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Design and Validation of Non-Digital Game-based Lesson Plans (Act, Play, Do) for Teaching Moon Phases in Primary Science

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ABSTRACT

This study aimed to design and validated non-digital game-based lesson plans for teaching Moon phases in primary science using the Act, Play, Do (A.P.D) approach and the ADDIE instructional design model. The lesson plans were developed systematically through the analysis, design and development phases to support the teaching of abstract science concepts among Year 5 pupils. The A.P.D approach consisted of simulation using body movement, card-based game activities and hands-on modelling using Oreo biscuits to support understanding of the relationship between the Earth, Moon and Sun, the sequence of Moon phases and the illuminated portion of the Moon. Expert validation involving one lecturer and two Excellent Science Teachers was conducted using the Content Validity Index (CVI). The findings showed that the I-CVI and S-CVI values for all constructs were 1.00, indicating high content validity and agreement among experts. User validation through interviews during a pilot study revealed the need for clearer instructions, visual aids and additional worksheet questions. Overall, the findings suggest that the non-digital game-based lesson plans developed using the A.P.D approach are suitable, practical and relevant for primary science classrooms, particularly in contexts with limited access to digital resources, while supporting active learning, interaction, engagement and conceptual understanding.

Keywords: ADDIE instructional design model, "Act, Play, Do (A.P.D)", moon phases, non-digital game-based learning, primary science

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INTRODUCTION

Planning instruction is recognised as a fundamental responsibility of teachers as effective teaching depends on how well

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a lesson is structured and prepared in advance (Nipyrakis et al., 2025; Dahalan et al., 2025). A daily lesson plan serves as a structured guide that outlines what pupils are expected to learn, how the learning process is conducted and how the achievement of learning objectives can be determined (Mohamed Zohomi & Mahamod, 2023). It includes key components such as learning objectives, content, teaching activities, teaching aids, assessment methods and reflection, which contribute to systematic and purposeful instruction (Ismail, 2025). In the Malaysian context, the preparation of a lesson plan is a professional requirement and a formal document that reflects teachers' planning, implementation and evaluation practices in the classroom (Banda et al., 2024; Hatch & Clark, 2021; Kementerian Pendidikan Malaysia, 2017; Mmbaga et al., 2025; Nordin & Mohamed, 2024).

In primary science education, careful lesson planning is particularly important when teaching abstract topics such as Moon phases, which are included in the Year 5 Science curriculum under the Earth and Space theme. This topic is recognised as abstract because the Moon's phases change slowly, and pupils are unable to directly observe the changes over a short duration of time (Plummer et al., 2022; Şensoy & Kocakuşak, 2025; Zou et al., 2023). As a result, pupils often have difficulty visualising the process and tend to develop misconceptions, especially in understanding the relationships among the Earth, Moon, and Sun. From a developmental perspective, pupils at this level are in the concrete operational stage, where learning is more effective when supported by concrete materials and direct experiences (Piaget, 2003). Previous studies have demonstrated that simulations and hands-on activities can help make abstract concepts more meaningful and improve pupils' understanding and engagement (Hwang & Chang, 2024; Plummer et al., 2022; Zou et al., 2023).

Although previous studies have highlighted the value of simulations, hands-on activities and game-based learning in supporting the teaching of abstract science concepts, these approaches are often discussed as separate instructional strategies. In the context of teaching Moon phases, there remains a need for a structured non-digital instructional sequence that connects bodily simulation, rule-based peer plays and concrete modelling in a gradual manner (Skulmowski & Rey, 2022; Zhong et al., 2023). This gap is important because pupils are required not only to observe the shapes of the Moon but also to understand the direction of light, identify the sequence of phases and represent the Moon phases in one complete cycle. Therefore, the A.P.D approach was developed to organise these learning demands into three connected stages: Act, Play and Do.

In many classrooms, conventional teaching approaches that rely on explanation and worksheet-based activities may limit pupils' active participation, particularly when teaching abstract topics such as Moon phases. In response to this issue, this study introduces the Act, Play, Do

(A.P.D) approach, which consists of three stages: Act, Play and Do. The Act stage involves simulation using body movement, the Play stage involves card-based game activities, and the Do stage involves hands-on modelling using Oreo biscuits. Hence, the purpose of this study is to design and validate non-digital game-based lesson plans using the A.P.D approach for teaching Moon phases in primary science.

Research Objective

This study aims to develop and validate daily lesson plans for non-digital game-based learning through the A.P.D approach designed to support pupils' achievement in the Moon phases topic and science self-efficacy among SJKT pupils.

RESEARCH BACKGROUND

Teaching Abstract Concepts in Primary Science

In primary science, teaching abstract concepts such as Moon phases in Year 5 Science should take into consideration suitable planning and teaching strategies, as the changes are not easily noticeable within a short duration of time. Pupils are required to understand the relationship between the Earth, Moon, and Sun, as well as the changes in the illuminated portion of the Moon, which makes the concept difficult to visualise. At the primary level, most pupils are at the concrete operational stage, where they can think logically but still rely on concrete, observable experiences for understanding (Piaget, 2003). Consequently, they tend to struggle with learning abstract science concepts, such as imagining where the light is on the lunar surface and the order of changes over time. Pupils often develop misconceptions because of these difficulties, such as failing to recognise the various phases of the Moon or believing that the Moon produces its own light (Plummer et al., 2022). These misconceptions may impact their general knowledge and use of the concept.

Thus, innovative pedagogical methods to facilitate better learning of abstract concepts are needed. These concepts can be made more visible and meaningful through the use of concrete materials, simulations and hands-on activities, which will enable pupils to gain a more concrete understanding. By offering pupils the opportunity to manipulate materials and engage with simulations, research has indicated that this can support their learning of Moon phases (Hwang & Chang, 2024; Plummer et al., 2022; Zou et al., 2023) and is congruent with their cognitive ability, providing opportunities to learn through first-hand experiences rather than abstract explanations.

Non-Digital Game-Based Learning

Game-based learning is a strategy that incorporates game elements and activities to support the learning process and encourage active participation, interaction and engagement which in turn can lead to an improvement in pupils' understanding of the concepts (Nautiyal et al., 2024; Nguyen et al., 2024; Sim & Othman, 2024). It can be delivered via digital or non-digital methods. Non-digital game-based learning, however, is designed without technological devices or internet access, and is better suited to a classroom-based environment that is resource-intensive (Plass et al., 2015; Plummer et al., 2022; Zou et al., 2023). For many schools, particularly those that are not dependent on the internet, digital tools can be difficult to use for teaching. Thus, a more practical and accessible approach is to use non-digital tools. Using physical tools like cards and basic resources allows teachers to facilitate valuable learning experiences without relying on technology, which can be more convenient and adaptable in various school settings (Othman et al., 2025; Zou et al., 2023).

Non-digital game-based learning also supports simulation and hands-on activities allowing pupils to interact directly with learning materials and experience the concept being taught (Plass et al., 2015; Sim & Othman, 2024). For instance, when learning about Moon phases, simulation activities give pupils a grasp of how light works, and hands-on activities give pupils an opportunity to build and model the various phases. It helps to make the concept more tangible and comprehensible (Sim & Othman, 2024). Besides, the use of games can also help improve the pupils' participation and their motivation to learn, because the learning activity is similar to playing games, pupils will be more willing to learn actively and pay attention to the learning process, and pupils' interaction with others will trigger and improve communication and collaborative learning (Nautiyal et al., 2024; Nguyen et al., 2024; Sim & Othman, 2024). Research has already proved that gamification can lead to more meaningful learning experiences as a result of cognitive engagement, interaction, and emotional involvement (Plass et al., 2015). On the whole, non-digital game-based learning is appropriate and feasible in primary school classrooms to engage and to provide conceptual understanding of abstract science concepts.

Instructional Design Rationale: ADDIE Model

Instructional design refers to a systematic process used to plan, develop, implement and improve teaching and learning activities to ensure effective learning experiences (Senadheera et al., 2024). It also functions as a structured framework that connects learning objectives, instructional strategies and assessment methods to produce meaningful learning outcomes (Saçak et al., 2022) and ensures that lesson planning follows a clear sequence aligned with intended outcomes rather than being carried out randomly (Weng et al., 2024). Several instructional design models are commonly used in education, such as the ASSURE model, Dick and Carey model and Gagné's Nine Events of Instruction.

In this study, the ADDIE model was selected as the instructional design framework, consisting of five phases: Analysis, Design, Development, Implementation and Evaluation (Branch, 2009), as it provides a systematic and organised approach to lesson planning.

During the analysis phase, teachers can identify pupils' needs and learning difficulties to ensure relevance (Dousay & Branch, 2022) while the design and development phases ensure alignment between learning objectives, activities and assessment methods (Shakeel et al., 2023). In addition, the ADDIE model offers flexibility, allowing each phase to be reviewed and improved based on feedback (Li & Cheong, 2023), which is particularly important in non-digital game-based learning. Note that activities may need to be adapted to pupils' engagement and understanding, which can be practical for classroom use because they do not depend on digital tools (Nguyen et al., 2024). Overall, the ADDIE model is suitable for this study as it supports systematic planning, flexibility and continuous improvement.

Theoretical Foundations

The development of the non-digital game-based lesson plans in this study is grounded in three main learning theories, namely Piaget's Cognitive Development Theory, Bandura's Social Learning Theory and Kolb's Experiential Learning Theory, which together provide a strong foundation for designing learning activities that are appropriate for primary school pupils and support meaningful understanding of abstract concepts. According to Piaget's Cognitive Development Theory, pupils at age 11 are in the concrete operational stage, where they are able to think logically but still depend on concrete materials to understand concepts (Piaget, 2003). Pupils learn best at this stage by being able to interact with real objects and see the concept applied. Hence, the learning activities, which are concrete contents and experiences, are important to enrich pupils' understanding of abstract learning, such as learning about the Moon phases. The Body movement, Card games and Oreo-based activities in this study give pupils concrete representations to aid their understanding. Furthermore, the Social Learning Theory of Bandura argues that learning is an observational and imitative process (Bandura, 1986), in which pupils learn from their peers' actions and use the same method in their learning. Activities such as playing card games and completing hands-on tasks in pairs or groups allow pupils to observe and imitate their peers, supporting understanding and contributing to pupils' confidence in learning science.

Furthermore, Kolb's Experiential Learning Theory highlights that learning is a process where knowledge is constructed through experience (Kolb, 1984), occurring when pupils are actively involved in activities and able to reflect on their experiences. In this study, pupils actively participated in the simulation and hands-on activities. For an example, the modelling Moon phases using Oreo biscuits where this helps pupils to transform abstract ideas into meaningful understanding via direct interaction with learning resources. These three theories are integrated into the A.P.D approach used in this study. Table 1 below presents the integration of three learning theories in the A.P.D approach.

Table 1
Integration of learning theories in the A.P.D approach

Theory	A.P.D Stage	Application in Learning
Piaget (2003)	Act (A)	Pupils use body movement as a concrete representation to understand light and shadow on the Moon.
	Play (P)	Card games act as concrete materials to help pupils learn the sequence of Moon phases.
	Do (D)	Oreo biscuits are used as physical materials to model Moon phases.
Bandura (1986)	Play (P)	Pupils observe and imitate peers while arranging Moon phase sequences using cards.
	Do (D)	Pupils observe peers while modelling Moon phases using Oreo biscuits.
Kolb (1984)	Act (A)	Pupils engage in simulation through body movement to experience the concept directly.
	Play (P)	Pupils actively participate in hands-on card activities.
	Do (D)	Pupils construct Moon phases through direct hands-on experience.

Source: Authors' own work

Research Gap and Originality of the A.P.D Approach

Previous studies have shown that simulations, hands-on activities and concrete learning materials can support pupils' understanding of abstract science concepts such as Moon phases (Hwang & Chang, 2024; Plummer et al., 2022; Zou et al., 2023). This is consistent with Piaget's (2003) view that pupils at the concrete operational stage learn more effectively when abstract ideas are supported by concrete representations and direct experiences. However, in the context of teaching Moon phases, these approaches are often presented as separate strategies such as simulation, hands-on learning or game-based activities. Therefore, there is a need for a more structured non-digital instructional sequence that connects these strategies in a gradual and purposeful manner.

The A.P.D approach was developed to address this gap by organising pupils' learning experiences into three connected stages: Act, Play and Do. The Act stage uses body movement as an embodied simulation to help pupils represent the direction of light on the Moon's surface. The Play stage extends this initial representation through a card-based game in which pupils arrange and name the Moon phases in the correct sequence. The Do stage consolidates the concept through hands-on modelling using Oreo biscuits, where pupils represent the Moon phases in one complete cycle. This sequence is aligned with the learning demands of the Moon phases topic which require pupils to understand light direction, identify the order of the phases and represent the complete lunar cycle.

The originality of A.P.D lies in its progressive integration of embodied simulation, rule-based peer plays and concrete modelling within a non-digital game-based learning structure. It differs from ordinary hands-on learning because pupils do not only manipulate materials instead, but they also first use their body to represent the concept then interact with peers through a game and finally construct a concrete model. It also differs from simulation-based teaching because simulation is used only as the initial stage and is followed by card-based sequencing and hands-on modelling. In relation to the 5E instructional model, A.P.D does not replace the broader lesson flow. Instead, the 5E model organises the teaching process while A.P.D organises the specific learning activities within that process. This distinction is important because ADDIE supports systematic instructional development (Branch, 2009) while lesson activities still need to be aligned with objectives, materials and assessments (Dousay & Branch, 2022; Li & Cheong, 2023; Shakeel et al., 2023).

A.P.D also differs from general non-digital game-based learning because the game element is not used only to increase enjoyment or participation. Instead, the Play stage is linked directly to the conceptual requirement of arranging and naming the Moon phases in the correct order. This is consistent with the idea that game-based learning can support cognitive engagement, interaction, feedback and motivation when the game elements are connected to learning goals (Plass et al., 2015). The non-digital nature of A.P.D also makes it practical for classroom contexts that may have limited access to digital resources as the activities use accessible materials such as body movement, Moon phase cards and Oreo biscuits (Nguyen et al., 2024). Therefore, A.P.D contributes as a structured, theory-informed and classroom-practical instructional approach for designing lesson plans to teach Moon phases in primary science.

METHODOLOGY

Research Design

This study employed a design and development research approach to develop and validate non-digital game-based lesson plans for teaching Moon phases in primary science. The development process was guided by the ADDIE instructional design model which consists of five phases: Analysis, Design, Development, Implementation and Evaluation (Branch, 2009). The model was selected because it provides a systematic process for identifying learning needs, designing instructional activities, developing materials, implementing the lesson plans in a classroom context and evaluating the quality of the developed instructional materials.

In this study, the ADDIE model was applied within the scope of lesson plan development and validation. The Analysis phase involved identifying pupils' learning needs and difficulties in the Moon phases topic through a survey, diagnostic test and interviews. The Design phase involved planning the learning objectives, instructional strategies, A.P.D activities, teaching materials and assessment tasks. The Development phase involved producing eight A.P.D-based lesson plans and supporting materials including simulation activities, Moon phase cards, worksheets and Oreo-based modelling activities. The Implementation phase was conducted through a pilot study to examine the practicality of the lesson plans in the classroom context. The Evaluation phase involved expert validation using the Content Validity Index (CVI) and user validation through interviews with one teacher and two pupils.

It is important to clarify that the scope of this article is limited to the design and validation of the A.P.D-based lesson plans. Although the lesson plans were developed to support the teaching of Moon phases and science self-efficacy, this article does not report an experimental effectiveness test. Therefore, the findings should be interpreted in terms of content validity, face validity and practicality, rather than evidence of improved pupils' achievement or science self-efficacy.

Development of Lesson Plans

Systematically, the lesson plans were designed using the ADDIE instructional design model, which provides a structured process from identifying learning needs to planning instructional activities. The development was oriented towards non-digital game-based lesson plans that are based on the A.P.D approach, which prioritises simulation and hands-on activities. Eight lesson plans for the Year 5 Science topic of Moon phases were created and delivered over eight weeks. Furthermore, all the lesson plans were tied to the Kurikulum Standard Sekolah Rendah (KSSR), which ensures that the learning objectives, activities, and assessments are aligned. Simulation activities were primarily used in the Act stage, and hands-on activities were used more in the Play and Do stages to help build understanding of abstract concepts through hands-on experiences (Hwang & Chang, 2024; Plummer et al., 2022; Zou et al., 2023). Practicality was also achieved through the use of simple materials like card games and Oreo biscuits, which did not require digital materials.

Analysis Phase

In the analysis phase, the researcher used a survey, a diagnostic test and interviews to determine pupils' learning needs and the problem of pupils in learning about the Moon phases. The findings from a survey of 60 Year 5 pupils showed that the most difficult Science topic was Moon phases, with a mean score of $M = 4.15$. In addition, a 20-question diagnostic test showed low mastery with 58.3% of pupils at the minimum level, 36.7% at the satisfactory level, and 5.0% at the good level. Interviews with two Science teachers and two pupils also revealed the challenges in comprehending abstract ideas, poor engagement in regular Science lessons, inadequate teaching materials, and low confidence in answering questions. The overall results indicated that a more structured lesson plan was needed that would include non-digital, game-based learning and hands-on activities to help pupils better understand and be engaged in the lesson plan.

Design Phase

The design phase was to plan the lesson plans based on results found during the analysis phase, such as learning objectives, instructional strategies, activities, materials, and assessments. The lesson plans were developed based on the Year 5 Science topic on Moon phases under the KSSR curriculum. The instructional approach adopted was A.P.D., that is: Act (Simulation), Play (Card-based Activity), and Do (Hands-on Activity using Concrete Materials). The lesson plans were also designed using the 5E instructional model and were based on game-based learning principles, including engagement, interaction, feedback, and motivation. Furthermore, the design was inspired by Piaget's notion of Cognitive Development Theory, Bandura's Social Learning Theory, and Kolb's Experiential Learning Theory, which were used to encourage experiential and student-centred learning.

Development Phase

For the development, lesson plans and supporting materials were developed based on the design specifications. Eight total non-digital game-based lesson plans were designed using the ADDIE model for the topic of Moon phases and were executed over eight weeks. Materials created for the A.P.D covered simulation activities, card games and practical activities using Oreo biscuits. The materials were chosen so that they are easy to obtain, simple to use and do not require digital resources. The lesson plans were designed and recorded with objectives, teacher input, activities, evaluation, and monitoring and were prepared for validation and implementation in the classroom.

Act, Play, Do Framework

The instructional approach used in this study is mainly the A.P.D framework. It is a non-digital game-based learning technique that focuses on simulation and practical activities at three phases: Act (A), Play (P), and Do (D). The Act stage involves pupils using their body to represent light on the surface of the Moon in various ways, including head position, finger shape and facial orientation. During the Play stage, pupils play a card game with Moon phase cards to put them in order in pairs. During the Do step, pupils model Moon phases using Oreo biscuits and create the Moon phases cycle. These stages are linked in that the Act helps gain an initial understanding, Play assists in reinforcing learning and Do helps to deepen understanding through hands-on learning. Table 2 presents the structure of the A.P.D framework. Figure 1 illustrates the Act

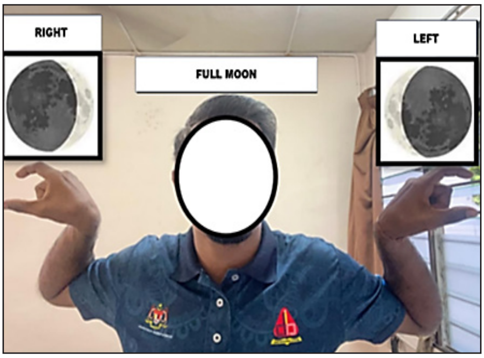

Figure 1. Act stage
Source: Authors' own work

Table 2
Structure of the Act-Play-Do (A.P.D) framework

Stage	Type of Activity	Description	Learning Focus
Act (A)	Simulation (Body Movement)	Pupils use head movement, finger shapes and facial orientation to represent light on the Moon's surface.	Understanding light direction and visualising Moon phases
Play (P)	Card Game (Pair Work)	Pupils arrange Moon phase cards in the correct sequence through a game.	Understanding the sequence and naming of Moon phases
Do (D)	Hands-on (Oreo Activity)	Pupils use Oreo biscuits to model the phases of the Moon in a complete cycle.	Understanding the spatial and temporal relationships of Moon phases

Source: Authors' own work

stage; Figure 2 depicts the Play stage and Figure 3 depicts the Do stage.

Although the activities use simple and easily available materials, the instructional purpose is systematic because each stage addresses a specific learning demand such as visualising light direction, sequencing the Moon phases and representing the complete Moon phase cycle.

To clarify the distinctive position of the A.P.D approach, Table 3 compares A.P.D with related instructional approaches commonly associated with the teaching of

Figure 2. Play stage
Source: Authors' own work

Figure 3. Do stage
Source: Authors' own work

Table 3
Distinctive features of the A.P.D Approach Compared with Related Instructional Approaches

Related Instructional Approach	Main Emphasis	Distinctive Feature of A.P.D in this Study
Hands-on learning	Emphasises pupils' direct interaction with concrete materials to support understanding of abstract concepts (Hwang & Chang, 2024; Kolb, 1984; Piaget, 2003; Plummer et al., 2022; Zou et al., 2023).	A.P.D is not limited to the manipulation of materials. It begins with body movement in the Act stage, continues with card-based peer play in the Play stage, and ends with Oreo-based concrete modelling in the Do stage.
5E instructional model	Provides a general instructional flow through engagement, exploration, explanation, elaboration and evaluation to organise the teaching and learning process. (Bybee, 1987)	A.P.D does not replace the 5E model. In this study, 5E organises the lesson flow, while A.P.D organises the specific learning activities within the lesson.
Simulation-based learning	Uses action, movement or representation to model a concept or process that pupils cannot easily observe directly (Hwang & Chang, 2024; Plummer et al., 2022; Zou et al., 2023).	In A.P.D, simulation is used specifically in the Act stage to represent the direction of light on the Moon's surface. This is followed by Play and Do to reinforce sequencing and complete-cycle representation.
Non-digital game-based learning	Uses game elements, interaction, feedback, motivation and physical materials without depending on digital technology (Nguyen et al., 2024; Plass et al., 2015).	A.P.D uses non-digital game elements, but the Play stage is connected to a specific conceptual task, namely arranging and naming the Moon phases in the correct sequence.
Concrete modelling	Uses physical objects or concrete representations to make abstract concepts more visible and meaningful for pupils (Kolb, 1984; Piaget, 2003; Plummer et al., 2022; Zou et al., 2023).	In A.P.D, concrete modelling appears in the Do stage after pupils have experienced the concept through body movement and card-based sequencing. This makes the modelling activity part of a progressive sequence rather than a stand-alone activity.

Source: Authors' own work

abstract science concepts. The comparison shows that A.P.D is not merely a hands-on activity, a simulation activity, a 5E lesson structure or a general non-digital game. Instead, it functions as a structured instructional sequence that links embodied simulation, card-based peer plays and concrete modelling according to the learning demands of the Moon phases topic.

Validation Process

Expert Validation

Expert validation was conducted to determine the content and face validity of the A.P.D-based lesson plans (Haynes et al., 1995; Polit & Beck, 2006; Ramli et al., 2023; Yusoff, 2019). Three experts, consisting of one lecturer in Science Education and two

Excellent Science Teachers, evaluated eight lesson plans developed using the A.P.D approach. The expert validation instrument was a content and face validity questionnaire designed to assess the suitability of the lesson plans and the integration of the A.P.D approach.

The validation specifically examined the instructional approach embedded in the lesson plans. For the Act stage, experts evaluated the suitability of the body-movement simulation in helping pupils visualise the direction of light on the Moon's surface. For the Play stage, experts evaluated the suitability of the Moon phase card activity in supporting pupils to arrange and name the eight Moon phases in the correct sequence. For the Do stage, experts evaluated the suitability of the Oreo-based modelling activity in helping pupils represent the Moon phases in one complete cycle. The experts also considered the format of the activities, the choice of materials and the practicality of implementing the A.P.D stages in the primary science classroom.

The instrument consisted of seven constructs: alignment of learning objectives, accuracy and clarity of science content, integration of non-digital game-based learning through the A.P.D approach, clarity of teaching steps and classroom feasibility, potential of the lesson plans to support pupils' achievement in the Moon phases topic, potential of the lesson plans to support pupils' science self-efficacy, and presentation of the lesson plans in terms of text and language. The A.P.D integration construct specifically evaluated whether the Act stage supported pupils in identifying the new crescent and old crescent based on the direction of light, whether the Play stage supported pupils in arranging and naming the eight Moon phases, and whether the Do stage supported pupils in representing the Moon phases in one complete cycle using Oreo biscuits.

The instrument used a four-point relevance scale: 1 = not relevant, 2 = somewhat relevant, 3 = relevant and 4 = highly relevant. Scores of 3 and 4 were treated as expert agreement, while scores of 1 and 2 were treated as non-agreement (Grant & Davis, 1997). The Item-level Content Validity Index (I-CVI) was calculated by dividing the number of experts who rated an item as relevant or highly relevant by the total number of experts (Polit, Beck, & Owen, 2007). The Scale-level Content Validity Index based on average method (S-CVI/Ave) was calculated by averaging the I-CVI values across items within each construct. In this study, an I-CVI value of 1.00 was adopted because three experts were involved, while an S-CVI/Ave value of .80 or above was considered acceptable (Polit & Beck, 2006; Davis, 1992).

User Validation

User validation was conducted through semi-structured interviews during the pilot study to examine the practicality and usability of the A.P.D-based lesson plans from the perspective of the teacher and pupils. The participants consisted of one Year 5 Science teacher who implemented the A.P.D lesson plans and two Year 5 pupils who participated in the pilot implementation.

The interview protocol served as the user validation instrument and consisted of open-ended questions for the teacher and pupils to obtain feedback on the clarity, practicality and usability of the A.P.D-based lesson plans. The interview protocol focused on the clarity of instructions, ease of implementation, suitability of the Act, Play and Do activities, use of teaching materials, pupils' understanding of activity procedures and suggestions for improving the lesson plans. For the teacher, the questions focused on the clarity of the lesson plan steps, feasibility of implementation within the allocated time, suitability of materials and difficulties encountered during the Act, Play and Do stages. For the pupils, the questions focused on whether they understood the activity instructions, whether the activities were easy to follow and which parts of the activities caused confusion. The interview responses were analysed thematically to identify practical issues that emerged during the pilot implementation. The themes were then used to revise the A.P.D-based lesson plans before the final version was produced.

FINDINGS

Expert Validation

The expert validation results were analysed using the Content Validity Index (CVI), consisting of I-CVI and S-CVI/Ave across seven constructs. As shown in Table 4, all constructs obtained an S-CVI/Ave value of 1.00, indicating full agreement among the experts. The A.P.D integration construct also obtained an S-CVI/Ave value of 1.00, showing that the experts agreed on the suitability of the Act, Play and Do stages in terms of activity format, material choice and classroom implementation. Table 4 shows the scale-level content validity results by construct.

Table 4
Scale-level content validity results by construct

Construct	Item Numbers	Number of Items	S-CVI/ Ave	Interpretation
Alignment of learning objectives	1–4	4	1.00	Excellent content validity
Accuracy and clarity of science content	5–8	4	1.00	Excellent content validity
Integration of non-digital game-based learning / A.P.D	9–13	5	1.00	Excellent content validity
Clarity of teaching steps and feasibility	14–17	4	1.00	Excellent content validity
Potential to support achievement in Moon phases	18–21	4	1.00	Excellent content validity
Potential to support science self-efficacy	22–25	4	1.00	Excellent content validity
Presentation of lesson plans	26–29	4	1.00	Excellent face validity

Source: Authors' own work

The findings indicate that the A.P.D-based lesson plans had strong content and face validity. The lesson plans were considered well organised, aligned with the curriculum requirements and suitable for primary science classroom implementation. However, expert feedback indicated that the Do-stage Oreo-based modelling activity required clearer instructions regarding the roles of the teacher and pupils. Therefore, the lesson plans for Weeks 6, 7 and 8 were revised by adding more specific instructions. These included the distribution of Oreo biscuits, toothpicks, paper, marker pens and tissues; pupils' task of forming eight Moon phases using the Oreo cream; arranging the phases in one complete cycle; labelling the phases; and teacher checking of pupils' work. Hygiene reminders and safety guidance for the use of toothpicks were also added.

The validation process also focused specifically on the A.P.D instructional approach. The experts evaluated whether the Act-stage body-movement simulation was suitable for helping pupils visualise the direction of light on the Moon's surface, whether the Play-stage Moon phase card activity was suitable for supporting pupils in arranging and naming the eight Moon phases, and whether the Do-stage Oreo-based modelling activity was suitable for helping pupils represent the Moon phases in one complete cycle. Therefore, the validation did not only address the general structure of the lesson plans, but also examined the format, choice of materials and suitability of the simulation, card-based activity and hands-on modelling activity within the A.P.D framework.

User Validation

The user validation findings were obtained from semi-structured interviews with one Year 5 Science teacher and two Year 5 pupils who were involved in the pilot implementation of the A.P.D-based lesson plans. The findings were organised into three themes: confusion in implementing the Act-stage simulation, unclear procedures for the Play-stage card game, and limited worksheet questions. The first theme was confusion in implementing the simulation of the "correct C" and "inverted C" hand positions during the Act stage. The teacher explained that the written instructions in the lesson plan were insufficient because there were no visual references to guide the demonstration. The teacher stated: "In the lesson plan, it only instructed pupils to make the 'correct C' and 'inverted C' hand shapes, but when I wanted to demonstrate it in class, pupils were confused about which one should be used for a particular phase. I also had to pause for a while to think about which one was the 'correct C' and which one was the 'inverted C' because there was no picture as a reference" (Teacher). This difficulty was also reflected in the pupils' responses. One pupil stated, "The teacher mentioned 'correct C', but I did not know which hand should open to the left or to the right, so I just followed the friend beside me" (Student 1). Another pupil explained, "When the teacher asked us to make the 'inverted C' shape, I was confused because it looked the same as the 'correct C'" (Student 2). These responses indicate that the Act-stage simulation required clearer visual support. Therefore, actual pictures showing the "correct C" and "inverted C" hand positions were added to the lesson plans and labelled accordingly. The pictures were also included in the PowerPoint slides to support pupils' understanding during classroom implementation.

The second theme was the lack of clarity in the Play-stage card game procedures. The teacher reported that the card-game instructions were too brief and did not clearly explain how pupils should arrange the Moon phases. The teacher stated: "The instructions for the card game in the lesson plan were quite brief. Some pupils arranged the cards based only on what they remembered because I did not explain clearly how the sequence should be arranged" (Teacher). The pupils also indicated that they were unsure about the game procedure. One pupil stated, "The teacher gave us the cards and asked us to arrange them, but I was not sure which direction to arrange first" (Student 1). Another pupil said, "The teacher did not tell us when the game would end, so we just waited until the teacher asked us to stop" (Student 2). These findings suggest that the Play-stage activity required more explicit procedural guidance. As a result, the card-game instructions were revised into seven step-by-step procedures, the number of cards for each player was specified, and the condition for ending the game was added to the lesson plans.

The third theme was the limited number of worksheet questions. The teacher noted that the worksheets in Week 2 and Week 8 contained only three questions and did not provide enough practice for pupils to draw the Moon phases in a complete cycle. The teacher stated: "The worksheets in Week 2 and Week 8 had only three questions, so the pupils' practice was quite limited. Pupils only drew certain Moon phases, not the whole sequence of Moon phases in one complete cycle" (Teacher). This issue was also mentioned by the pupils. One pupil stated, "The worksheet only asked us to draw a few Moon phases, not all of them" (Student 1). Another pupil said, "We only drew a little, and after that we did not continue until the full Moon phase cycle was complete" (Student 2). Based on this feedback, two additional questions were added to the Week 2 and Week 8 worksheets. The revised worksheets required pupils to draw the eight Moon phases in one complete cycle, allowing them to practise the full sequence rather than only selected phases.

Overall, the user validation findings indicated that the A.P.D-based lesson plans were usable but required technical revisions to improve clarity during implementation. The revisions focused on adding visual support for the Act stage, providing clearer step-by-step instructions for the Play stage and expanding worksheet questions to support the complete representation of the Moon phases cycle.

DISCUSSION

Based on the findings of this study, it can be concluded that the non-digital game-based lesson plans that were created using the A.P.D approach have high content validity and are suitable for learning about the Moon phases in primary science. The results in I-CVI and S-CVI are signs of a perfect alignment between the lesson plans and curriculum requirements, learning objectives and instructional strategies. These results not only demonstrate the validity of the instrument but also the need for a systematic design of the teaching method for supporting the teaching of abstract concepts in science at the primary level. The study demonstrates the potential of a structured non-digital game-based learning approach as a pedagogically sound strategy in the primary science classroom, especially in contexts where digital resources are limited.

One of the greatest benefits of this study is the use of simulation, game-based learning and hands-on activities in a learning structure. The A.P.D approach is grounded in Piaget's Cognitive Development Theory, Bandura's Social Learning Theory, and Kolb's Experiential Learning Theory and provides multiple opportunities for pupils to build understanding. The Act stage provides the opportunity for pupils to physically act out something to support the cognitive processing of the concrete operational stage (Piaget, 2003). The Play stage encourages social interaction and learning from others, where pupils can practice what they have understood from their peers. The Do stage encourages pupils to learn through a hands-on modelling experience. This combination is indicative of the multi-dimensionality of learning that involves cognitive, social, and experiential aspects working together to contribute to conceptual understanding. The results also indicate that the application of body movement, interaction, and manipulation of materials in this study helps to lower the abstractness of the Moon phases by converting the abstract concept into a concrete and meaningful learning experience.

Apart from that, these findings are consistent with recent studies on non-digital and paper-based game-based learning. Nguyen et al. (2024) highlighted that board games in STEM education can support engagement, motivation and learning outcomes, while Nautiyal et al. (2024) emphasised the practicality of educational board games for classroom-based learning. In primary science, Sim and Othman (2024) reported that paper-based board games supported pupils' academic performance, motivation and social interaction. Similarly, Othman et al. (2025) found that board games in collaborative science learning can enhance scientific knowledge acquisition, engagement and collaborative skills. Therefore, the findings of this study support the relevance of using non-digital game-based learning materials, such as Moon phase cards and Oreo-based modelling activities, to teach abstract science concepts.

The findings also reinforce the importance of active learning when teaching abstract science topics such as Moon phases. It is challenging to understand spatial and temporal relationships among objects, as these concepts cannot be directly observed, especially at the primary level (Plummer et al., 2022; Zou et al., 2023). The A.P.D approach offers opportunities for pupils to visualise ideas, engage with resources and build understanding through first-hand experiences and simulation. It helps to reinforce the concept that science should be learned through hands-on activities rather than by passively hearing the information.

Instructional design is still in development and there is always a need for continuous improvement in the iterative process of instructional design based on expert and user feedback. The level of agreement was high in the first validation however; practical issues were identified during the user feedback in relation to the clarity of instructions and implementation of the activities. The lesson plans were improved by the inclusion of visuals, steps and an improved worksheet design to make them more usable and effective. This is in accordance with the ADDIE model, which emphasises the evaluation and modifications that should be made to ensure quality teaching. The results also indicate that the effectiveness of non-digital GBL depends on teachers' capacity to manage the interactive nature of classroom activities and to provide clear instruction that guides the learning process. Furthermore, teachers might need guidance and preparation to effectively implement interactive game-based learning activities in the classroom which can be delivered using non-digital games.

The user validation excerpts further support the need for these revisions. For example, pupils' confusion with the "correct C" and "inverted C" hand positions showed that the Act-stage simulation required clearer visual guidance. Similarly, pupils' uncertainty about the direction of card arrangement and the ending point of the card game indicated that the Play-stage activity needed more explicit step-by-step instructions. The comments on the limited worksheet questions also showed that pupils needed more opportunities to represent the complete Moon phase cycle. These excerpts strengthen the discussion by showing that the revisions were not only based on expert judgement but also on practical issues observed during classroom implementation.

The findings provide pedagogical implications for the teaching of abstract science concepts in primary science. Based on the research, it is recommended that the teachers do not rely on explanation-based learning anymore in teaching abstract science concepts but use more interactive and experiential learning. Structured, non-digital game-based activities might foster deeper understanding and engagement because pupils are actively engaging, collaborating with peers, and being immersed in learning materials. The results also corroborate current focus in primary science education on student-centred and experiential learning approaches. Furthermore, the materials employed in the study are practical, allowing the method to be easily transferable to other classroom settings without the need for extensive technological resources.

The study results indicate that the strategy developed and tested is a theory-based and practically applicable strategy for teaching abstract concepts in general.

The A.P.D framework provides a model that combines simulation, interaction and hands-on learning in a structured yet flexible way to facilitate the learning of meaningful science. In a broader context, the results highlight the importance of developing learning contexts that facilitate the understanding of abstract science concepts, which are cognitively and concretely accessible for pupils in primary school.

LIMITATION AND FUTURE RESEARCH

This study has several limitations. First, the validation process involved a small number of participants. Expert validation was conducted with three experts, while user validation involved one Year 5 Science teacher and two Year 5 pupils during the pilot study. Although this sample is acceptable for initial content and face validation, the findings should be interpreted as preliminary evidence of suitability, clarity and practicality rather than broad generalisability.

Second, this study was limited to the design and validation of the A.P.D-based lesson plans. It did not examine the effectiveness of the lesson plans in improving pupils' achievement in the Moon phases topic or their science self-efficacy. Therefore, the findings do not provide empirical evidence of learning gains. Future studies should employ experimental or quasi-experimental designs with larger samples to investigate the effects of the A.P.D approach on pupils' achievement, conceptual understanding and science self-efficacy.

Third, the user validation was conducted in a limited pilot context. The practicality of the lesson plans may vary according to school setting, teacher experience, class size and availability of materials. Future research may involve more teachers and pupils from different school contexts to examine the usability and adaptability of the A.P.D-based lesson plans more comprehensively.

CONCLUSION

The purpose of this study was to design and validate non-digital game-based lesson plans for the implementation of the Moon phases concept in primary science using the ADDIE instructional design model. This study aimed at developing and testing non-digital game-based lesson plans for implementing the Moon phases concept in primary science education by applying the ADDIE instructional design model. The findings of the expert and user validation revealed that the lesson plans formulated are well-structured, relevant, and appropriate for classroom implementation, with a good level of agreement across all the validation constructs. The A.P.D framework incorporates simulation, game-based activities, and hands-on learning, providing a consistent and practical approach to support the teaching of abstract science concepts.

The study constructs a teaching model systematically based on theory, which is particularly applicable to primary schools and the environment with limited digital resources, promoting science education. The A.P.D approach combines cognitive, social, and experiential learning to provide an alternative to the traditional teaching style that can enhance pupil engagement and conceptual understanding.

However, the effectiveness of the lesson plan in improving pupils' learning outcomes is not examined in this study, which is limited to the design and validation process. Future research should extend this work with empirical studies that involve larger sample sizes and more sophisticated research designs to explore how the A.P.D approach impacts pupils' achievement, conceptual understanding, and science self-efficacy. Therefore, there is potential for further research using this method with other science topics or in other educational contexts to enhance its generalisability.

Based on the results, it can be concluded that a lesson plan that was designed based on a systematic instructional design process using non-digital games can be useful as a pedagogical material to facilitate abstract concepts learning in primary science education. The A.P.D approach is an example of how simulation, interaction, and hands-on learning can transform abstract learning in science into concrete, meaningful learning for the primary school. In the broader perspective of this study, it is pertinent that teaching strategies should be theoretical, applicable, and adequate to the learning needs and classroom realities of primary education.

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