

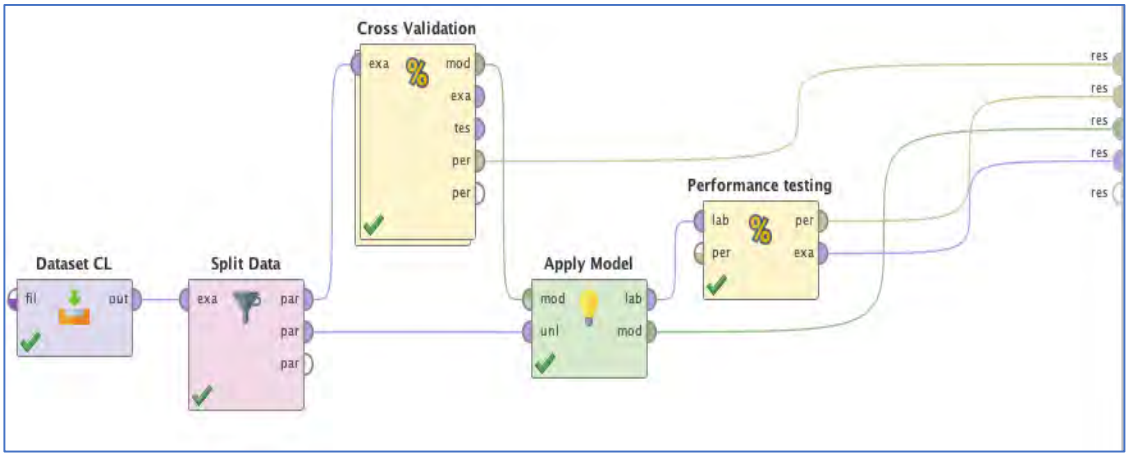


Figure 4.30. Classification model of the Naive Bayes algorithm in RapidMiner

As described in the figure above is the main naive bayes model in RapidMiner for further design that has been done can be used to create and manage the process of analyzing the classification of creative and logical development in children. In

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accordance with the training and testing data, the division is carried out using an operator, namely split data in RapidMiner. Cross-validation techniques are used in classification models to evaluate model performance by dividing data into overlapping subsets for training and testing, this is done to measure how well the model can generalize to new data that has never been seen before (Schaffer, 1993). In this study, the model provided accurate predictions for the training data by using three loops to divide the data into k-folds of equal size. This is also explained by (Zhang & Yang, 2015) the benefits of cross-validation provide a more consistent estimate of model performance by using multiple tests, as well as minimizing evaluation bias and maximizing the use of limited datasets. The naive Bayes algorithm model is then used in the cross-validation. See picture 4.31.

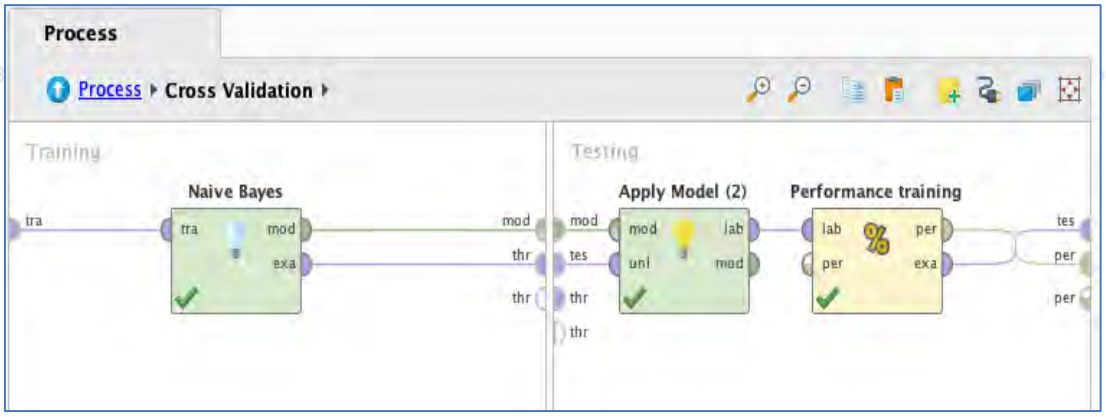


Figure 4.31. Naive bayes model in RapidMiner

In this study, the performance of training and testing data entered into RapidMiner is determined using two tools. Then the results of the classification performance are known in the form of the accuracy values on the training data and the test data. As described in Figure 4.32. The experiments carried out in this study show that k-fold cross-validation gives the best results in terms of performance, by trying every type of sample that cross-validation has to offer.

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Figure 4.32. Accuracy performance of training and testing data based on sampling type

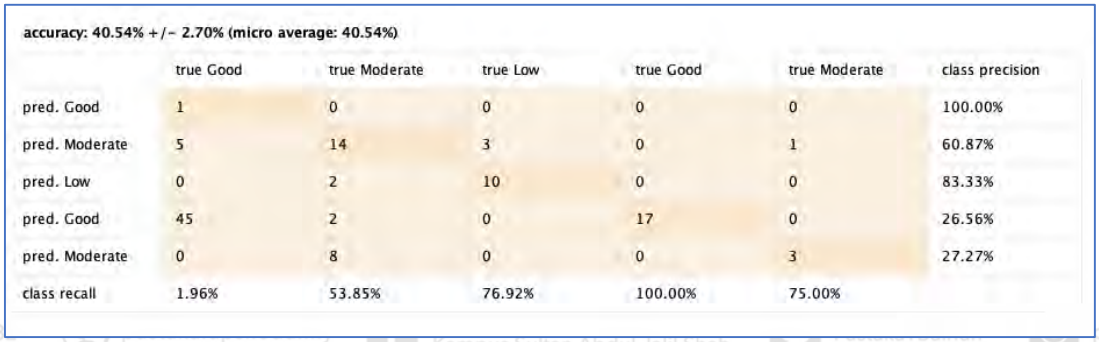
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The accuracy performance of training and testing data is based on the type of sampling performed on the classification model, where the sampling method in the cross-validation model has 4 models, namely 1) linear sampling, 2) shuffled sampling, 3) stratified sampling and 4) random sampling (automatic). A performance value of each data was found by comparing the accuracy value in each sampling type to get the best model in the process of classification data on creative and logical development in children. In the linear sampling type for the training data the accuracy value is 42.34% and for the testing data the accuracy value is 41.67%. The accuracy value of the training data is greater than the accuracy value of the test data, this leads to overfitting of the data where there is too much data when training, so the model does not classification the data correctly because there is too much detail and noise. The shuffled sample type for the training data accuracy value is 38.74% and the testing data accuracy value is 41.67%, this makes the data categorized in the form of good data because the testing

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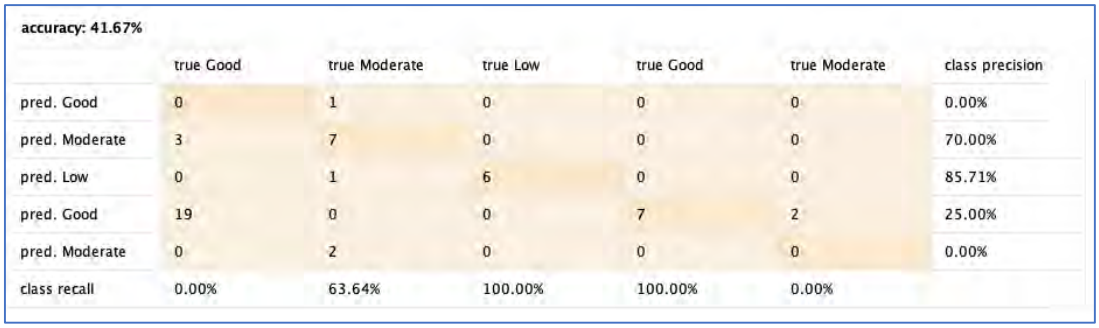
data is greater than the training data. Whereas for the stratified and random sample type, the accuracy value of the training data is 40.54% and the accuracy value of the testing data is 41.67%. This makes the stratified and random sampling type provide a very good accuracy value than other sampling types, so this sampling type is used in population statistics or the dataset is divided into subsets called strata. Each stratum contains a group of units with similar characteristics. The accuracy output is shown in Figures 4.33 and 4.34.



accuracy: 40.54% +/- 2.70% (micro average: 40.54%)

	true Good	true Moderate	true Low	true Good	true Moderate	class precision
pred. Good	1	0	0	0	0	100.00%
pred. Moderate	5	14	3	0	1	60.87%
pred. Low	0	2	10	0	0	83.33%
pred. Good	45	2	0	17	0	26.56%
pred. Moderate	0	8	0	0	3	27.27%
class recall	1.96%	53.85%	76.92%	100.00%	75.00%	

Figure 4.33. Accuracy training data naive bayes model



accuracy: 41.67%

	true Good	true Moderate	true Low	true Good	true Moderate	class precision
pred. Good	0	1	0	0	0	0.00%
pred. Moderate	3	7	0	0	0	70.00%
pred. Low	0	1	6	0	0	85.71%
pred. Good	19	0	0	7	2	25.00%
pred. Moderate	0	2	0	0	0	0.00%
class recall	0.00%	63.64%	100.00%	100.00%	0.00%	

Figure 4.34. Accuracy testing data naive bayes model

The above figure shows the results for the confusion matrix training data and testing data. On the predicted and correct good class are 1, predicted moderate turns out to be the correct good class is 5, predicted low turns out to be the correct good class is 0, predicted good turns out to be the correct good class is 45, and predicted moderate turns

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out to be the correct moderate class is 0. For the predicted correct moderate class good is 0, predicted and correct for the correct moderate class is 14, predicted low turns out to be the correct moderate class is 2, predicted good turns out to be the correct moderate class is 2, predicted moderate turns out to be the correct moderate class is 8. For the predicted correct low class good is 0, predicted moderate turns out the correct low class is 0, predicted and correct for the correct low class is 10, predicted good and moderate turns out the correct low class is 0. For the predicted correct good class good is 0, predicted moderate and low turns out the correct good class is 0, predicted and correct for the correct good class is 7, predicted moderate turns out the correct good class is 0. For the predicted correct moderate class good is 0, predicted moderate turns out to be the correct moderate class is 0, predicted low turns out to be the correct moderate class is 0, predicted good turns out to be the correct moderate class is 2, and predicted and correct for the moderate class is 0.

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The results of the classification of the testing data with the Naive Bayes algorithm using RapidMiner show that the class decision for 'Good' is 0.459, the class for 'Moderate' is 0.234 and the class for 'Low' is 0.117. While the next class for 'Good' is 0.153 and the class for 'Moderate' is 0.036. The classification results of the testing data are shown in Figure 4.35.

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R...	UserNa...	Result	prediction(...	confi...	confid...	confid...	confi...	confide...	Category	Sessions	Game 1	Game 2	Game 3	Game 4
1	Child 1	Good	Good	0.001	0.000	0.000	0.999	0.000	Creativity	Sessions 1	3	3	3	3
2	Child 6	Good	Good	0.000	0.000	0.000	1.000	0.000	Creativity	Sessions 1	3	3	2	3
3	Child 8	Good	Moderate	0	1.000	0.000	0	0.000	Creativity	Sessions 1	3	3	3	1
4	Child 10	Good	Good	0.001	0.000	0.000	0.999	0.000	Creativity	Sessions 1	3	3	3	3
5	Child 15	Good	Good	0.001	0.000	0.000	0.999	0.000	Creativity	Sessions 1	3	3	3	3
6	Child 19	Good	Good	0.000	0.000	0.000	1.000	0.000	Creativity	Sessions 1	3	3	2	3
7	Child 4	Good	Good	0.000	0.000	0.000	1.000	0.000	Creativity	Sessions 2	3	3	1	3
8	Child 11	Good	Good	0.001	0.000	0.000	0.999	0.000	Creativity	Sessions 2	3	3	3	3
9	Child 12	Good	Good	0.000	0.000	0.000	1.000	0.000	Creativity	Sessions 2	3	3	2	3
10	Child 16	Good	Good	0.000	0.000	0.000	1.000	0.000	Creativity	Sessions 2	3	3	2	3
11	Child 18	Moderate	Good	0.547	0.222	0.009	0	0.222	Creativity	Sessions 2	3	2	1	3
12	Child 20	Moderate	Moderate	0.000	0.953	0.047	0	0	Creativity	Sessions 2	2	2	1	2
13	Child 3	Low	Low	0	0.001	0.999	0	0.000	Creativity	Sessions 3	3	0	0	0
14	Child 4	Good	Good	0.213	0.003	0.000	0.784	0.000	Creativity	Sessions 3	3	3	1	3

ExampleSet (48 examples, 8 special attributes, 6 regular attributes)

Figure 4.35. Classification results from testing data with RapidMiner

In addition, for the precision and recall values in the classification model process using the creative and logical development dataset in children, the precision value is 59.61% and the recall value is 61.55%. The concept of precision is defined as the ratio of related items selected to all items selected. Precision can be interpreted as a match between the game and the results obtained from each game session. Whereas recall is defined as the ratio of relevant items selected to the total number of relevant items available. It is known that the recall value can reach 60%. This indicates that the selected variables can and must be a recommendation.

The Naive Bayes algorithm does not perform well, with an accuracy value below 50% of the test results using the Naive Bayes classification model. This makes the Naive Bayes classification model unsuitable for the data tested. There are several reasons, due to the characteristics of the data, insufficient data volume and inappropriate data pre-processing, why the data set on the creative and logical development of children aged 3-4 years did not perform well.

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4.6.1.3.2 Multilayer Perceptron (MLP)Algorithm

The next classification analysis is performed using the Multilayer Perceptron (MLP) algorithm, which was explained in Chapter 3, Section 3.4.2.4. MLP is one of the artificial neural network methods for solving classification problems. The architecture of this type of artificial neural network consists of several layers that are connected to each other. The layers consist of an input layer, a hidden layer and an output layer. An example of the network architecture used is shown in Figure 4.36.

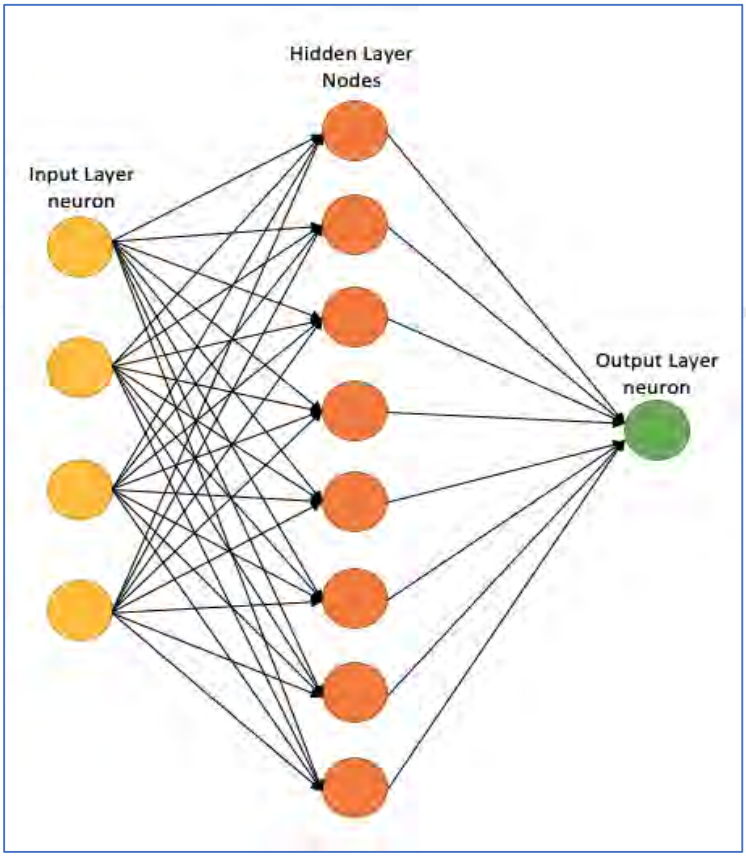


Figure 4.36. Artificial neural network architecture (Schaffer, 1993)

This second model uses the same dataset as used in the naive Bayes model. A dataset of 159 records is used. The MLP modelling process is performed with RapidMiner, as for the previous model. However, in the MLP process, the dataset is pre-processed by changing the data from nominal to numerical. This process is carried out because neural

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networks work by identifying data in binary/integer form in the form of values such as 0 and 1 (Paradarami et al., 2017; Schaffer, 1993).In this research, the data pre-processing uses the attributes available in RapidMiner, namely nominal to numerical, as shown in Figure 4.37. After pre-processing the dataset, data changes are obtained, as shown in Figure 4.38.

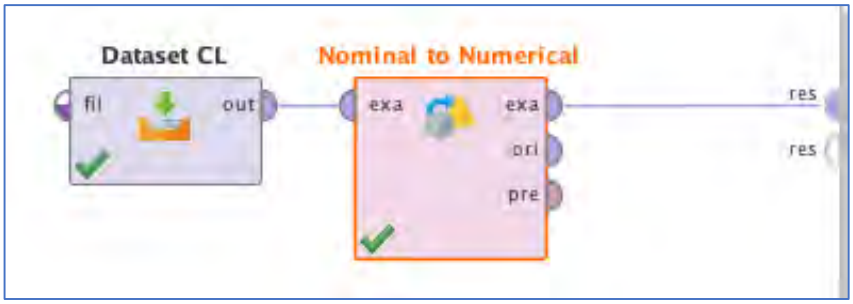
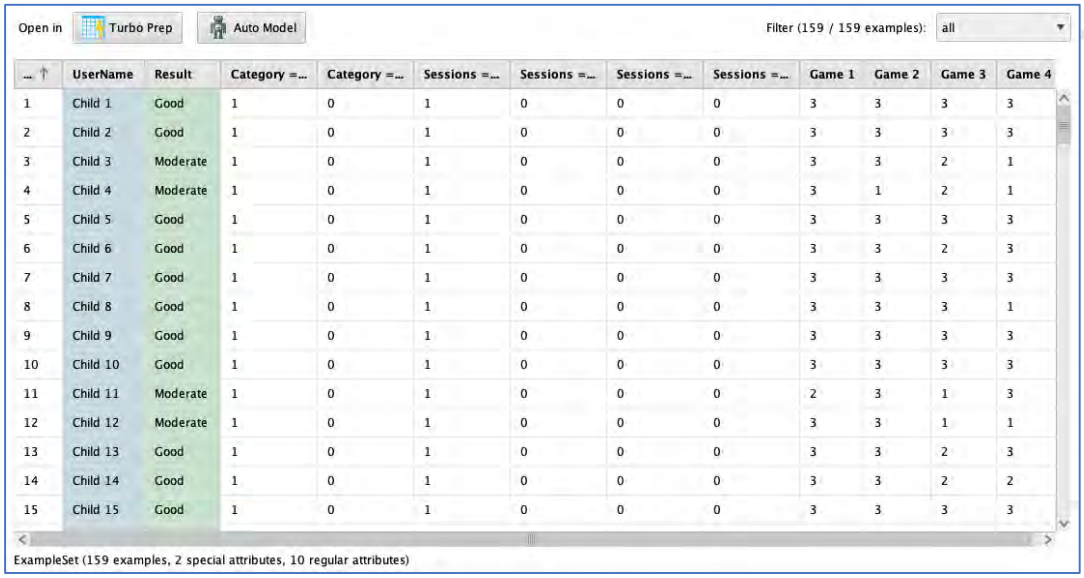


Figure 4.37. Pre-processing dataset nominal to numerical in RapidMiner


Open in Turbo Prep Auto Model Filter (159 / 159 examples): all

...	UserName	Result	Category =...	Category =...	Sessions =...	Sessions =...	Sessions =...	Sessions =...	Game 1	Game 2	Game 3	Game 4
1	Child 1	Good	1	0	1	0	0	0	3	3	3	3
2	Child 2	Good	1	0	1	0	0	0	3	3	3	3
3	Child 3	Moderate	1	0	1	0	0	0	3	3	2	1
4	Child 4	Moderate	1	0	1	0	0	0	3	1	2	1
5	Child 5	Good	1	0	1	0	0	0	3	3	3	3
6	Child 6	Good	1	0	1	0	0	0	3	3	2	3
7	Child 7	Good	1	0	1	0	0	0	3	3	3	3
8	Child 8	Good	1	0	1	0	0	0	3	3	3	1
9	Child 9	Good	1	0	1	0	0	0	3	3	3	3
10	Child 10	Good	1	0	1	0	0	0	3	3	3	3
11	Child 11	Moderate	1	0	1	0	0	0	2	3	1	3
12	Child 12	Moderate	1	0	1	0	0	0	3	3	1	1
13	Child 13	Good	1	0	1	0	0	0	3	3	2	3
14	Child 14	Good	1	0	1	0	0	0	3	3	2	2
15	Child 15	Good	1	0	1	0	0	0	3	3	3	3

ExampleSet (159 examples, 2 special attributes, 10 regular attributes)

Figure 4.38. Dataset after nominal to numerical pre-processing

The results of the nominal-numeric preprocessing of the data into 10 regular attributes and 2 special attributes namely Id and Label with polynominal and integer types. As shown in Table 4.28.

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Table 4.28

Variable and attribute dataset pre-processing nominal to numerical

No	Variabel	Attribute	Type
1.	UserName	Id	Polynominal
2.	Result	Label	Polynominal
3.	Creativity	Regular	Integer
4.	Logic	Regular	Integer
5.	Sessions 1	Regular	Integer
6.	Sessions 2	Regular	Integer
7.	Sessions 3	Regular	Integer
8.	Sessions 4	Regular	Integer
9.	Game 1	Regular	Integer
10.	Game 2	Regular	Integer
11.	Game 3	Regular	Integer
12.	Game 4	Regular	Integer

MLP algorithm that performs learning by minimising the error rate as a way of adjusting the weights based on the difference between the output and the desired target. MLP uses a standard sigmoid function with units arranged in layers of a feed-forward neural network topology (Jeyanathan, 2018), where the weight sum of a number of inputs and biases is input to the activation level through a transfer function to produce the output. In this study, the process was carried out using RapidMiner with an input layer of 10 variables as described in Table 4.28. As in the previous model, the dataset ratio between training and testing data is 70:30, which is done to obtain different data

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performance values to compare the classification models. The procedure is as shown in Figure 4.39.

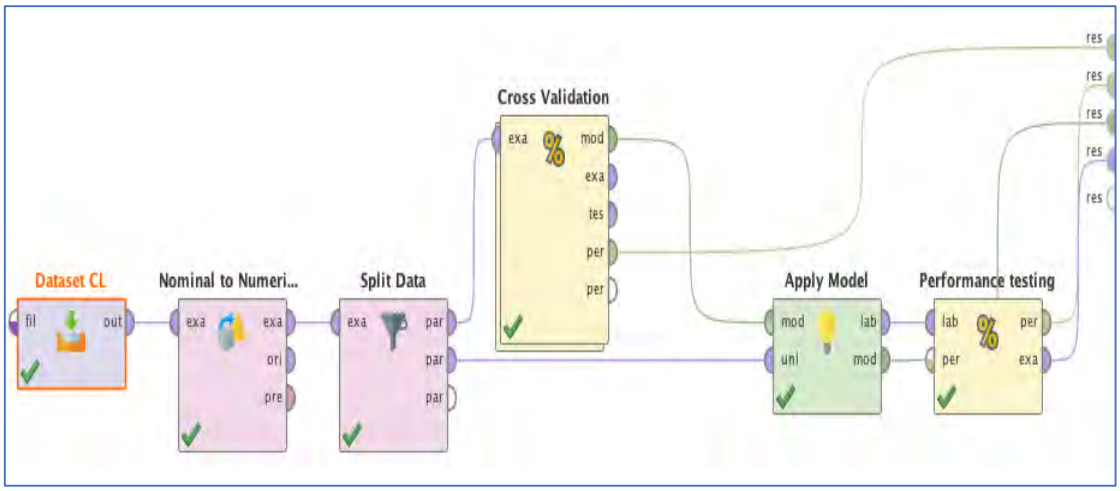


Figure 4.39. Classification model of the MLP algorithm in RapidMiner

The figure above explains the classification model process for the MLP algorithm. Prior to the classification model process using the MLP algorithm, the data set is pre-processed, which has been explained in the previous section. After pre-processing the data, the data is split into 2 parts, namely training data and testing data using split data. Cross-validation is used to maximize the training data to be processed in MLP modelling, as shown in Figure 4.40. As for the test data that is generated in the split data, it is connected to the apply model to determine the performance of the data that is generated in the accuracy value

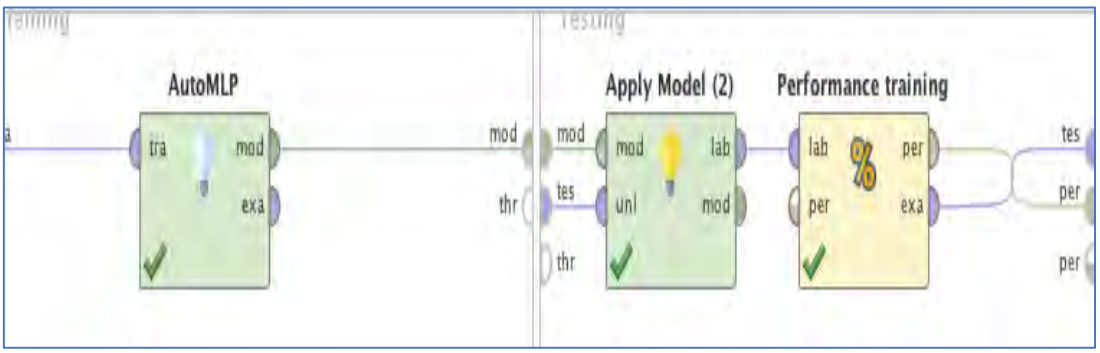


Figure 4.40. MLP model in RapidMiner

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The Learning Analytics classification model of creative and logical development in children aged 3-4 years is based on the power of MLP. The network topology is very important when designing an artificial neural network. Like the human brain, it consists of a network of interconnected neurons, with a weight associated with each connection. These weights are adjusted based on the learning experience of the algorithm. In the model, we can see that the network architecture consists of an input layer, a hidden layer and an output layer, so it has up to 7 nodes in the hidden layer with different weights. As shown in Table 4.29. Network topology Neurons in MLP that are interconnected have the weight of each hidden layer.

Table 4.29

The interconnected neuron network topology in MLP has a weight for each hidden layer

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Input Layer	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7
Creativity	-1,428	-1,331	0,276	2,002	1,299	0,21	1,471
Logic	1,501	1,294	-0,327	-2,034	-1,32	-0,189	-1,53
Sessions 1	-1,405	0,777	1,449	-0,14	-0,572	-0,105	-0,576
Sessions 2	1,294	1,271	2,13	-0,155	-3,193	-0,597	-0,951
Sessions 3	-0,419	1,237	1,024	2,731	-1,174	1,04	2,095
Sessions 4	2,122	-0,464	1,4	-0,117	-0,911	-0,313	-0,51
Game 1	-2,362	-0,38	1,928	1,233	-5,493	-1,644	0,638
Game 2	-4,208	2,265	2,378	-0,25	-3,762	-1,152	0,089
Game 3	-2,426	-1,061	3,913	2,111	-2,95	-2,092	-0,487
Game 4	-4,251	-3,037	2,381	1,015	-3,825	-1,112	0,74
Threshold	-0,787	-1,392	-2,942	-1,141	2,921	0,038	-0,06

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In addition, the classification analysis process carried out by MLP on the data set of the development of creativity and logic in children aged 3-4 years, classifies in 5 outputs, namely 1) good, 2) moderate, 3) low, 4) good, 5) moderate. Selected classifications in the hidden layer by sigmoid activation function on each neuron. As for the value of each output layer is shown in Table 4.30.

Table 4.30

Performance of the output layer in MLP classification

Hidden Layer	Good	Moderate	Low	Good	Moderate
Node 1	-1,036	-6,568	3,437	-1,138	3,119
Node 2	0,144	3,477	-2,948	-0,73	-0,584
Node 3	1,135	-3,608	-2,543	3,094	-3,465
Node 4	3,362	0,303	-1,567	-2,758	-1,327
Node 5	-6,126	5,092	1,579	-1,682	-3,54
Node 6	-1,749	-0,559	2,146	-2,119	-1,82
Node 7	1,569	-0,213	-0,243	-2,933	-1,607
Threshold	-1,051	-1,246	-3,69	-2,419	0,21

Figure 4.41 shows the graphical representation of the performance obtained from the value of each output layer generated by MLP.

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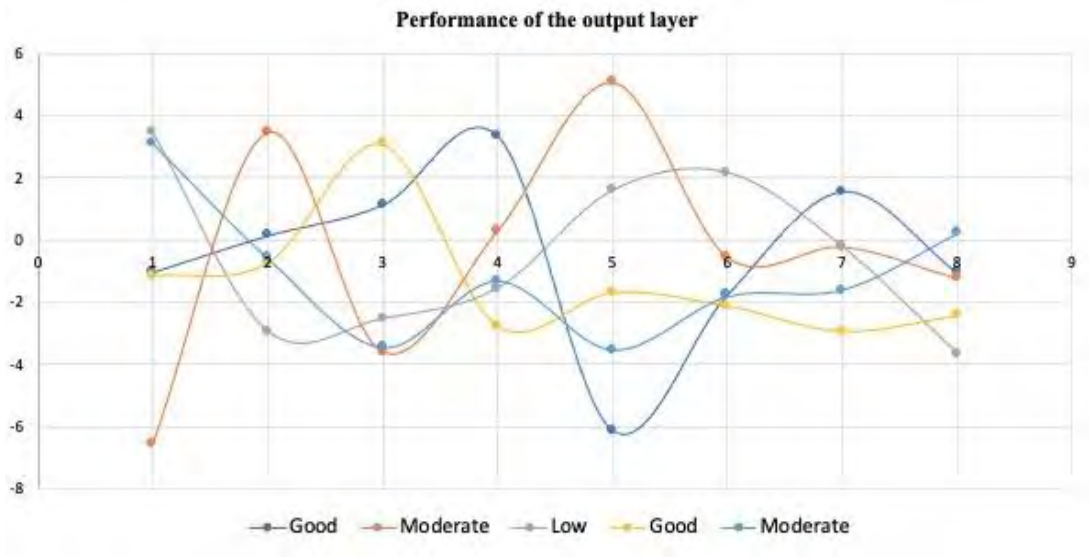


Figure 4.41. The performance output layer (MLP) is shown graphically

From the classification results in the modelling process described above, the accuracy performance of the training and test data is obtained based on the type of sampling performed on the classification model. The sampling method in the cross-validation model has 4 models, namely 1) linear sampling, 2) shuffled sampling, 3) stratified sampling, and 4) random sampling (automatic). It was found that the accuracy value of each sampling type is different, as shown in Figure 4.42. For the linear sampling type, the accuracy value of the training data is 60.36% and the accuracy value of the testing data is 85.42%. For the shuffled sample type, the accuracy value of the training data is 72.97% and the accuracy value of the testing data is 79.17%. While the stratified and random sample types have the same accuracy value, the accuracy value of the training data is 81.98% and the accuracy value of the testing data is 79.17%. Judging from the results of the accuracy value of each sample type, it can be said that the accuracy value of the test data is better than that of the training data for the liner and shuffled sample types. This provides a more objective evaluation of the model by using the entire dataset

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for training and testing, so that the model works well for the classification process. In contrast, for stratified and random sample types, the accuracy value of the training data is greater than the value of the testing data, resulting in overfitting or overfitting of the data to the testing data.

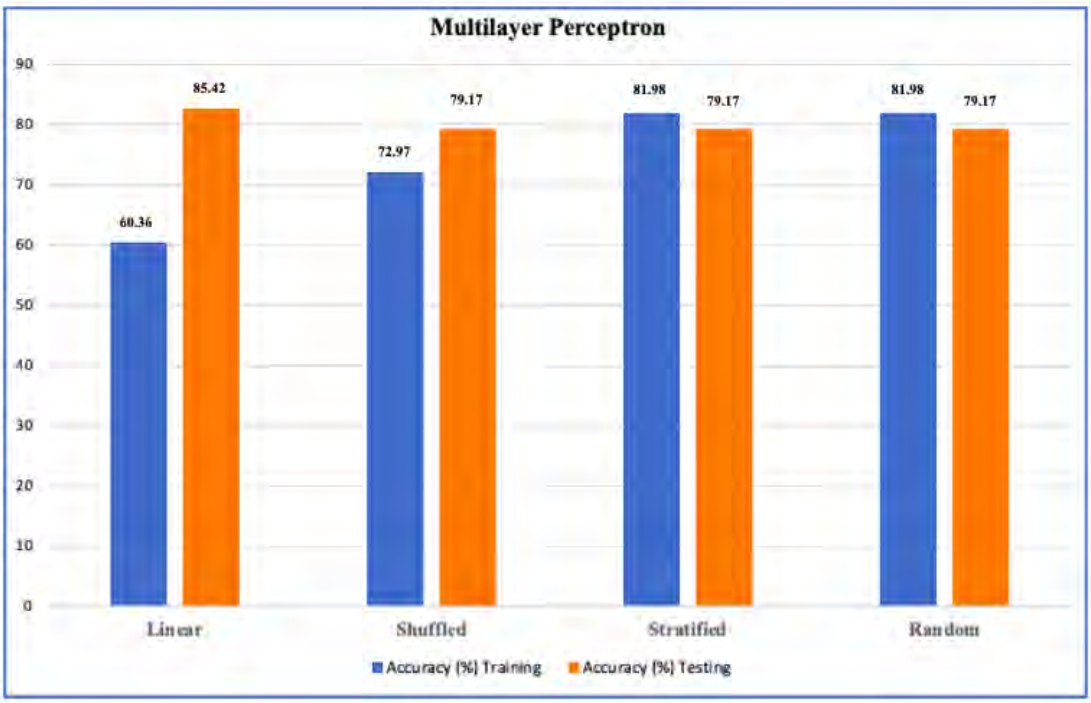


Figure 4.42. Accuracy performance of training and testing data based on sampling type

The performance measure for the classification model of the MLP algorithm, where the output is 5 classes, is described in the form of a confusion matrix. The confusion matrix is a table with different combinations of predicted and actual values. The accuracy value of the training data and the testing data reaches more than 70%, where the accuracy value of the test data is better than the training data, making the MLP model better in the classification of creative and logical development in children 3-4 years-old and the data can be said to be "Appropriate". The results of this research can be seen in Figures 4.43 and 4.44.

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accuracy: 72.97% +/- 9.74% (micro average: 72.97%)

	true Good	true Moderate	true Low	true Good	true Moderate	class precision
pred. Good	43	6	0	10	1	71.67%
pred. Moderate	3	16	0	0	1	80.00%
pred. Low	0	1	13	0	0	92.86%
pred. Good	5	1	0	7	0	53.85%
pred. Moderate	0	2	0	0	2	50.00%
class recall	84.31%	61.54%	100.00%	41.18%	50.00%	

Figure 4.43. Confusion matrix training data MLP

accuracy: 79.17%

	true Good	true Moderate	true Low	true Good	true Moderate	class precision
pred. Good	19	1	0	4	1	76.00%
pred. Moderate	0	9	0	0	0	100.00%
pred. Low	0	0	6	0	0	100.00%
pred. Good	1	0	0	3	0	75.00%
pred. Moderate	2	1	0	0	1	25.00%
class recall	86.36%	81.82%	100.00%	42.86%	50.00%	

Figure 4.44.Confusion matrix testing data MLP

From the figure above, the results obtained for the confusion matrix training data on the predicted and correct good class are 43, predicted moderate turns out to be the correct good class is 3, predicted low turns out to be the correct good class is 0, predicted good turns out to be the correct good class is 5, and predicted moderate turns out to be the correct moderate class is 0. For the predicted moderate correct class good is 6, predicted and correct for the correct moderate class is 16, predicted low turns out the correct moderate class is 1, predicted good turns out the correct moderate class is 1,

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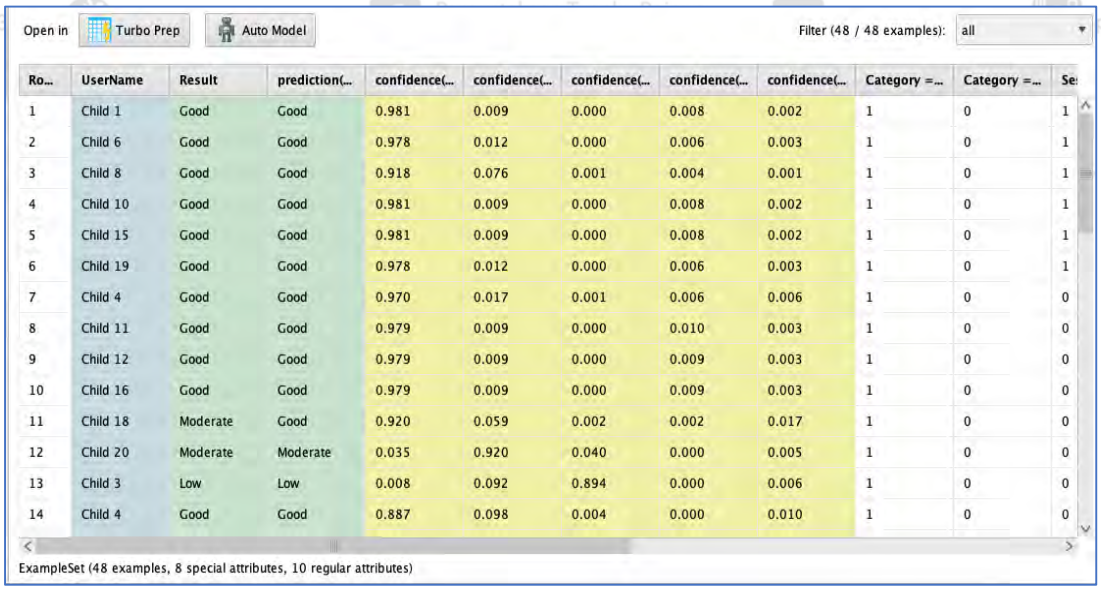
predicted moderate turns out the correct moderate class is 2. For the predicted good low class is 0, predicted moderate it turns out that the true low class is 0, predicted and true for the true low class is 6, predicted good and moderate it turns out that the true low class is 0. For the predicted good class good is 4, predicted moderate and low it turns out that the true good class is 0, predicted and true for the true good class is 7, predicted moderate it turns out that the true good class is 0. For the predicted moderate true class good is 1, predicted moderate it turns out that the moderate true class is 1, predicted low it turns out that the moderate true class is 0, predicted good it turns out that the moderate true class is 0, and predicted and true for the moderate class is 2. While the results for the confusion matrix data testing on the predicted and correct good class are 19, predicted moderate turns out to be the correct class good is 0, predicted low turns out to be the correct class good is 0, predicted good turns out to be the correct class good is 1, and predicted moderate turns out to be the correct class good is 2. For the predicted correct moderate class good is 1, predicted and true for the correct class moderate is 9, predicted low turns out to be the correct class moderate is 0, predicted good turns out to be the correct class moderate is 0, predicted moderate turns out to be the correct class moderate is 1. For the predicted correct low class good is 0, predicted moderate turns out to be the correct low class is 0, predicted and correct for the correct low class is 6, predicted good and moderate turns out to be the correct low class is 0. For the predicted correct good class good is 4, predicted moderate and low turns out to be the correct good class is 0, predicted and correct for the correct good class is 3, predicted moderate turns out to be the correct good class is 0. For the predicted moderate correct class good is 1, predicted moderate turns out to be the correct moderate class is 0, predicted low turns out to be the correct moderate class is 0,

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predicted good turns out to be the correct moderate class is 0, and predicted and correct for the moderate class is 1.

The classification results of the testing data generated by the MLP algorithm, as shown in Figure 4.45. Where there are 48 data sets with 8 special attributes and 10 regular attributes. The 8 special attributes are as follows: 1) UserName, 2) Result, 3) Prediction Result, 4) Confidence Good, 5) Confidence Moderate, 6) Confidence Low, 7) Confidence Good, 8) Confidence Moderate. While the 10 regular attributes are as follows: 1) Creativity category, 2) Logic category, 3) Sessions 1, 4) Sessions 2, 5) Sessions 3, 6) Sessions 4, 7) Game 1, 8) Game 2, 9) Game 3, 10) Game 4. The resulting evaluation metrics for the classification model are 69.67 % for precision and 67.41 % for recall.


Open in Turbo Prep Auto Model Filter (48 / 48 examples): all

Ro...	UserName	Result	prediction(...	confidence(...	confidence(...	confidence(...	confidence(...	confidence(...	Category =...	Category =...	Se
1	Child 1	Good	Good	0.981	0.009	0.000	0.008	0.002	1	0	1
2	Child 6	Good	Good	0.978	0.012	0.000	0.006	0.003	1	0	1
3	Child 8	Good	Good	0.918	0.076	0.001	0.004	0.001	1	0	1
4	Child 10	Good	Good	0.981	0.009	0.000	0.008	0.002	1	0	1
5	Child 15	Good	Good	0.981	0.009	0.000	0.008	0.002	1	0	1
6	Child 19	Good	Good	0.978	0.012	0.000	0.006	0.003	1	0	1
7	Child 4	Good	Good	0.970	0.017	0.001	0.006	0.006	1	0	0
8	Child 11	Good	Good	0.979	0.009	0.000	0.010	0.003	1	0	0
9	Child 12	Good	Good	0.979	0.009	0.000	0.009	0.003	1	0	0
10	Child 16	Good	Good	0.979	0.009	0.000	0.009	0.003	1	0	0
11	Child 18	Moderate	Good	0.920	0.059	0.002	0.002	0.017	1	0	0
12	Child 20	Moderate	Moderate	0.035	0.920	0.040	0.000	0.005	1	0	0
13	Child 3	Low	Low	0.008	0.092	0.894	0.000	0.006	1	0	0
14	Child 4	Good	Good	0.887	0.098	0.004	0.000	0.010	1	0	0

ExampleSet (48 examples, 8 special attributes, 10 regular attributes)

Figure 4.45. Classification results from testing data with RapidMiner

This shows that the level of positive prediction error and sensitivity in the LAP dataset of creativity and logic development in children aged 3-4 years where there are

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actually some children such as child 18 with moderate results MLP algorithm predicts with good results in this case MLP predicts errors in prediction.

4.6.1.3.3 Decision Tree Algorithm

The next analysis uses the decision tree algorithm, which is one of the techniques widely used in the classification process. A decision tree is a graph that represents choices and outcomes in the form of a tree (Mahesh Batta, 2020). The nodes in the graph represent an event or choice and the edges of the graph represent rules or decision conditions. Each tree has nodes and branches. Each node represents an attribute in a group to be classified and each branch represents a value that can be taken by that node. This has been explained in the previous chapters and sections. The structure of the model generated by the decision tree algorithm is shown in Figure 4.46.

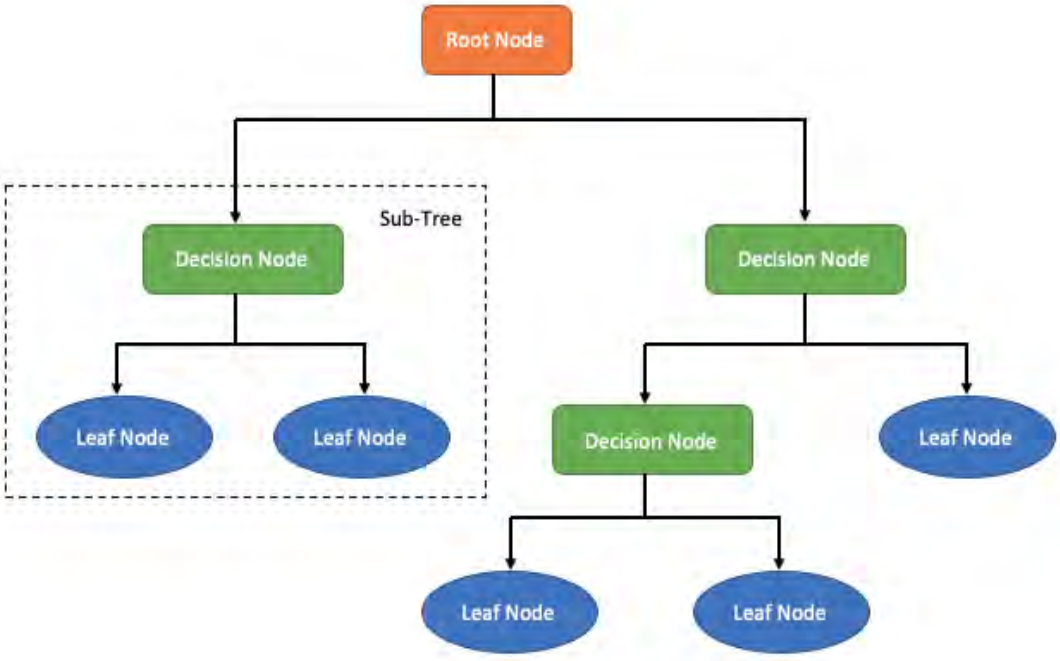


Figure 4.46. Model structure of decision tree algorithm (Charbuty & Abdulazeez, 2021)

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The dataset used for the classification modelling process uses the same data in the Naive Bayes and MLP processes. The number of data is 159 records, which are used from the learning analytics platform process. The classification modelling process uses a decision tree algorithm running on RapidMiner, which was run in the previous modelling. The testing process is shown in Figure 4.47.

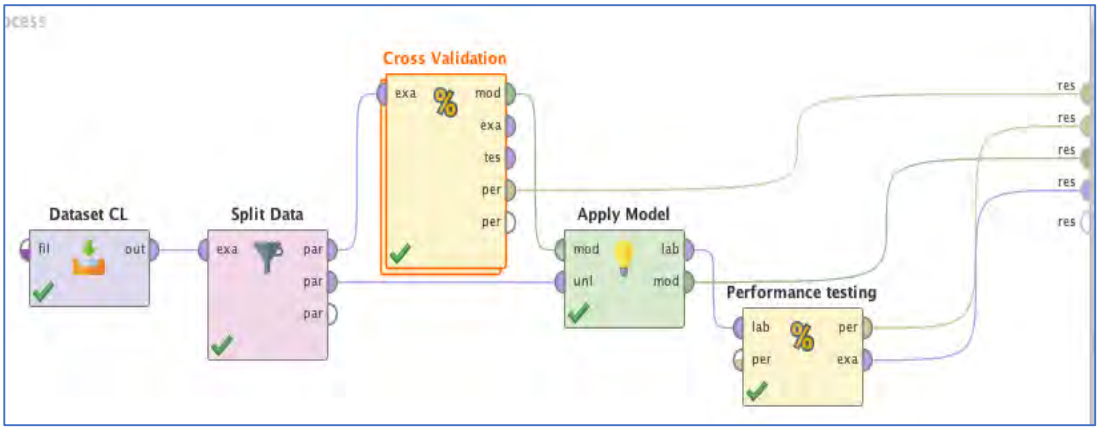


Figure 4.47. Classification model of the decision tree algorithm in RapidMiner

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In the classification process with the decision tree algorithm performed on RapidMiner. The data ratio is split into two parts, namely training and testing data, as described in the previous section, the split ratio is 70:30 for this process, the split data operator is used. The use of cross validation is done to get maximum performance in the classification process, this is done by taking specific samples from the data set whose models are not trained. It is also used to protect the model from overfitting, which is a model that is very good only on training data and poor when tested on new data. The decision tree model is applied to the classification process, for the process of evaluating the model performance, the decision tree algorithm is used in the cross-validation operator. As shown in Figure 4.48.

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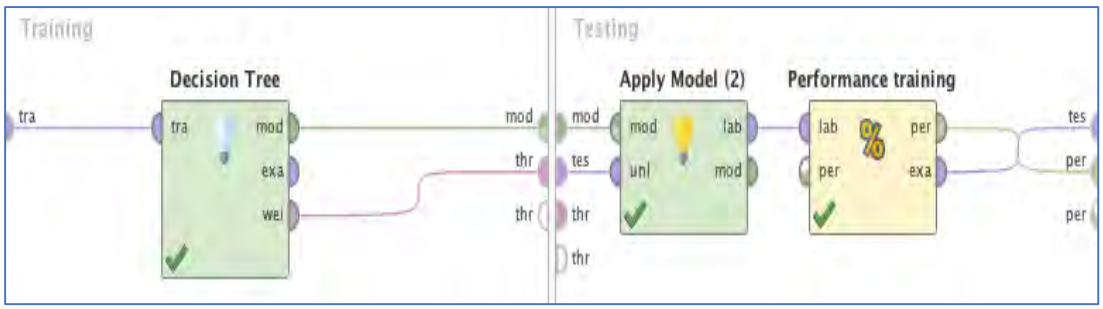
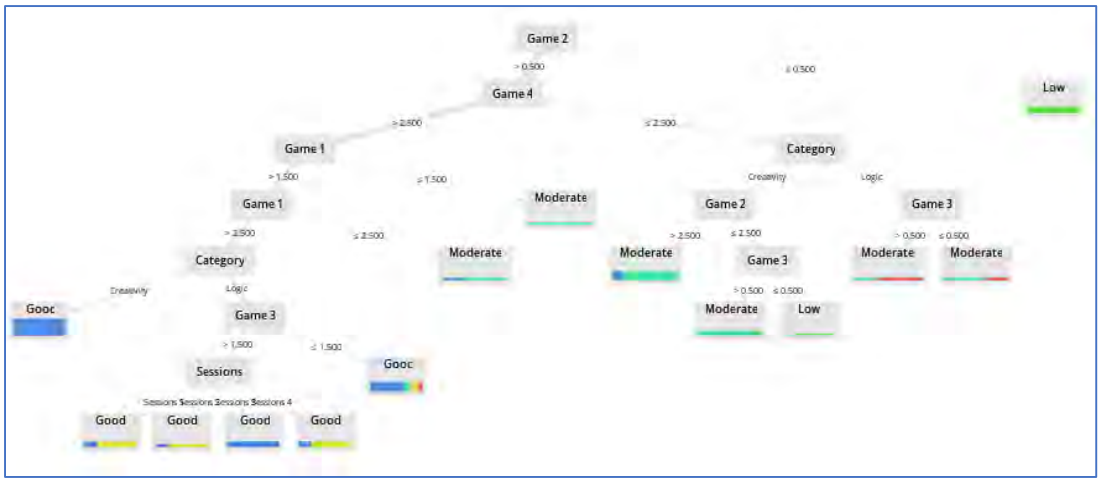


Figure 4.48. Decision tree model in RapidMiner

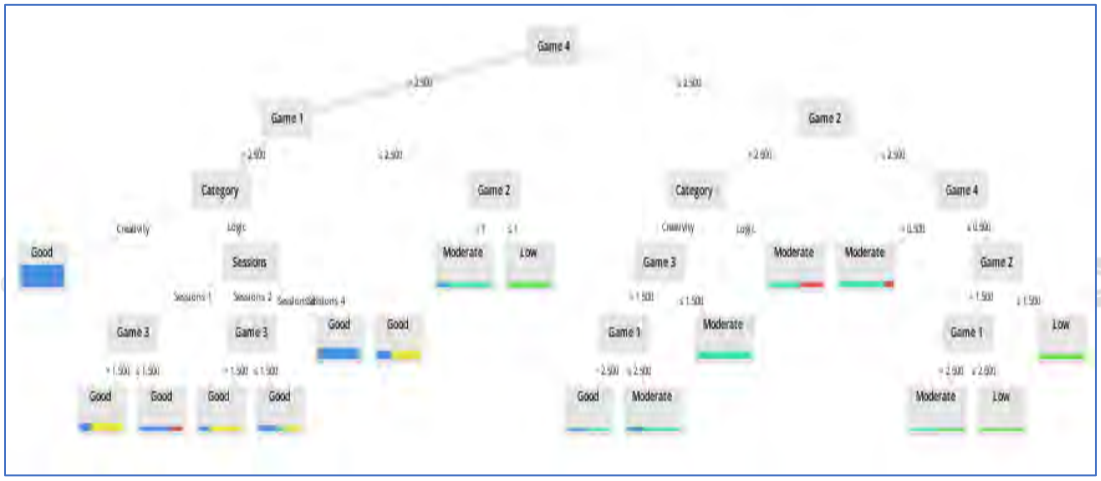
The learning analytic classification model of creative and logic development in children aged 3-4 years is built in the form of a decision tree algorithm. The training and testing process is carried out by conducting experiments by dividing the nodes and building a tree structure using a comparison with the experimental criteria in the decision tree model, namely Gain Ratio, Information Gain and Gini Index. This is also done by (Charbuty & Abdulazeez, 2021) parameters to separate attributes, with each criterion that can be selected must be able to optimize the split value of the decision tree. Gain Ratio is to adjust the information for each attribute to allow for breadth and uniformity of attributes (Jun et al., 1997). Information Gain is to calculate the entropy of all attributes and select the one with the lowest entropy value for splitting. This criterion has a bias towards selecting attributes with a large number of values (Charbuty & Abdulazeez, 2021; Tangirala, 2020). The Gini index is a measure of the inequality between the distributions of label features, and splitting the selected attributes results in a reduction in the average Gini index of the resulting set of parts (Tangirala, 2020). As shown in Figure 4.49.

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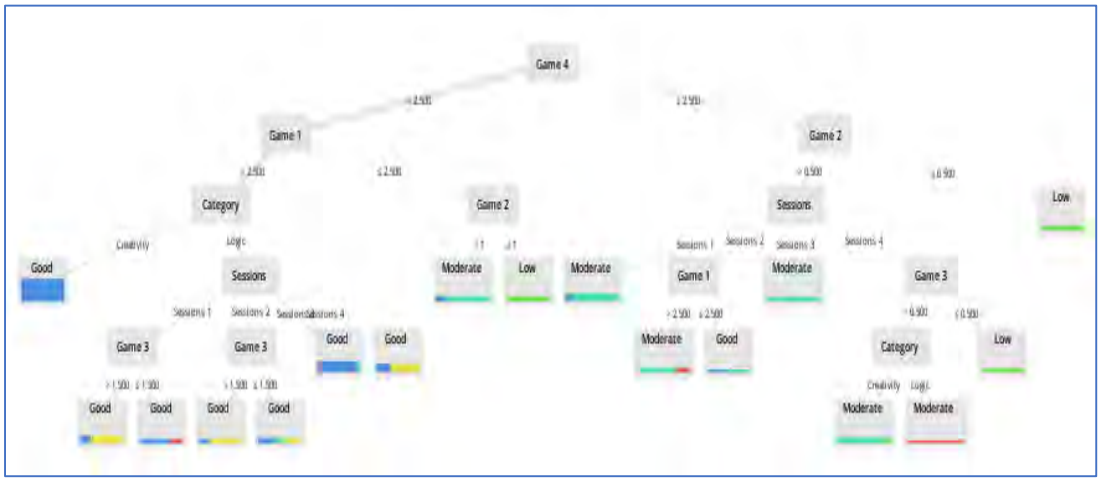
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Gain Ratio



Information Gain



Gain Index

Figure 4.49. Comparison gain ratio, information gain, and gain index of criteria model structure of the decision tree algorithm

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It can be seen in the figure that in the Gain Ratio criterion, the Game 2 attribute becomes the root node and has only one branch node to the left, namely Game 4. While the Information Gain and Gini Index criteria give the same model results where the root node is the Game 4 attribute and this root node has two branches to the left and right.

The left branch node is the Game 1 attribute and the right branch node is the Game 2 attribute. Techniques were applied to the model to reduce tree complexity, prevent overfitting and improve model generalization, namely pre-pruning and post-pruning. This needs to be done before the model is fully built as (Charbuty & Abdulazeez, 2021) to limit or stop the growth of the tree before it reaches a level of complexity that could lead to overfitting. Minimum gain of 0.01, minimum leaf size of 2, minimum split size of 4, and number of pre-pruning alternatives of 3.

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From the classification results in the decision tree algorithm process, the performance of the accuracy values of the training and testing data is obtained based on the type of sampling performed on the classification model. The sampling method in the cross-validation model has 4 models, namely 1) linear sampling, 2) shuffled sampling, 3) stratified sampling, and 4) random sampling (automatic). The performance results of the accuracy value are compared to obtain the optimal value for each trial based on the criteria tested in each model, as shown in Table 4.31. Based on the table, it is known that the performance results of each data have different accuracy values.

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Table 4.31

Comparison accuracy performance based on DT criterion

Criterion	Linear (%)		Shuffled (%)		Stratified (%)		Automatic (%)	
	Training	Testing	Training	Testing	Training	Testing	Training	Testing
Gain Ratio	57.66	77.08	72.09	77.08	76.58	77.08	76.58	77.08
Information Gain	36.94	79.17	66.67	79.17	70.27	79.17	70.27	79.17
Gini Index	37.84	70.83	67.57	70.83	69.37	70.83	69.37	70.83

Based on the table above, each training and testing data test performed on the classification model with the decision tree algorithm has a difference in the performance value of each data test. The tests are performed by trying each criterion on each model. As shown in Figure 4.50.

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Figure 4.50. Accuracy performance of training and testing data on the gain ratio criterion

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On the chart, the blue is the training data and the orange is the testing data. It shows that the accuracy value with the Gain Ratio criterion on linear sampling, the training data has a value of 57.66%. For the shuffled sampling, the training data has a value of 72.09%. For stratified and automatic sampling, the training data has a value of 76.58%. For the accuracy value of the testing data with the Gain Ratio criterion in all sampling types has the same value of 77.08%. For the performance with the Information Gain criterion, see Figure 4.51.

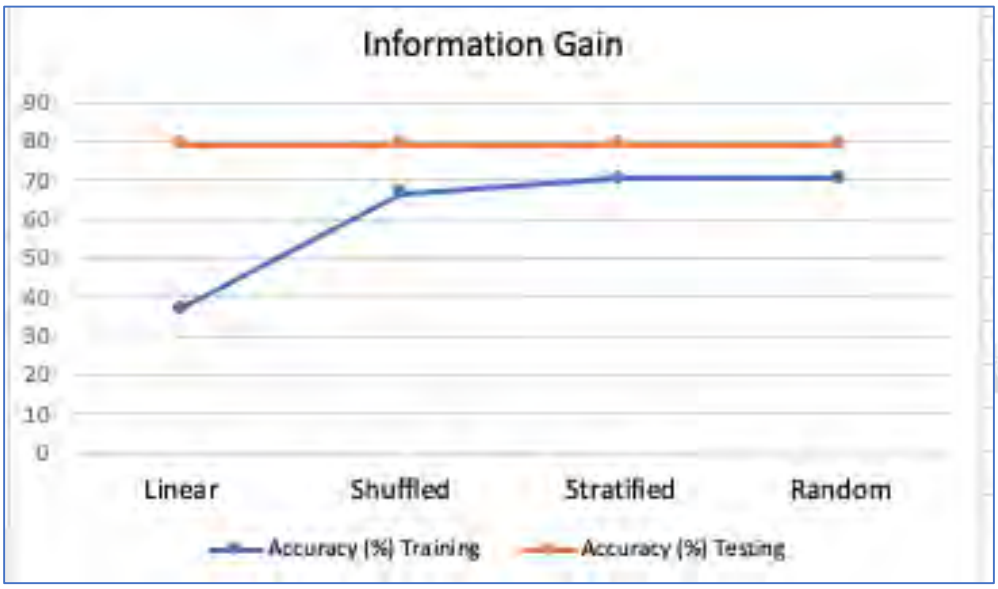


Figure 4.51. Accuracy performance of training and testing dan on the information gain criterion

The chart above explains that the blue colour is the training data and the orange colour is the test data. Accuracy value performance with Information Gain criteria on linear sampling, the training data has a value of 37.84%. In the case of mixed sampling, the training data has a value of 67.57%. The training data has a value of 70.27% for stratified and automatic sampling. The accuracy value of the test data with the information gain criteria has the same value of 79.17% in all types of sampling. For the performance with the Gini index criteria, shown in Figure 4.52.

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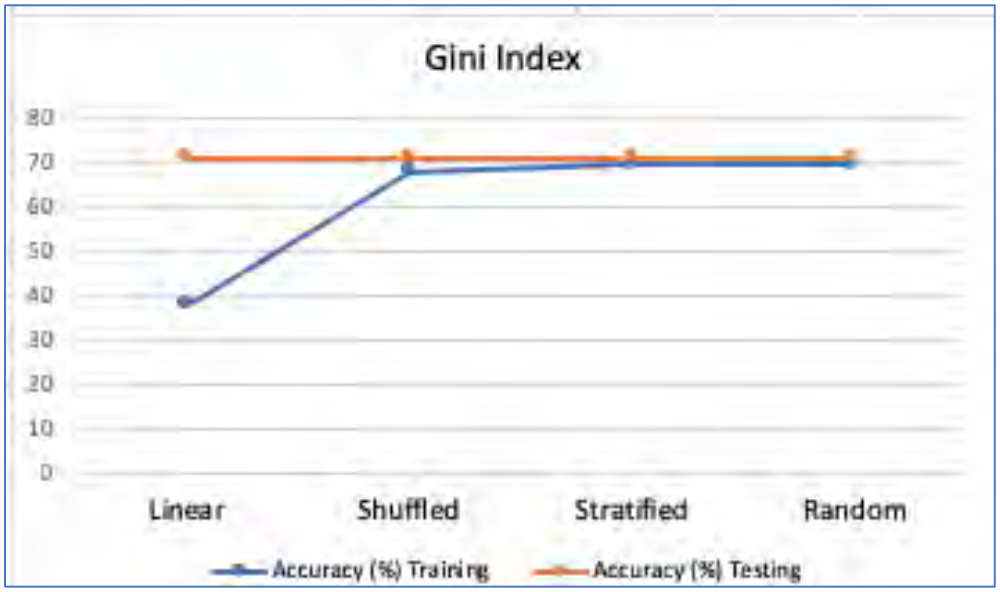


Figure 4.52. Accuracy performance of training and testing data on the Gini index criterion

This chart shows that blue is training data and orange is testing data. Performance of the accuracy value with the Gini index criteria on linear sampling, the training data has a value of 36.94%. For mixed sampling, the training data has a value of 66.67%. For stratified and automatic sampling, the training data has a value of 69.37%. For the accuracy value of the test data with the Gini index criterion in all types of sampling has the same value of 70.83%.

The results show that the maximum accuracy value obtained by the Decision Tree algorithm model with the Information Gain criterion on stratified and automatic sampling is 70.27% for training data and 79.17% for testing data. From the information gain criterion with a data split of 70:30, the rule obtained for the data in this study is:

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Game 4 > 2.500

| Game 1 > 2.500

| | Category = Creativity: Good {Good=26, Moderate=0, Low=0, Good =0, Moderate =0}

| | Category = Logic

| | | Sessions = Sessions 1

| | | | Game 3 > 1.500: Good {Good=2, Moderate=0, Low=0, Good =6, Moderate =0}

| | | | Game 3 ≤ 1.500: Good {Good=3, Moderate=0, Low=0, Good =0, Moderate =1}

| | | Sessions = Sessions 2

| | | | Game 3 > 1.500: Good {Good=1, Moderate=0, Low=0, Good =3, Moderate =0}

| | | | Game 3 ≤ 1.500: Good {Good=2, Moderate=1, Low=0, Good =2, Moderate =0}

| | | Sessions = Sessions 3: Good {Good=11, Moderate=1, Low=0, Good =0, Moderate =0}

| | | Sessions = Sessions 4: Good {Good=3, Moderate=0, Low=0, Good =6, Moderate =0}

| Game 1 ≤ 2.500

| | Game 2 > 1: Moderate {Good=1, Moderate=4, Low=0, Good =0, Moderate =0}

| | Game 2 ≤ 1: Low {Good=0, Moderate=0, Low=5, Good =0, Moderate =0}

Game 4 ≤ 2.500

| Game 2 > 2.500

| | Category = Creativity

| | | Game 3 > 1.500

| | | | Game 1 > 2.500: Good {Good=1, Moderate=1, Low=0, Good =0, Moderate =0}

| | | | Game 1 ≤ 2.500: Moderate {Good=1, Moderate=2, Low=0, Good =0, Moderate =0}

| | | Game 3 ≤ 1.500: Moderate {Good=0, Moderate=8, Low=0, Good =0, Moderate =0}

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| | Category = Logic: Moderate {Good=0, Moderate=3, Low=0, Good =0, Moderate =2}
| Game 2 ≤ 2.500
| | Game 4 > 0.500: Moderate {Good=0, Moderate=5, Low=0, Good =0, Moderate =1}
| | Game 4 ≤ 0.500
| | | Game 2 > 1.500
| | | | Game 1 > 2.500: Moderate {Good=0, Moderate=1, Low=1, Good =0, Moderate =0}
| | | | Game 1 ≤ 2.500: Low {Good=0, Moderate=0, Low=2, Good =0, Moderate =0}
| | | Game 2 ≤ 1.500: Low {Good=0, Moderate=0, Low=5, Good =0, Moderate =0}

The confusion matrix generated from the accuracy measurement is shown in Figures 4.53 and 4.54. The accuracy value on the generated training data is 70.27 % and on the generated testing data is 79.17 %. Therefore, the decision tree algorithm included in the supervised learning method to predict educational data on the development of creativity and logic in children aged 3-4 years. The resulting evaluation metric on the classification model for the precision value is 65.10 % and the recall value is 68.96 %.

accuracy: 70.27% +/- 4.68% (micro average: 70.27%)

	true Good	true Moderate	true Low	true Good	true Moderate	class precision
pred. Good	40	7	0	4	2	75.47%
pred. Moderate	3	14	2	0	2	66.67%
pred. Low	0	5	11	0	0	68.75%
pred. Good	8	0	0	13	0	61.90%
pred. Moderate	0	0	0	0	0	0.00%
class recall	78.43%	53.85%	84.62%	76.47%	0.00%	

Figure 4.53. Confusion matrix training data DT

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accuracy: 79.17%

	true Good	true Moderate	true Low	true Good	true Moderate	class precision
pred. Good	17	2	0	1	1	80.95%
pred. Moderate	1	9	0	0	0	90.00%
pred. Low	0	0	6	0	0	100.00%
pred. Good	4	0	0	6	1	54.55%
pred. Moderate	0	0	0	0	0	0.00%
class recall	77.27%	81.82%	100.00%	85.71%	0.00%	

Figure 4.54. Confusion matrix testing data DT

From the figure above, the results obtained for the confusion matrix training data on the predicted and correct good class are 40, predicted moderate is the correct good class is 3, predicted low is the correct good class is 0, predicted good is the correct good class is 8, and predicted moderate is the correct moderate class is 0. For the predicted moderate correct class good is 7, predicted and correct for the correct moderate class is 14, predicted low is the correct moderate class is 5, predicted good and moderate is the correct moderate class is 0. For the predicted correct moderate class good is 7, predicted and correct for the correct moderate class is 14, predicted low turns out to be the correct moderate class is 5, predicted good and moderate turns out to be the correct moderate class is 0. For the predicted correct low class good is 0, predicted moderate turns out to be the correct low class is 2, predicted and correct for the correct low class is 11, predicted good and moderate turns out to be the correct low class is 0. For the predicted good class good is 4, predicted moderate and low turns out to be the correct good class is 0, predicted and correct for the correct good class is 13, predicted moderate turns out to be the correct good class is 0. For the predicted moderate correct class good is 2, predicted moderate turns out to be the correct moderate class is 2,

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predicted low and good turns out to be the correct moderate class is 0, and predicted and true for the moderate class is 0. While the results for the confusion matrix data tests on the predicted and correct good class are 17, predicted moderate turns out to be the correct class good is 1, predicted low turns out to be the correct class good is 0, predicted good turns out to be the correct class good is 4, and predicted moderate turns out to be the correct class good is 0. For the predicted moderate correct class good is 2, predicted and correct for the correct class moderate is 9, predicted low turns out to be the correct class moderate is 0, predicted good and moderate turns out to be the correct class moderate is 0. For the predicted low true class good is 0, predicted moderate turns out to be the true low class 0, predicted and correct for the true low class is 6, predicted good and moderate turns out to be the true low class 0. For the predicted good true class good is 1, predicted moderate and low turns out to be the true good class 0, predicted and correct for the true good class is 6, predicted moderate turns out to be the true good class 0. For the predicted moderate true class good is 1, predicted moderate turns out to be the true moderate class is 0, predicted low turns out to be the true moderate class is 0, and good turns out to be the true moderate class is 1, and predicted and true for the moderate class is 0.

4.6.2 Comparison classification models

At this stage, researchers are comparing classification algorithm models that have been run on training and testing data to get the best performance in classifying data learning analytics for creativity and logic development in children aged 3-4 years. Having a balanced performance between accuracy values on training and testing data is an

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important goal when building machine learning models. The model can make better predictions and generalise better on data it has never seen before with a good balance between accuracy on training and test data. The classification comparison stage is based on the percentage of information obtained, which is measured based on the accuracy performance of each model. From the classification modelling process, the previous explanation can be summarised in Table 4.32.

Table 4.32

Summary of the performance accuracy of the Naive Bayes, MLP, and Decision Tree classification models on the training and testing data

Classification models	**Linear**		**Shuffled**		**Stratified**		**Random**	
	Training	Testing	Training	Testing	Training	Testing	Training	Testing
Naïve Bayes	42.34	41.67	38.74	41.67	40.54	41.67	40.54	41.67
MLP	60.36	85.42	72.97	79.17	81.98	79.17	81.98	79.17
Decision Tree	36.94	79.17	66.67	79.17	70.27	79.17	70.27	79.17

On the basis of the table above, we can see that each model has a different value of accuracy for each type of sampling. As shown in Figure 4.55. In the linear sampling type, each model has a different accuracy value, such as the Naive Bayes model for training data, the accuracy value is 42.34 %, while in the test data the accuracy value is 41.67 %. In the MLP model, the accuracy value for training data is 60.36 %, while the accuracy value for testing data is 85.42 %. In the Decision Tree model, the accuracy value is 36.94 % while in the testing data the accuracy value is 79.17 %. From this process, it can be seen that the MLP model has a high accuracy value on both training and testing data. In this process, the performance of each model does not give maximum results, for the Naive Bayes model the performance experiences overfitting data where

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the accuracy value in the training data is greater than the testing data. For the MLP and Decision Tree models, the performance is underfitting data where the accuracy value in the training data is much lower than the testing data, indicating that the model is not sufficiently able to learn the patterns in the data.

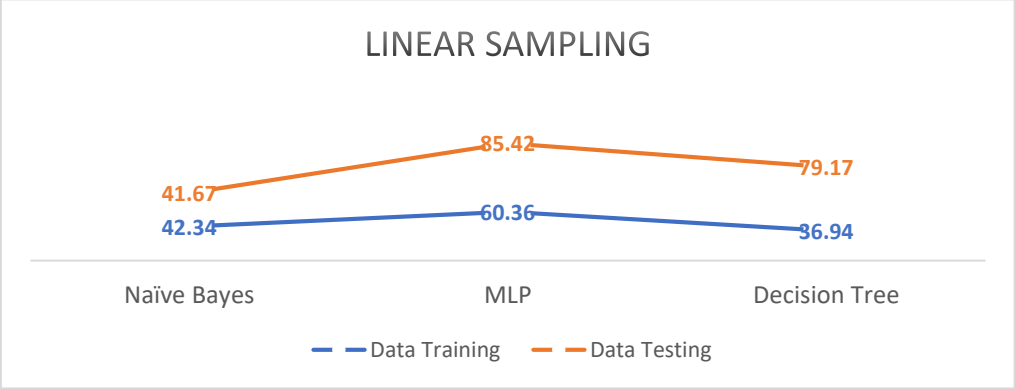


Figure 4.55. Comparison the accuracy of classification algorithms based on linear sampling

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As for the modelling process in the shuffled sampling type, it can be seen in Figure 4.56. In the shuffled sampling type, the MLP model has a very good performance compared to other models. With an accuracy value on training data of 72.97 % and an accuracy value on test data of 79.17 %. As for the Decision Tree model, it has a good performance from the MLP model, with an accuracy value on training data of 66.67 % and an accuracy value on testing data of 79.17 %, which is same to the accuracy value on testing data for the MLP model. The Naïve Bayes model performs worse than the other models, with an accuracy of 38.74 % on training data and 41.17 % on testing data.

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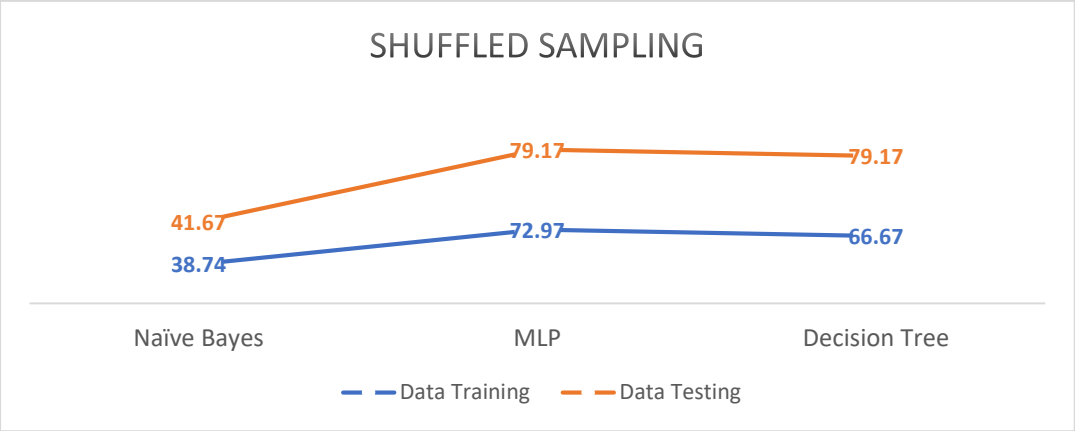


Figure 4.56. Comparison the accuracy of classification algorithms based on shuffled sampling

As for the modelling process in the type of stratified sampling and random sampling (automatic) has the same accuracy value for each of the training data and testing data. can be seen in Figure 4.57. From the figure it can be seen that the MLP model has a high accuracy value than other models, with an accuracy value of 81.98 % for training data and 79.17 % for testing data. For the Decision Tree model, the accuracy value on the training data is 70.27 % and the accuracy value on the testing data is 79.17 %. The Naive Bayes model has an accuracy score of 40.54 % on the training data and an accuracy score of 41.67 % on the testing data. However, with this type of sampling, the MLP model experiences data overfitting. The accuracy value of the training data is higher than that of the testing data.

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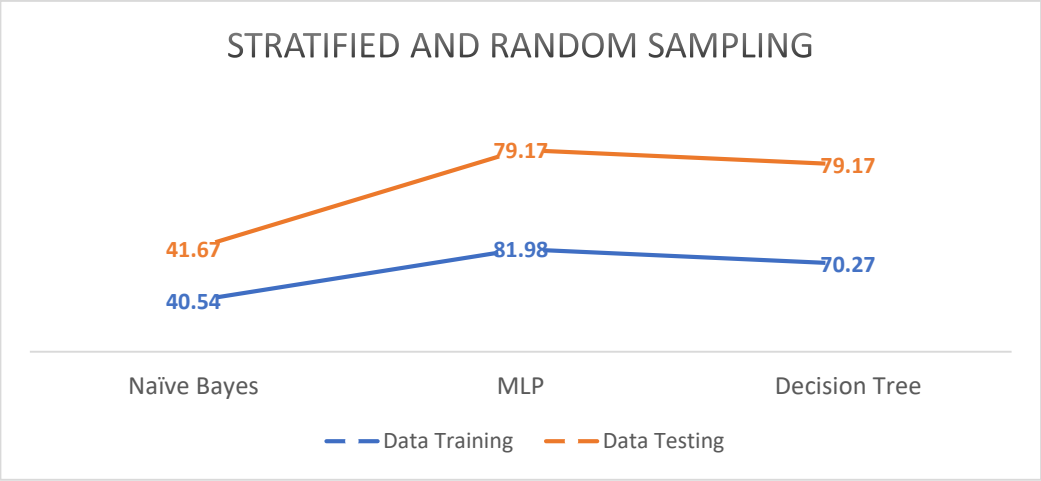


Figure 4.57. Comparison the accuracy of classification algorithms based on stratified and random sampling (automatic)

4.6.3 Summary modelling classification

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From the results of the modelling process, it can be concluded that the classification model uses data learning analysis of creativity and logic development in children aged 3-4 years, comparing the Naive Bayes, MLP and Decision Tree algorithms with a training and testing data ratio of 70:30. It was found that the MLP algorithm model provided excellent performance in classifying the data. By using the shuffled sampling type, the accuracy value on the training data is 72.97 %, and on the testing data is 79.17 %. While the evaluation metrics generated in the MLP model for the precision value is 69.67 % and the recall value is 67.41 %. It can be understood that the Multilayer Perceptron (MLP) model in learning data classification has an accurate and significant recognition rate from other models. This is also proved in (Jeyanathan, 2018) in breast classification based on thermogram transformation, where the performance of the MLP measure for classification shows a low error score.

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In addition, based on the tested model, the clustering for the development of creativity and logic in children of 3-4 years of age can be carried out earlier than the game in the third session. However, the development is different for each game. For the development of creativity, children can be grouped from the third game in the third session, while for the development of logic, children can be grouped from the first game in the third session.

4.7 Usability study of The Game-based Learning Analytics Platform Using System Usability Scale

The procedure for carrying out the usability study of game-based learning has been explained in detail in Chapter 3. Furthermore, this section will present the results of the usability study of the game-based learning analytic that has been developed. Respondents were 4 teachers, 20 parents and 20 children from two different institutions namely: TASKA PERMATA, NCDRC, UPSI and PAUD Manhajul Husna. In this study, SUS has been used to assess the usability of both games as well as learning analytic platforms. Teachers and parents have answered the SUS questionnaire prepared according to the procedures mentioned in section 3.6.5, in Chapter 3.

Feedback from teachers is invaluable in the evaluation and development of creative and logic game applications and learning analytics platforms. Teachers have a deep understanding of the needs and characteristics of the children in their learning environment. By observing children while playing games, teachers can see first-hand how children react, interact, and learn through using the platform. Their feedback on the learning analytics platform is also very important. Meanwhile, responses from

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parents in the questionnaire can provide valuable insights for the development of a learning analytics platform. This allows them to identify areas of improvement, adjust content or features, and ensure that the platform is acceptable and useful for parents in supporting children's learning in the home environment. As for the children, the questions had been explained to them by their teacher, and they answered by selecting 'smiling face' for 'YES' or 'Frowning face' for 'NO'. In this study, children only answered six questions related to their experience of playing creative and logical games.

4.7.1 Usability Results for Logic Game

4.7.1.1 Teachers

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This questionnaire data is a question given to teacher respondents by using games that have been carried out by their children. Divided into 3 parts. The first part is the teacher's information. The second part is questions 1 to 10 using the Linkert scale, namely (1) strongly disagree (2) disagree (3) neutral (4) agree (5) strongly agree. While the third part has two questions, which question 11 needed them to answer ‘Yes’ or ‘No’, and question 12 is a free-filled answer, where they need to give their feedback on suggestion for improvement, if any. Shown in the Table 4.33, while Table 4.34 shows the description for all the values based on the teacher’s respond.

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Table 4.33

Logic game questionnaire for teacher

Part	Question
one	- Name - Gander
second	1. I think children would like to play this (logic) game regularly 2. I find the game (logic) unnecessarily complex for children 3. I think the (logic) game is easy to play by children 4. I think children need adult support/help to play this (logic) game 5. I find the various functions in this (logic) game are well integrated 6. I find too many inconsistencies in this (logic) game 7. I find most children learn to use this (logic) game quickly 8. I find children are very awkward playing this (logic) game 9. I find children are very confident when playing this (logic) game 10. I think children need to learn a lot of things before they can play this (logic) game
third	11. Are you satisfied with this (logic) game? 12. Suggestions for game improvement, if any

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Table 4.34

The description of all the values based on the teacher's respond

Name	Type	Width	Decimals	Values	Measure
Gender	Numeric	8	0	1 = Woman 2 = Man	Nominal
Question 1 - 10	Numeric	8	0	1 = Strongly Disagree 2= Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree	Ordinal
Question 11	Numeric	8	0	1 = Yes 2 = No	Ordinal

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The results of the recapitulation of data obtained from 4 teachers, for questions 1 to 10. while respond for Q11 and Q12 will be as the additional information for future reference. Can be seen in table 4.35. For table 4.36 The overall SUS score for logic game form teachers.

Table 4.35

The score for each item based on teacher's respond

Respondent	**Gender**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**
T1	1	5	1	4	1	4	2	4	2	4	1	1
T2	1	5	1	4	1	4	2	4	2	4	1	1
T3	2	4	2	5	2	5	1	5	2	5	2	1
T4	1	5	2	5	2	5	1	5	1	5	1	1

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Table 4.36

The overall SUS score for logic game form teachers

System Usability Scale (SUS)													Score
Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total	(Total x 2,5)
T1	1	4	4	3	4	3	3	3	3	3	4	34	85
T2	1	4	4	3	4	3	3	3	3	3	4	34	85
T3	2	3	3	4	3	4	4	4	3	4	3	35	88
T4	1	4	3	4	3	4	4	4	4	4	4	38	95
							Total						353
							Average Score						88,13

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The results of calculations with 4 respondents obtained with a total score of 353 then the average value or SUS score obtained is 88,13. Based on the average score, the game acceptability aspect based on questions to the teacher is included in the category 'Best Imaginable'. As mentioned in Chapter 3, Section 3.6.5.2, Table 3.11 has been referred to, showing the acceptable SUS score as stated by Aaron Bangor, et al., (2008)

Apart from that, when analysing the responds from these teachers on Q11 and Q12 which are more to their satisfaction and suggestion for improvement, the respond from them is very positive and it shows that overall, the teachers are satisfied with the logic game application but with improvement, such as increase the number of games as well as the games difficulties, so that children will be more motivated to solve the games. These results are shown in Table 4.37.

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Table 4.37

Teacher' respond for question 11 and 12

Respondent	Gender	Q11	Q12
T1	1	1	
T2	1	1	
T3	2	1	*Kekalkan dan tambahkan lagi game*
T4	1	1	*Permainan yang dimainkan perlu ada sedikit kesusahan supaya kanak-kanak lebih bersemangat untuk bermain lebh tekun*

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4.7.1.2 Children

For children the questionnaire is still being developed based on the SUS presented in Table 3.8 in Chapter 3. In this process, the teacher asks questions to the children, and the children answer by choosing a 'smiling face' for 'YES' or a 'frowning face' for 'NO'. Only six items were asked of the children, to get their responses to the games they had played. This questionnaire is divided into two parts. The first part is the child's information, while the second part is questions 1 to 6 using a scale of 1 to represent 'NO' which corresponds to 'Strongly Disagree' and 5 to represent 'YES' which corresponds to 'Strongly Agree'. Table 4.38 shows the questions that must be answered by the child, while Table 4.38 shows an overview of all values based on the child's answers.

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Table 4.38

Logic game questionnaire for children

Part	Question
one	- Name - Gander
second	1. I think I would like to play this (logic) game regularly 2. I thought I need adult support/help to play this (logic) game 3. I thought the (logic) game is easy to play 4. I learn to use (logic) game quickly 5. I felt very awkward playing this (logic) game 6. I felt very confident when playing this (logic) game

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Table 4.39

The description of all the values based on the children's respond

Name	Type	Width	Decimals	Values	Measure
Gender	Numeric	8	0	1 = Girl 2 = Boy	Nominal
Question 1 - 6	Numeric	8	0	1 = No 5 = Yes	Ordinal

The results of data recapitulation were obtained from 20 children, for questions 1 to 6 presented in Table 4.39. This result shows the score for each answer before calculating the SUS score. While Table 4.40 shows the final score after calculating the SUS score, based on the formula used by Lewis, James & Sauro, Jeff, 2018. As stated in section 3.6.5.1, Chapter 3, the calculation of the SUS score results from children is slightly different, because the number of items said positive and negative tone is different as previously described in Table 3.7. Because the items used are less than ten, the maximum score contribution is adjusted to four multiplied by the number of items used (4 x 6) which is then equated to 24 not 40. So, to get a multiplier from this SUS, one hundred is divided by twenty four (100 /24), which will result in a new multiplier of 4.166 instead of 2.5 (Lewis & Sauro, 2018).

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Table 4.40

The score for each item based on children's respond

Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6
C1	2	1	5	5	1	1	1
C2	1	5	5	5	5	1	5
C3	1	5	5	5	5	5	5
C4	2	1	1	1	5	1	1
C5	2	5	5	5	5	5	5
C6	2	5	5	5	5	5	5
C7	1	5	5	5	5	1	5
C8	1	5	5	5	5	1	5
C9	2	5	5	5	5	5	5
C10	2	5	5	5	5	5	5
C11	2	5	5	5	5	5	5
C12	2	1	5	5	5	5	5
C13	1	5	1	5	5	1	5
C14	1	5	1	5	5	1	5
C15	1	5	5	5	5	5	5
C16	2	5	1	5	5	1	5
C17	1	5	1	5	5	1	5
C18	1	5	5	1	5	1	5
C19	1	5	5	5	5	5	5
C20	1	5	5	5	5	5	5

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Table 4.41

The overall SUS score for logic game from children

System Usability Scale (SUS)								Total	Score (Total x 4,1667)
Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6		
C1	2	0	0	4	0	4	0	8	33,3336
C2	1	4	0	4	4	4	4	20	83,334
C3	1	4	0	4	4	0	4	16	66,6672
C4	2	0	4	0	4	4	0	12	50,0004
C5	2	4	0	4	4	0	4	16	66,6672
C6	2	4	0	4	4	0	4	16	66,6672
C7	1	4	0	4	4	4	4	20	83,334
C8	1	4	0	4	4	4	4	20	83,334
C9	2	4	0	4	4	0	4	16	66,6672
C10	2	4	0	4	4	0	4	16	66,6672
C11	2	4	0	4	4	0	4	16	66,6672
C12	2	0	0	4	4	0	4	12	50,0004
C13	1	4	4	4	4	4	4	24	100,0008
C14	1	4	4	4	4	4	4	24	100,0008
C15	1	4	0	4	4	0	4	16	66,6672
C16	2	4	4	4	4	4	4	24	100,0008
C17	1	4	4	4	4	4	4	24	100,0008
C18	1	4	0	0	4	4	4	16	66,6672
C19	1	4	0	4	4	0	4	16	66,6672
C20	1	4	0	4	4	0	4	16	66,6672
					Total				1450
					Average Score				72,50

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The results of calculations with 20 respondents obtained with a total score of 1450 then the average value or SUS score obtained is 72,50. Based on the average score, the acceptability aspect of the game based on questions to children is included in the category 'GOOD'.

4.7.2 Usability Results for Creative Game

4.7.2.1 Teachers

The same process was repeated to get feedback from teachers about the usefulness of this creative game. In this case, 4 parents were involved, where these parents were parents who had given consent for their children and themselves to be involved in this study. The questions are the same as those used previously to evaluate the usefulness of logic games given to teachers as shown in Table 4.33, but these questions are for creative games, as shown in Table 4.42. Therefore, here the overall results based on parental responses are shown in Table 4.43. This result shows the score for each answer before calculating the SUS score. While Table 4.44 shows the final score after calculating the SUS score, based on the formula used by Aaron Bangor, et al., (2008).

Table 4.42

Creative game questionnaire for teacher

Part	Question
one	- Name - Gander

(continue)

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Table 4.42 *(continue)*

Part	Question
second	1. I think children would like to play this (creative) game regularly 2. I find the game (creative) unnecessarily complex for children 3. I think the (creative) game is easy to play by children 4. I think children need adult support/help to play this (creative) game 5. I find the various functions in this (creative) game are well integrated 6. I find too many inconsistencies in this (creative) game 7. I find most children learn to use this (creative) game quickly 8. I find children are very awkward playing this (creative) game 9. I find children are very confident when playing this (creative) game 10. I think children need to learn a lot of things before they can play this (creative) game
third	11. Are you satisfied with this (creative) game? 12. Suggestions for game improvement, if any

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Table 4.43

The score creative for each item based on teacher's respond

Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
T1	1	5	1	4	1	4	1	5	2	5	1	1
T2	1	4	3	4	1	4	2	4	2	4	1	1
T3	2	5	1	4	2	4	2	4	2	4	2	1
T4	1	2	5	1	5	4	2	4	4	4	2	2

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Table 4.44

The overall SUS score for creative game from teachers

System Usability Scale (SUS)												Total	Score (Total x 2,5)
Respondent	Gender	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q 10		
T1	1	4	4	3	4	3	4	4	3	4	4	37	93
T2	1	3	2	3	4	3	3	3	3	3	4	31	78
T3	2	4	4	3	3	3	3	3	3	3	3	32	80
T4	1	1	0	0	0	3	3	3	1	3	3	17	43
							Total						293
							Average Score						73,13

The results of calculations with 4 respondents obtained with a total score of 293, then the average value or SUS score obtained is 73,13. Based on the average score, the game acceptability aspect based on questions to the teacher is included in the category 'GOOD'. In addition, when analysing the responses from these teachers in Q11 and Q12, one teacher said 'NO' to the satisfaction of creative games. For suggestions for improvement, their responses were positive and showed that overall, the teachers were satisfied with the application of creative games but with improvements. These results are shown in Table 4.45.

Table 4.45

Teacher' respond for question 11 and 12 (creative)

Respondent	Gender	Q11	Q12
T1	1	1	
T2	1	1	
T3	2	1	*Pelbagaikan lagi game yang krratif* - *Ada beberapa elemen semasa permainan ini berjalan. Cth: sensentif dengn permukaan tab menyebabkan kanak-kank sering menggunakan.*
T4	1	2	- *Permainan perlu lebih menyeronokkan dan sesuai dengan kanak-kanak*

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4.7.2.2 Children

For children's questionnaires on creative games, the same process was repeated to elicit responses from children on logic games. For children the questionnaire is still being developed based on the SUS presented in Table 3.8 in Chapter 3. In this process, the teacher asks questions to the children, and the children answer by choosing a 'smiling face' for 'YES' or a 'frowning face' for 'NO'. Only six items were asked of the children, to get their responses to the games they had played. This questionnaire is divided into two parts. The first part is the child's information, while the second part is questions 1 to 6 using a scale of 1 to represent 'NO' which corresponds to 'Strongly Disagree' and 5 to represent 'YES' which corresponds to 'Strongly Agree'. Table 4.46 shows the questions that must be answered by the child, while showing an overview of all values based on the child's answers, as in Table 4.38 in the logic game.

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Table 4.46

Creative game questionnaire for children

Part	Question
one	- Name - Gander
second	1. I think I would like to play this (creative) game regularly 2. I thought I need adult support/help to play this (creative) game 3. I thought the (creative) game is easy to play 4. I learn to use (creative) game quickly 5. I felt very awkward playing this (creative) game 6. I felt very confident when playing this (creative) game

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The results of data recapitulation were obtained from 20 children, for questions 1 to 6 presented in Table 4.47. This result shows the score for each answer before calculating the SUS score. While Table 4.48, shows the final score after calculating the SUS score, based on the formula used by Lewis, James & Sauro, Jeff, 2018. This process is repeated, the same as the data recapitulation process obtained from logical games.

Table 4.47

The score creative for each item based on children's respon

Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6
C1	2	1	5	5	5	1	5
C2	1	5	5	5	5	1	5
C3	1	5	5	5	5	5	5
C4	2	1	1	5	5	1	5
C5	2	5	5	5	5	5	5
C6	2	5	5	5	5	5	5
C7	1	5	5	5	5	1	5
C8	1	5	5	5	5	1	5
C9	2	5	5	5	5	5	5
C10	1	5	5	1	5	5	5
C11	2	1	5	1	5	1	5
C12	1	5	5	5	5	5	5
C13	1	5	5	5	5	1	5
C14	2	5	5	1	5	1	5
C15	2	5	5	5	5	1	5
C16	2	5	5	5	5	5	5
C17	1	5	5	5	5	1	5
C18	1	5	5	1	5	1	5
C19	1	5	5	5	5	1	5
C20	1	5	5	1	5	1	5

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Table 4.48

The overall SUS score for creative game from children

System Usability Scale (SUS)								Total	Score
Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6		(Total x 4,1667)
C1	2	0	0	4	4	4	4	16	67
C2	1	4	0	4	4	4	4	20	83
C3	1	4	0	4	4	0	4	16	67
C4	2	0	4	4	4	4	4	20	83
C5	2	4	0	4	4	0	4	16	67
C6	2	4	0	4	4	0	4	16	67
C7	1	4	0	4	4	4	4	20	83
C8	1	4	0	4	4	4	4	20	83
C9	2	4	0	4	4	0	4	16	67
C10	1	4	0	0	4	0	4	12	50
C11	2	0	0	0	4	4	4	12	50
C12	1	4	0	4	4	0	4	16	67
C13	1	4	0	4	4	4	4	20	83
C14	2	4	0	0	4	4	4	16	67
C15	2	4	0	4	4	4	4	20	83
C16	2	4	0	4	4	0	4	16	67
C17	1	4	0	4	4	4	4	20	83
C18	1	4	0	0	4	4	4	16	67
C19	1	4	0	4	4	4	4	20	83
C20	1	4	0	0	4	4	4	16	67
					Total				1433
					Average Score				71,67

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The results of calculations with 20 respondents obtained with a total score of 1433 then the average value or SUS score obtained is 71,67. Based on the average score, the acceptability aspect of the game based on questions to children is included in the category 'GOOD'.

4.7.3 Usability Results for Learning Analytics Platform

4.7.3.1 Teachers

As mentioned in the previous section, feedback from teachers was collected for the logic game application and learning analytics platform. The questions are similar to those used previously to evaluate the usefulness of logic games. However, for the use of learning analytics platforms, there are other questions that are added to obtain additional information about how far the platform helps teachers and parents in getting information about children's development and development in real time. However, this question was excluded from the SUS calculation, because it was considered as additional information for researchers in this study. Table 4.49 shows the questions that must be answered by the teacher.

Table 4.49

Learning analytic platform questionnaire for teacher

Part	Question
One	- Name - Gander

(continue)

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Table 4.49 *(continue)*

Part	Question
Second	1. I think I would like to use this analytics platform regularly 2. I find the analytics platform unnecessarily complex 3. I think the analytic platform is easy to be used 4. I need technical people support/help to use this analytic platform 5. I find the various functions in this analytics platform are well integrated 6. I find too many inconsistencies in this analytic platform 7. I learn to use this analytic platform quickly 8. I feel very awkward when using this analytic platform 9. I feel very confident when using this analytic platform 10. I think I need to learn many things before I can use this analytic platform 11. Information about children progress in this analytic platform make it easy for me to monitor my children's development in real time
Third	12. Are you satisfied with this analytic platform? 13. Suggestions for analytic platform improvement, if any

The overall results based on teacher responses are shown in Table 4.50. This result shows the score for each answer before calculating the SUS score. While Table 4.51 shows the final score after calculating the SUS score, based on the formula used by Aaron Bangor, et al., (2008). For the overall SUS score, only the scores for Q1 to Q10 will be considered, while the responses for Q11, Q12 and Q13 will be additional information for future reference.

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Table 4.50

The score for each item based on teacher's respond

Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
T1	1	4	2	4	1	4	2	5	1	4	21	2
T2	1	5	1	4	1	4	1	5	1	4	1	4
T3	2	5	2	5	2	5	2	4	2	4	1	5
T4	1	4	1	5	1	5	1	5	1	5	2	5

Table 4.51

The overall SUS score for learning analytic platform from teachers

System Usability Scale (SUS)												Total	Score
Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		(Total x 2,5)
T1	1	3	3	3	4	3	3	4	4	3	4	34	85
T2	1	4	4	3	4	3	4	4	4	3	4	37	93
T3	2	4	3	4	3	4	3	3	3	3	4	34	85
T4	1	3	4	4	4	4	4	4	4	4	3	38	95
							Total						358
							Average Score						89.38

The results of calculations with 4 respondents obtained with a total score of 358 then the average value or SUS score obtained is 89,38. Based on the average score, the game acceptability aspect based on questions to the teacher is included in the category ‘Best Imaginable’. As for Q11, most of the teachers agreed that this platform has the potential to give information about the children’s development and this platform helps

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them in monitoring children's development in real time. Apart from that, when analysing the responds from these teachers on Q12 and Q13, all of them are satisfied with the learning analytic platform but with improvement, by suggesting that the game should be made in desktop version aside the mobile version so that children can have a more flexible platform to get access to the game.

4.7.3.2 Parents

The same process was repeated to get feedback from parents about the usefulness of this learning analytics platform. In this case, 20 parents were involved, where these parents were parents who had given consent for their children and themselves to be involved in this study. The questions are the same as those used previously to evaluate the usefulness of the learning analytic platform provided to teachers as shown in Table 4.49. Therefore, here the overall results based on parental responses are shown in Table 4.52. This result shows the score for each answer before calculating the SUS score. While Table 4.53 shows the final score after calculating the SUS score, based on the formula used by Aaron Bangor, et al., (2008).

The results of 20 respondents obtained a total score of 1313, with the average value or SUS score obtained being 78.75. Based on acceptable SUS scores as stated by Aaron Bangor, et al., (2008), the average SUS scores for this learning analytic platform by parents indicated that the platform was 'Acceptable' and ‘Excellent’. As for Q11, most parents agree that this platform has the potential to provide information about child development and this platform helps them monitor child development in real time

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as shown in Table 4.31. As for Q12, all of them are satisfied with the learning analytics platform, but for Q13, there is no response given by parents.

Table 4.52

The score for each item based on parent's respond

Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
P1	1	5	5	5	4	4	5	5	1	4	5	5
P2	1	4	4	4	5	4	2	4	1	4	4	2
P3	2	5	5	5	5	4	1	4	4	4	4	4
P4	2	4	4	5	5	4	4	5	5	5	2	4
P5	1	4	4	5	4	4	1	4	2	4	4	4
P6	1	4	4	4	4	4	4	4	4	4	4	4
P7	1	4	4	5	4	4	4	5	2	5	4	4
P8	2	5	5	5	5	4	2	4	4	4	4	4
P9	2	5	5	4	4	4	2	4	4	4	4	4
P10	1	4	4	5	4	4	4	5	2	5	4	4
P11	2	4	2	4	2	4	2	4	2	4	2	4
P12	1	4	4	4	2	4	2	4	2	4	2	4
P13	2	4	4	4	4	4	4	4	4	4	4	4
P14	1	4	4	5	2	4	2	5	1	4	1	5
P15	2	4	5	5	2	2	2	4	2	5	4	5
P16	1	4	4	5	4	5	2	4	1	5	1	5
P17	1	5	2	5	2	4	1	4	1	4	1	4
P18	2	5	2	5	2	5	2	4	2	4	2	5
P19	1	4	2	4	4	4	2	4	2	4	4	4
P20	2	4	2	4	2	5	2	4	1	4	2	4

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Table 4.53

The overall SUS score for learning analytic platform from parents

System Usability Scale (SUS)												Total	Score
Respondent	Gender	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		(Total x 2,5)
P1	1	4	0	4	1	4	0	4	4	3	0	23	58
P2	1	1	1	3	0	3	3	3	4	3	1	24	60
P3	2	4	0	4	0	4	1	3	1	4	1	23	58
P4	2	4	1	4	0	4	1	4	0	4	3	23	58
P5	1	3	1	4	1	3	1	3	3	3	1	26	65
P6	1	3	1	3	1	3	1	3	1	3	1	20	50
P7	1	4	1	4	1	4	1	4	3	4	1	25	63
P8	2	4	0	4	0	4	3	3	1	4	1	22	55
P9	2	4	0	4	1	4	3	3	1	4	1	22	55
P10	1	3	1	4	1	4	1	4	3	4	1	25	63
P11	2	3	3	3	3	3	3	3	3	3	3	30	75
P12	1	3	1	3	3	3	3	3	3	3	3	28	70
P13	2	3	1	3	1	3	1	3	1	3	1	20	50
P14	1	3	1	4	3	3	3	4	4	3	4	32	80
P15	2	3	0	4	3	1	3	3	3	4	1	25	63
P16	1	3	1	4	1	4	3	3	4	4	4	31	78
P17	1	4	3	4	3	3	4	3	4	3	4	35	88
P18	2	4	3	4	3	4	3	3	3	3	3	33	83
P19	1	3	3	3	1	3	3	3	3	3	1	26	65
P20	2	3	3	3	3	4	3	3	4	3	3	32	80
							Total						1313
							Average Score						78.75

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4.7.4 Overall Usability Results for the Game-based Learning Analytics Platform

As described in sections 4.6.1 to 4.6.3, the overall results of the usability study on this game-based Learning Analytics Platform, can be summarised in Table 4.54 and Figure 4.58. It can be seen that the overall average SUS scores for teachers, children and parents for the creativity and logic game, as well as the learning analytics platform are above 70, which according to Aaron Bangor et al, (2008), these game applications and platforms are considered 'Acceptable' and in the range of 'Good' and Excellent'. However, despite the SUS score received, respondents also provided some suggestions for improvement and from the observations made during this study, it can be seen that the platform has the potential to be used as an aid in teaching and learning, to attract the attention of children with 'Slow learner' learning problems. Feedback from the teachers of PAUD Manhajul Husnal in Indonesia, they found that, one of their children had problems understanding shapes and colours, but after the children went through the learning process with creative and logic games, the children showed a better understanding of shapes and colours, when the teachers asked randomly about it by using reversed cards. In addition, the children were able to generate innovative new ideas from a shape drawing into a creative art expression such as a drawing of an animal, such as a fish, cat, butterfly, snake or caterpillar. According to the teachers, children were able to distinguish, understand and name shapes and colours when asked, after playing with the games. This observation is interesting and could be investigated further in future research.

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Table 4.54

The overall SUS score obtained from the SUS method (Bangor et al., 2008)

	SUS FOR LOGIC GAME		SUS FOR CREATIVE GAME		SUS FOR PLATFORM	
	Teacher	**Children**	**Teacher**	**Children**	**Teacher**	**Parent**
No of Respondent	4	20	4	20	4	20
Mean SUS Score	88,13	72,50	73,13	71,67	89,38	78,75
Acceptability Range	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Adjective Ratings	Best Imaginable	Good	Good	Good	Best Imeginable	Excellent

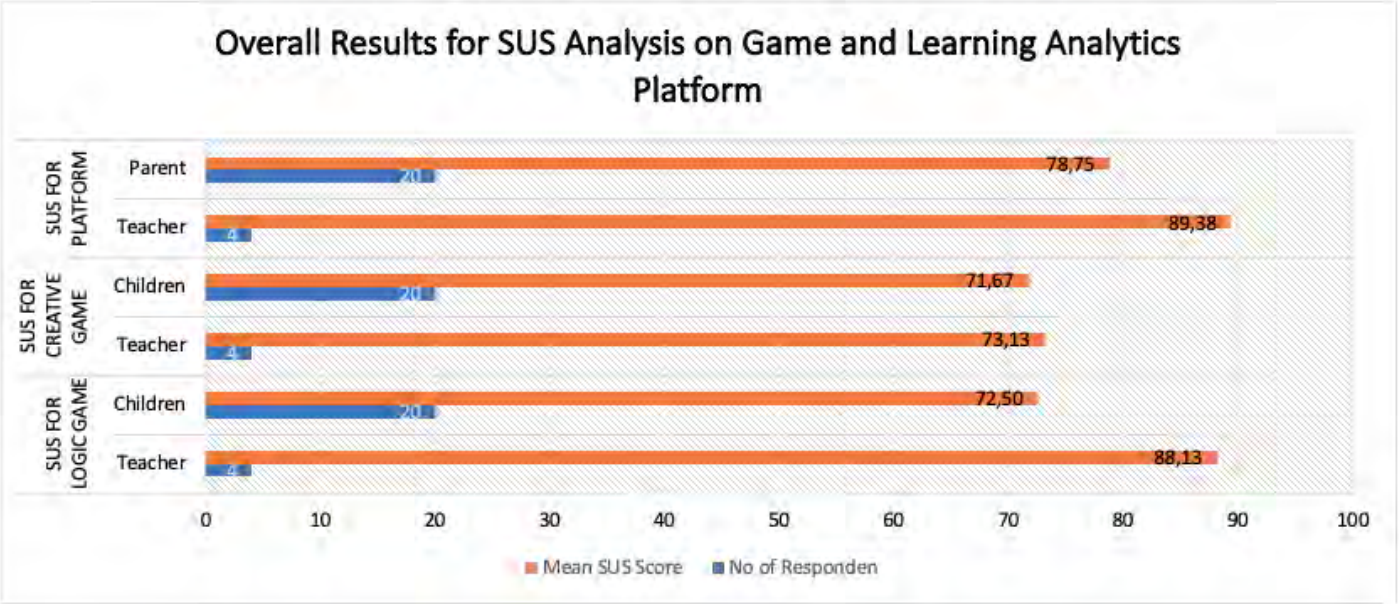


Figure 4.58. The Overall results for SUS Analysis on Games and Learning Analytics Platform

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4.8 Validation and Evaluation Game Based Learning Analytics Platform (GBLAP)

This section is a presentation of the results of the validation and evaluation process which was the subject of the previous chapter. Validation and evaluation test process was carried out by two experts, namely learning material experts and learning media experts. The process of validation and evaluation is carried out in stages, because in this case the validation test is carried out in two games, namely creativity games and logic games, the first stage is carried out by learning material experts and the second stage by learning media experts. Validation of learning materials by learning materials experts was carried out by Verawati Mandey S.Pd. Banjarmasin, Indonesia. While the learning media validity testing process by learning media experts was conducted by Muhammad Edya Rosadi, M.Kom. Department of Informatics Engineering, Faculty of Information Technology, Islamic University of Kalimantan MAB Banjarmasin.

4.8.1 Validation of Creative Game on GBLAP

The process of validating the Creative Games, which are aimed at children aged 3-4, took place in two stages. In the first stage, it was carried out on a team of experts in learning materials. S.Pd, Head Teacher at Manhajul Husna, Banjarmasin, Indonesia. The results of the instrument answered by the expert on learning materials are shown in Table 4.55.

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Table 4.55

Validation results from Material Experts: Creative Game

Variable	Sub Variable	Indicator	Score
Learning Material Validation	Learning	The suitability of the presented learning material	4
		The clarity of the material presented	4
		The simplicity with which learning materials can be understood	3
	Content	The accuracy of the content of the learning material	3
		The correct procedure for learning materials	3
		The suitability of learning materials with the curriculum	3
		The presented material can enhance children's knowledge	3
	Presentation	The simplicity of the language used in the presentation of learning materials	3
		The suitability of learning materials with children's basic skills	3
		The suitability of the materials to the learning objectives	3
	Effectiveness	The presented learning materials are effective for learning purposes	3
		The effectiveness of media in learning material delivery based on users	4
		TOTAL	39

Table 4.55 presents the results of the learning material validation instrument assessment conducted by the learning material validator using the measurements described in Table 3.17 and a Likert scale. The level of validity of learning materials on creativity games is calculated according to the process described in section 3.5.2, which yielded the following results:

$$PSP = \frac{\sum score\ of\ all\ aspects}{\max \sum score\ of\ all\ aspects\ x\ N}\ x\ 100\% \qquad (3.19)$$

$$PSP = \frac{39}{48}\ x\ 100\%$$

$$PSP = 81\%$$

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The validation results for the learning materials were 81%, placing them in the 'Valid' category. Although the media meets the desired criteria, improvements must still be made in the next stage. The learning material expert validator gave a score of 3 in several indicators, including the simplicity of understanding the learning materials, the accuracy of their content, the correct learning procedures, their suitability with the curriculum, their ability to enhance children's knowledge, the simplicity of language used, their suitability with children's basic skills, their alignment with learning objectives, and their effectiveness for learning purposes

The second validation test process involves learning media validation conducted by experts in the field, including Muhammad Edya Rosadi M.Kom, a lecturer from the Informatics Engineering department at the Faculty of Information Technology, Islamic University of Kalimantan MAB Banjarmasin. The validation process is carried out by completing a questionnaire. The results of the questionnaire answered by the experts are shown in Table 4.56.

Table 4.56

Validation results from Media Experts: Creativity Game

Variable	Sub Variable	Indicator	Score
Learning Media Validation	Interface	The suitability of the theme used	4
		The attractiveness of the characters used	3
		The attractiveness of the animation used	3
		The attractiveness of colour	3
		The suitability of the design colour with the layout	3
		The attractiveness of the images used	3

(continue)

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Table 4.56 *(continue)*

Variable	Sub Variable	Indicator	Score
		The suitability of the image for the layout	3
	Font size	The clarity of the font or letters to read	3
		The suitability of the font size used	3
		The suitability of the font colour used	3
	Audio	The suitability of the background music used	2
		The attractiveness of the background music used	2
	Instruction	The clarity of instructions for the use of GBLAP media	3
	Comfortable	The simplicity of using GBLAP media	3
		The simplicity of the language used in GBLAP media	2
		TOTAL	43

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Table 4.56 presents the results of the learning media validation instrument assessment conducted by learning media validators. The measurement was carried out using a Likert scale, as shown in Table 3.17. The validity level of the learning media for creativity games was calculated according to the process described in section 3.5.2, with the following outcomes:

$$PSP = \frac{\sum score\ of\ all\ aspects}{\max \sum score\ of\ all\ aspects\ x\ N}\ x\ 100\%$$

$$PSP = \frac{43}{60}\ x\ 100\%$$

$$PSP = 72\%$$

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The learning materials validation results scored 72%, placing it in the 'Valid' category. While the media meets the desired criteria, there are still areas for improvement in the next stage. The learning media expert validator gave a score of 2 on several indicators, including the suitability and attractiveness of the background music used, as well as the simplicity of the language used in GBLAP media

4.8.2 Validation of Logic Games on GBLAP

Logic games designed for 3-4 year olds were used for the validation test. The first stage involved a team of learning materials experts under the leadership of Verawati Mandey S.Pd, head teacher at Manhajul Husna in Bangmasin, Indonesia. Verawati Mandey is a teacher at Manhajul Husna in Banjarmasin, Indonesia. The results of the learning materials experts' responses to the instrument are shown in Table 4.57.

Table 4.57

Validation results from Material Experts: Logic Game

Variable	Sub Variable	Indicator	Score
Learning Material Validation	Learning	The suitability of the presented learning material	4
		The clarity of the material presented	4
		The simplicity with which learning materials can be understood	4
	Content	The accuracy of the content of the learning material	4
		The correct procedure for learning materials	4
		The suitability of learning materials with the curriculum	4
		The presented material can enhance children's knowledge	4

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Table 4.57 *(continue)*

Variable	Sub Variable	Indicator	Score
	Presentation	The simplicity of the language used in the presentation of learning materials	3
		The suitability of learning materials with children's basic skills	3
		The suitability of the materials to the learning objectives	3
	Effectiveness	The presented learning materials are effective for learning purposes	4
		The effectiveness of media in learning material delivery based on users	3
		TOTAL	44

The results of the assessment of the validation tool carried out by the learning material validator are presented in Table 4.57. The measurements have been described in table 3.17 with the help of a Likert scale. The level of validity of the learning materials for creativity games has been calculated in accordance with the description in section 3.5.2.

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$$PSP = \frac{\sum score\ of\ all\ aspects}{\max \sum score\ of\ all\ aspects\ x\ N}\ x\ 100\% \qquad (3.19)$$

$$PSP = \frac{44}{48}\ x\ 100\%$$

$$PSP = 92\%$$

The learning materials achieved a validation score of 92%, placing them in the 'perfect' category. While the media meets the desired criteria, there are still areas for improvement that researchers should address in the next phase. The learning materials were evaluated by an expert validator who gave a score of 3 in several indicators,

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including the simplicity of the language used in the presentation of learning materials, the suitability of the materials with children's basic skills, the suitability of the materials to the learning objectives, and the effectiveness of media in delivering the learning materials to users. The second validation test process is the validation of the learning media, which is carried out by experts in the field of learning media, namely Muhammad Edya Rosadi M.Kom. Validation of learning media is done by answering the given questionnaire. The results of the questionnaire answered by the learning media experts are shown in Table 4.58.

Table 4.58

Validation results from Media Experts: Logic Game

Variable	Sub Variable	Indicator	Score
Learning Media Validation	Interface	The suitability of the theme used	4
		The attractiveness of the characters used	4
		The attractiveness of the animation used	3
		The attractiveness of colour	4
		The suitability of the design colour with the layout	4
		The attractiveness of the images used	4
		The suitability of the image for the layout	4
	Font size	The clarity of the font or letters to read	3
		The suitability of the font size used	3
		The suitability of the font colour used	3
	Audio	The suitability of the background music used	3
		The attractiveness of the background music used	3
	Instruction	The clarity of instructions for the use of GBLAP media	3
	Comfortable	The simplicity of using GBLAP media	3
		The simplicity of the language used in GBLAP media	3
		TOTAL	51

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The following table 4.58 shows the results of the evaluation of the learning material validation tool carried out by the learning material validator. Measurements described in Table 3.17 using a Likert scale. Procedure for calculating the level of validity of learning materials on creativity games. as described in section 3.5.2 with the following results:

$$PSP = \frac{\sum score\ of\ all\ aspects}{\max \sum score\ of\ all\ aspects\ x\ N}\ x\ 100\%$$

$$PSP = \frac{51}{60}\ x\ 100\%$$

$$PSP = 85\%$$

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The learning materials passed validation with a score of 72%, placing them in the 'Valid' category. However, the learning media expert validator identified several areas for improvement in the next stage, as the materials received a score of 3 on certain indicators. The evaluation criteria for GBLAP media include the clarity of instructions, ease of use, and language simplicity. The suitability of font size, colour, and animation, as well as the attractiveness of background music, are also important factors.

4.8.3 Evaluation Game Based Learning Analytics Platform (GBLAP)

The results of the manual learning were compared with the data from the game-based learning analytics platform, which are presented in Table 4.59. The sample size consisted of 10 children from TASKA NCDRC UPSI.

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Table 4.59

Comparing children's achievement for logic development based on teacher's assessment and game-based learning analytics platform (TASKA NCDRC, UPSI)

CHILDREN'S ACHIEVEMENT FOR LOGIC DEVELOPMENT (TASKA NCDRC, UPSI)		
	TEACHER	**GAME-BASED LEARNING ANALYTIC**
C1	LOW	MODERATE
C2	MODERATE	MODERATE
C3	MODERATE	MODERATE
C4	LOW	GOOD
C5	GOOD	GOOD
C6	LOW	MODERATE
C7	MODERATE	GOOD
C8	MODERATE	MODERATE
C9	MODERATE	MODERATE
C10	MODERATE	GOOD

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The comparison indicates that five children achieved the same score on both assessments, while five children scored higher on the game-based learning analytics platform than on the teacher assessment, as illustrated in Figure 4.59.

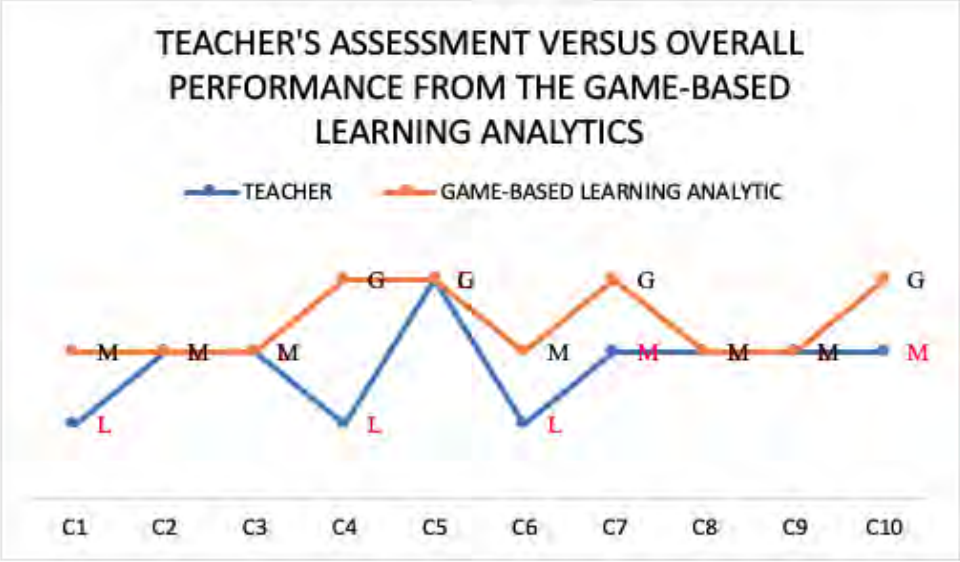


Figure 4.59. Comparison between the children's achievement for logic development based on teacher's assessment and game-based learning analytic platform

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As shown in Table 4.60, a sample of 10 children from PAUD Manhajul Husna Banjarmasin was analyzed for creativity.

Table 4.60

Comparing children's achievement for creativity development based on teacher's assessment and game-based learning analytics platform (PAUD MANHAJUL HUSNA, BANJARMASIN)

CHILDREN'S ACHIEVEMENT FOR CREATIVITY DEVELOPMENT (PAUD MANHAJUL HUSNA, BANJARMASIN)		
	TEACHER	**GAME-BASED LEARNING ANALYTIC**
C11	MODERATE	GOOD
C12	GOOD	GOOD
C13	MODERATE	GOOD
C14	GOOD	GOOD
C15	MODERATE	GOOD
C16	LOW	GOOD
C17	LOW	MODERATE
C18	MODERATE	MODERATE
C19	MODERATE	GOOD
C20	LOW	MODERATE

The comparison shows that 3 children scored the same, while 7 children scored higher than the game-based learning analytics platform, as shown in figure 4.60.

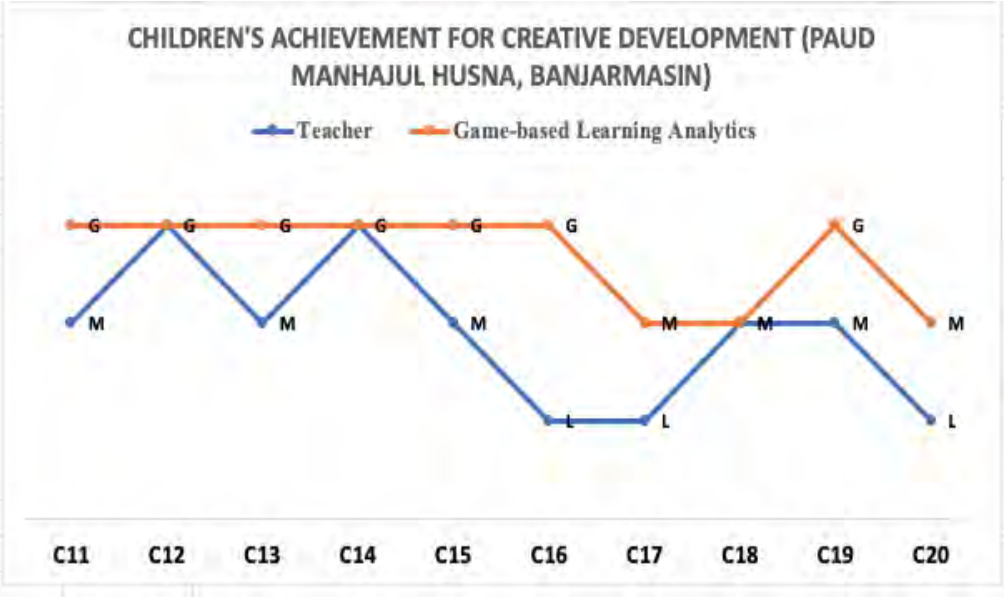


Figure 4.60. Comparison between the children's achievement for creativity development based on teacher's assessment and game-based learning analytic platform

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The results indicate that games can offer an interactive and engaging learning environment for children to learn and practice new concepts, such as shapes and colours. These findings are comparable to those of Kristanto et al. (2019), who found that educational game media is a viable and effective tool for learning (Kristanto, Mustaji, Mariono, Sulistiowati, & Afifah, 2019). Games can improve retention and understanding, as well as increase motivation and engagement. Game structures can present information in a way that is easier for children to understand, making the learning process less daunting and frustrating. This may contribute to improving children's understanding of creative and logical elements through game-based learning.

Games can provide a supportive environment for learning, increasing motivation and engagement. Papastergio's (2009) study found that game-based learning can lead to deeper learning, improving problem-solving and critical thinking skills. Kristanto (2019) argued that games are feasible and effective for learning. These studies demonstrate that game-based learning can enhance children's understanding and performance in various subjects. The results indicate that the game-based learning analytics platform has the potential to be used as an alternative tool for precise and efficient assessment of children's development. This could mark the beginning of a trend towards assessing children's development through digital games combined with learning analytics platforms.

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4.9 Chapter Summary

This chapter presents the research findings and discussions, covering all stages of the study. The study used data from the National Children's Data Centre (NCDC) to identify the most 'Not Achieved' of the 13 outcomes listed in the PERMATA checklist. The research also presented and discussed in detail the key findings related to the usability of the game-based learning analytics platform. The mean SUS scores for the creative and logical games and learning analytics platform were above 70, which is considered 'acceptable' and falls in the range of 'good' and 'excellent'. These scores were obtained from teachers, children, and parents. No subjective evaluations were included. The game-based learning analytics platform has the potential to serve as an alternative tool for assessing children's creativity and logical development. This is based on a comparison between teacher ratings and children's performance results while playing logic games. The platform could be used to assess more aspects of child development through digital games coupled with the learning analytics platform. Additionally, the use of artificial intelligence in the education of children aged 3 to 4 can be a powerful tool to enhance their learning experience by developing their creativity and logic. Artificial intelligence can quickly observe and analyses how each child responds and develops in their learning. This text describes an application of artificial intelligence in classification modelling, comparing the performance of Naïve Bayes, MLP, and Decision Tree algorithms using the LAP dataset to analyse the creativity and logic development of 3–4-year-olds. The results indicate that the MLP algorithm outperforms the Naïve Bayes and Decision Tree algorithms in classifying data related to the creativity and logic development of young children. The evaluation results, which

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include accuracy, precision, and recall, provide a comprehensive overview of the model's performance.

Validation and evaluation conducted on GBLAP for children's creativity and logic development showed that games can provide benefits in interactive learning environments, they provide an engaging and interactive learning experience for children and can effectively introduce new concepts and improve their memory and understanding of what is being taught. In addition, games can improve children's understanding of creativity and logic concepts and increase their motivation to learn. The next chapter, Conclusions and Future Research, discusses the main findings, contributions, limitations and future research directions.

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CHAPTER 5

CONCLUSION AND FUTURE RESEARCH

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5.1 Introduction

This chapter summarises the main findings, contributions, limitations and future research directions. Section 5.2 describes the research objectives that were achieved, and section 5.3 reports the research contributions. Section 5.4 states the limitations of the research, and section 5.5 outlines recommendations for future research. Finally, section 5.6 presents the research conclusion.

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5.2 Research Goals Attained

In this section the relationship between research aims, research methodology and research contribution is structured to demonstrate and explain the achievement of the research aims and to guide the research. The research problem statement states that in the development of creativity and logic in children aged 3-4 years, teachers find it difficult to capture children's attention and insight into their developmental process during the learning process, not only that the assessment of children's progress, which provides teachers with insight into their development, needs to know how far children have understood a learning topic, poses a challenge for teachers. This is because children move on to a new area of learning once the activity and assessment process is complete. For children who have 'not achieved' the concept or development in the learning process will be left behind.

To solve the research problem, this study set four main objectives. For each goal, there were specific objectives to be achieved. The first objective is to investigate the elements of creativity and basic logic development that have not been achieved in children aged 3-4 years based on data from The National Child Data Centre at NCDRC. The second objective is to develop a game-based learning model for the development of creativity and basic logic for children aged 3-4 years based on the elements identified in the first objective. The third objective is to develop a game-based learning analytics platform and compare classification algorithms on 3-4 years-old children's creativity and logic development data. The fourth objective is to conduct a usability study of the game-based learning analytics platform using the System Usability Scale (SUS).

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To achieve the research objectives, the research methodology consists of four phases. Each objective has a corresponding phase that indicates the main conclusions of the research contribution based on the technical analysis of the research objectives in each phase. The links between the research objectives, the research methodology phases, and the research objectives in each phase are shown in Table 5.1.

Table 5.1

The connection among research objectives, research methodology and research goals

Research Objective	**Research Methodology**	
	Phases	**Research Goals**
To Investigate	Phase: 1 Preliminary Study	• Literature review on 3-4 years old childhood education, learning theories, and game-based learning analytics approach. • Find out key gaps and challenges.
To Identify and develop game	Phase: 2 Identify	• Identify the process of developing children's creativity and logic. • Identify 'Not Achieved' development for childhood creativity and logic. • Develop and design learning needs. • Game requirement design. • Benchmark process develop creativity and logic.
To Develop Platform	Phase: 3 Development	• Develop a learning analytics platform for creativity and logic development needs. • Application of machine learning for modelling classification of creativity and logic development. • Usability Study using SUS
To validate and evaluate	Phase: 4 Validation and Evaluation	• Expert validation and evaluation of the game-based learning analytics platform.

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5.3 Research Contributions

This research represents a significant contribution to the field of educational technology by proposing the implementation of a data-driven analytical approach to the investigation and enhancement of the 3-4 year olds' creativity and logical reasoning abilities.

The application of AI and analytics-based assessments provides insights and recommendations for game developers, educators, and parents, which are designed to enhance learning outcomes and support children's optimal development. The integration of AI can be employed to analyse data in real-time, enabling the provision of personalised recommendations for each child based on their specific needs and abilities.

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This research contributes to the improvement of the quality of early childhood education by providing insights and data that can be used to enhance learning strategies. The methodology employed has been demonstrated to be effective in developing creativity and logic in young children through the analysis of data collected from the platform. The data and feedback provided by this research can assist teachers and parents in making more informed decisions regarding the learning methods employed.

Furthermore, the research provides insights into the learning processes of children aged 3-4 and practical tools and strategies for fostering their creativity and logic through advanced learning technologies. In addition to the development of creativity and logic, the resultant contribution is that social, emotional and cognitive

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skills on a game-based learning analytics platform provide an important dimension to a child's development. Social skills encompass collaboration and communication, and provide data on a child's abilities in these areas.

Emotional skills are where games challenge children with situations that require them to manage emotions such as frustration or happiness. Finally, cognitive skills, which require children to make quick decisions that affect outcomes, help children develop their ability to make good decisions based on information.

5.4 Research Limitations

This study has limitations that can be addressed in future research, as with any research. There are several limitations faced at this age, children may have limitations in understanding the complexity of the games created. Individual variability, where children have different levels of development, so adapting a game-based learning analytics platform to suit all children can be challenging. Limited access to technology, as not all children have equal access to technology, which can limit the implementation of the platform. The number of children that can be included in this study may be limited, which may limit the generalisability of the classification modelling results. In addition, children's datasets require special attention to privacy and ethics. Care should be taken in the management and use of children's data.

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5.5 Recommendations for Future Work

Future research is recommended as follows:

1. Conduct a more in-depth study of children's responses to different types of games or activities in a learning analytics platform. This will help in identifying the elements that are most effective in stimulating their creativity and logic.
2. Continue to develop a variety of games and activities that trigger children's creativity and logic. A variety of games helps maintain children's interest and maximiser learning, especially creativity games.
3. Focus on developing a more adaptive and personalized learning analytics platform to better tailor learning to children's individual needs using machine learning approaches.
4. Further exploration of the potential of artificial intelligence (AI) in support of early childhood learning. How artificial intelligence can enhance learning experiences that are more adaptive and responsive.

5.6 Research Summary

This research has produced a game-based learning analytics platform with the main features, namely creative and logic games, as well as a learning analytics platform website. The System Usability Scale (SUS) has been used to achieve the fourth objective, where the overall average SUS score for teachers, children and parents for the game and learning analytics platform is above 70, which is categorised as 'Acceptable' and is in the range of 'Good' and 'Excellent'. However, while the SUS score

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provides useful information about the usability of a system, it is only one metric and should be considered in the context of other system performance measures, such as user satisfaction, efficiency, and error rates, which we have considered in this study by asking Questions 11 to 13, to gain additional information especially on suggestions for improvement.

The results also show that the game has a positive impact on children's cognitive and motor development. It provides an engaging and interactive way for children to learn and practise skills, which helps build understanding and mastery of concepts. For the use of game-based learning analytics has the potential to significantly improve the learning experience for children by providing valuable information to teachers and parents.

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- Benefits for Teachers:
    1. A better understanding of childhood progress.
    2. Increased engagement and motivation.
    3. Data-driven insights.
    4. Improved assessment.
    5. Improved communication.

- Benefits for Parents:
    1. Increased understanding of child development.
    2. Data-driven insights, parents can use the data provided by game-based learning analytics to identify areas where additional support is needed for their child.

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3. Better assessment, providing a more comprehensive assessment of the child's learning than traditional methods.

In addition, the application of classification analysis methods to the prediction of creativity and logic development in 3-4 year-old children has great potential to improve the learning experience and to help teachers make better decisions through early detection. Through the use of classification methods to identify patterns or trends in educational data for creativity and logic development, the comparison results of Naïve Bayes, Decision Tree and Multilayer Perceptron classification algorithms used in the case study of a game-based learning analytics platform to assess the creativity and logic development of 3-4 year old children stated that the Multilayer Perceptron classification algorithm has the highest accuracy rate compared to Naïve Bayes and Decision Tree classification algorithms, the accuracy value on the training data is 72.97%, and on the testing data is 79.17%. While the evaluation metrics generated in the MLP model for the precision value is 69.67% and the recall value is 67.41%.

In addition, games are fun, and games are a unique approach to the learning of theory. It is capable of producing positive results for children's development. The PERMATA NEGARA Curriculum is a national education-based curriculum that aims to build and develop the potential of the individual child through early childhood education. Particularly in the development of aspects of creativity and personality. The results of a pilot study on the behaviour and skills of 3-4 year-old children playing educational games show that technology can be used to develop knowledge and skills. Educational games can provide knowledge in creative and logical learning. This research shows that all children have creative and logical abilities (Agus et al., 2020).

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APPENDIX

A. Ethical Approval

UNIVERSITI PENDIDIKAN SULTAN IDRIS
35900 Tanjong Malim
Perak Darul Ridzuan, Malaysia
Tel : 015 - 4879 7881 / 7882 / 7883
Faks : 015 – 4879 7268
http://www.upsi.edu.my Emel: ppp@upsi.edu.my

RECEIVED
13 DEC 2019
FSKIK
Pusat Pengurusan Penyelidikan dan Inovasi

Rujukan Tuan :
Your Reference
Rujukan Kami : UPSI/PPPI/PYK/ETIKA(M)/U14(38)
Our Reference
Tarikh : 23 Oktober 2019
24 SAFAR 1441H

Rahmadi Agus
Faculty of Art, Computing Creative Industry
Universiti Pendidikan Sultan Idris

Dear Sir/ Madam

APPROVAL OF HUMAN RESEARCH ETHICS COMMITTEE SULTAN IDRIS EDUCATION UNIVERSITY

Reference number	**: 2019-0038-01**
Date of Approval	**: 23 Oktober 2019 – 23 Oktober 2020**
Research Title	**: A Game-based Learning Analytics Platform for Assessing Children's Creativity and Logic in Malaysia: A Case Study on Children 3-4 Years Old in National Child Development Research Center**
Research Code (if applicable)	**: Nil**
Grant Name	**: Nil**

With all due respect I refer to the above matter.

2. Please be informed that the Research Ethics Committee Meeting No. 6/2019 held on 23 Oktober 2019 has **approved** your application for the proposed research activities.

3. The approved research period is valid until **23 Oktober 2020**. The Research Ethics Committee must be informed for any changes made on the research. The official approval certificate will follow later.

4. In this regard, the University congratulates and hopes that you will be able to conduct research in accordance with established research ethics.

Thank you.

"NO.1 EDUCATION UNIVERSITY"

Yours sincerely,

(PROFESOR DR. RAHMATTULLAH KHAN ABDUL WAHAB KHAN)

s.k. Deputy Vice-Chancellor (Research and Innovation)
Director of Research and Innovation Management Center
Deputy Dean (Research and Innovation) Faculty
Researcher Files

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B. The Consent Form for The Teachers

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

MEMO

PUSAT PENYELIDIKAN PERKEMBANGAN KANAK-KANAK NEGARA (NCDRC)
Tel : 015-48797129/7130 Faks : 015-48797294

Kepada	:	**En. Rahmadi Agus (P20162002516)** **Pelajar Doktor Falsafah (FSKIK), UPSI**
Daripada	:	**Prof. Dr. Sopia bt. Md Yassin** **Pengarah NCDRC**
Ruj. Kami	:	UPSI/NCDRC/AD/639/Jld. 3 (86)
Tarikh	:	6 September 2018 / 25 Zulhijjah 1439H

KELULUSAN PERMOHONAN UNTUK MENJALANKAN PENYELIDIKAN DOKTOR FALSAFAH DI NCDRC

Dengan segala hormatnya izinkan saya merujuk perkara di atas.

2. Adalah dimaklumkan bahawa pihak Pusat Penyelidikan Perkembangan Kanak-kanak Negara (NCDRC) meluluskan permohonan pihak tuan untuk menjalankan penyelidikan peringkat Doktor Falsafah yang akan diadakan seperti butiran berikut:

Tarikh	:	**7 – 15 September 2018**
Tajuk Kajian	:	**A Game-Based Learning Analytics Platform For Assessing Children's Creativity and Logic in Malaysia**

3. Bersama-sama ini disertakan jadual kanak-kanak seperti yang telah dibincangkan untuk makluman dan perhatian daripada pihak tuan selanjutnya.

Sekian, terima kasih.

"UNIVERSITI NO. 1 PENDIDIKAN "

(PROF. DR. SOPIA BT MD YASSIN)

a.k. Penyelia Tesis – Dr. Suzani bt. Mohamad Salmun (FSKIK)
Penyelia Tesis & Tesis NCDRC
Fail

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C. The Consent Form for The Parents

BORANG KEBENARAN IBU BAPA/PENJAGA

Kepada:	Rahmadi Agus Pusat Penyelidikan Perkembangan Kanak-kanak Negara Kampus Sultan Azlan Shah (KSAS), Universiti Pendidikan Sultan Idris, Proton City, 35900 Tanjung Malim, Perak.
Perkara:	**PERSETUJUAN UNTUK MENGAMBIL BAHAGIAN DALAM PENYELIDIKAN** **A Game-based learning analytics platform for assessing children's creativity and logic in Malaysia : A case study on children 3-4 year old in National child development research center (NCDRC)**

Dengan ini, saya memaklumkan bahawa, SAYA:
***Sila (√) pada kotak yang berkenaan.**

Membenarkan

Tidak Membenarkan

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

anak saya . No. Sijil lahir/My kad
dari TASKA untuk mengambil bahagian
dalam penyelidikan ini.

Ibu Bapa/Penjaga

Nama :

No. Kad Pengenalan :

Tandatangan :

No. Telefon :

Tarikh :

MAKLUMAN: Sila kembalikan borang ini kepada penyelidik

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D. The Consent Form for The Children

Ibu/Bapa/Penjaga,
Taska NCDRC-UPSI 27 August 2018

KEPADA SESIAPA YANG BERKENAAN

Tuan/Puan,

MEMOHON KEBENARAN UNTUK KAJI SELIDIK DAN MENGAMBIL GAMBAR

Perkara di atas adalah dirujuk dengan segala hormatnya.

2. Sukacita dimaklumkan kepada tuan/puan bahawa saya ialah pelajar Universiti Pendidikan Sultan Idris (UPSI) peringkat Ijazah Doktor Falsafah, ingin memohon kebenaran daripada pihak tuan/puan untuk mengambil gambar serta menemubual anak tuan/puan di Taska NCDRC UPSI bagi menyelesaikan penyelidikan saya ke atas kanak-kanak prasekolah.

3. Maklumat permohonan saya adalah seperti berikut:

Nama Pelajar	: Rahmadi Agus
No. Kad Pengenalan	: B 4950591
No. Matrik	: P20162002516
Program Pengajian	: Ijazah Doktor Falsafah
No. Telefon	: 017-5270638
E-mel	: radizqi@gmail.com
Tajuk Kajian	: A Game-based learning analytics platform for assessing children's creativity and logic in Malaysia: A case study on children 3-4 year old in National child development research center (NCDRC)

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Sampel Kajian : Guru, Kanak-kanak Task berumur 3 hingga 4 tahun.

4. Segala kerjasama daripada pihak tuan/puan saya dahulukan dengan jutaan terima kasih. Semoga Allah melimpahkan rahmat ke atas kita semua. Sekian.

Yang benar,

Rahmadi Agus

Denga ini saya…….. (ibu/bapa/penjaga) kepada …… membenarkan anak dibawah jagaan saya untuk diambil gambar dan ditemubual bagi mennyelesaikan penyelidikan kepada pelajar yang berkenaan.

Yang benar,

…….

( )

Tarikh:

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

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E. Expert Verification Form

Expert verification form

Borang ini mempunyai 3 bahagian utama, seperti berikut:

Bahagian 1: Maklumat Ibu Bapa

Bahagian 2: Soalan 1 hingga 11. Seksyen ini mempunyai 11 item yang mempunyai 4 skala berbentuk Likert. Anda dikehendaki menjawab setiap item tersebut dengan satu (1) pilihan skala.

Bahagian 3: Soalan 12 dan 13. Seksyen ini memerlukan anda untuk menulis jawapan berdasarkan pengalaman setelah menggunakan platform analitik ini.

Masa yang diperlukan untuk menjawab soalan-soalan ini adalah tidak melebihi 5 minit.

Terima kasih kerana sudi memberikan maklumbalas anda terhadap kebolehgunaan platform analitik ini.

Bahagian 1: Demografik

Maklumat Guru

1. Nama

_____

2. Jantina

Tandai satu oval saja.

- ◯ Lelaki
- ◯ Perempuan

Bahagian 2: Soalan 1 hingga 11

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F. Example of The SUS Form for Teacher

(Game Creative) Pendidik: Borang Kebolehgunaan Sistem (System Usability Scale)

Borang ini mempunyai 3 bahagian utama, seperti berikut:

Bahagian 1: Maklumat Pendidik

Bahagian 2: Soalan 1 hingga 10. Seksyen ini mempunyai 11 item yang mempunyai 4 skala berbentuk Likert. Anda dikehendaki menjawab setiap item tersebut dengan satu (1) pilihan skala.

Bahagian 3: Soalan 11 dan 12. Seksyen ini memerlukan anda untuk menulis jawapan berdasarkan pengalaman semasa mengendalikan sesi bermain game creative bersama pelajar-pelajar di bawah jagaan anda

Masa yang diperlukan untuk menjawab soalan-soalan ini adalah tidak melebihi 5 minit.

Terima kasih kerana sudi memberikan maklumbalas anda terhadap kebolehgunaan game creative ini.

05-4506832 ptbupsi

Bahagian 1: Demografik

Maklumat Pendidik

1. Nama

_____

2. Jantina

Tandai satu oval saja.

- ◯ Lelaki
- ◯ Perempuan

Bahagian 2: Soalan 1 hingga 10

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

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Pendidik: Borang Kebolehgunaan Sistem (System Usability Scale) - Permainan Digital 'A day at the Zoo'

Borang ini mempunyai 3 bahagian utama, seperti berikut:

Bahagian 1: Maklumat Pendidik

Bahagian 2: Soalan 1 hingga 10. Seksyen ini mempunyai 11 item yang mempunyai 4 skala berbentuk Likert. Anda dikehendaki menjawab setiap item tersebut dengan satu (1) pilihan skala.

Bahagian 3: Soalan 11 dan 12. Seksyen ini memerlukan anda untuk menulis jawapan berdasarkan pengalaman semasa mengendalikan sesi bermain game logic bersama pelajar-pelajar di bawah jagaan anda

Masa yang diperlukan untuk menjawab soalan-soalan ini adalah tidak melebihi 5 minit.

Terima kasih kerana sudi memberikan maklumbalas anda terhadap kebolehgunaan game logic ini.

Bahagian 1: Demografik

Maklumat Pendidik

05-4506832 ptbupsi

1. Nama

_____

2. Jantina

Tandai satu oval saja.

- ◯ Lelaki
- ◯ Perempuan

Bahagian 2: Soalan 1 hingga 10

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G. Example of The SUS Form for Parents

Ibu Bapa: Borang Kebolehgunaan Sistem (System Usability Scale) - Platform Analitik

Borang ini mempunyai 3 bahagian utama, seperti berikut:

Bahagian 1: Maklumat Ibu Bapa

Bahagian 2: Soalan 1 hingga 11. Seksyen ini mempunyai 11 item yang mempunyai 4 skala berbentuk Likert. Anda dikehendaki menjawab setiap item tersebut dengan satu (1) pilihan skala.

Bahagian 3: Soalan 12 dan 13. Seksyen ini memerlukan anda untuk menulis jawapan berdasarkan pengalaman setelah menggunakan platform analitik ini.

Masa yang diperlukan untuk menjawab soalan-soalan ini adalah tidak melebihi 5 minit.

Terima kasih kerana sudi memberikan maklumbalas anda terhadap kebolehgunaan platform analitik ini.

Bahagian 1: Demografik

Maklumat Ibu Bapa

1. Nama

_____

2. Jantina

Tandai satu oval saja.

- ◯ Lelaki
- ◯ Perempuan

Bahagian 2: Soalan 1 hingga 11

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H. Example of The SUS Form for Children

Kanak-kanak : Borang Kebolehgunaan Sistem (System Usability Scale) - Creative Game

Borang ini mengandungi dua (2) bahagian utama, seperti berikut:

Bahagian 1: Demografik (maklumat kanak-kanak)

Bahagian 2: Soalan 1 hingga 6. Seksyen ini mempunyai 6 item yang mempunyai 2 skala. Guru-guru dikehendaki membantu kanak-kanak menjawab setiap item tersebut dengan memilih (YA) atau (TIDAK) berdasarkan pengalaman kanak-kanak bermain Game Creative.

Terima kasih atas kerjasama anda membantu kanak-kanak mengisi borang ini.

* Menunjukkan pertanyaan yang wajib diisi

Bahagian 1: Demografik

1. Nama

_____

2. Jantina

Tandai satu oval saja.

- ◯ Lelaki
- ◯ Perempuan

Bahagian 2: Soalan 1 hingga 6

Seksyen ini mempunyai 6 item yang mempunyai 2 skala. Guru-guru dikehendaki membantu kanak-kanak menjawab setiap item tersebut dengan memilih (YA) atau (TIDAK) berdasarkan pengalaman kanak-kanak bermain permainan digital: A day at the Zoo

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Kanak-kanak : Borang Kebolehgunaan Sistem (System Usability Scale) - Logic Game

Borang ini mengandungi dua (2) bahagian utama, seperti berikut:

Bahagian 1: Demografik (maklumat kanak-kanak)

Bahagian 2: Soalan 1 hingga 6. Seksyen ini mempunyai 6 item yang mempunyai 2 skala. Guru-guru dikehendaki membantu kanak-kanak menjawab setiap item tersebut dengan memilih (YA) atau (TIDAK) berdasarkan pengalaman kanak-kanak bermain permainan digital: A day at the Zoo

Terima kasih atas kerjasama anda membantu kanak-kanak mengisi borang ini.

Bahagian 1: Demografik

1. Nama

_____

2. Jantina

Tandai satu oval saja.

- ◯ Lelaki
- ◯ Perempuan

Bahagian 2: Soalan 1 hingga 6

Seksyen ini mempunyai 6 item yang mempunyai 2 skala. Guru-guru dikehendaki membantu kanak-kanak menjawab setiap item tersebut dengan memilih (YA) atau (TIDAK) berdasarkan pengalaman kanak-kanak bermain permainan digital: A day at the Zoo

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