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(IJMOE)**www.gaexcellence.com/ijmoe**EXPLORING NON-DIGITAL GAME-BASED LEARNING
FOR BUILDING SCIENCE SELF-EFFICACY
IN PRIMARY EDUCATION**Punnithann Subramaniam¹, Nor Asniza Ishak^{2*}¹School of Educational Studies, Universiti Sains Malaysia, Malaysia punnithann@student.usm.my <https://orcid.org/0009-0001-1047-5902>²School of Educational Studies, Universiti Sains Malaysia, Malaysia asnizaishak@usm.my <https://orcid.org/0000-0001-6049-5779>

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Abstract:

This concept paper considers how non-digital game-based learning may support science self-efficacy among primary pupils. It uses conceptual theory synthesis to bring together literature on game-based learning, non-digital science activities, science self-efficacy and primary astronomy. Studies are considered in relation to the paper's focus, with evidence from other subjects, educational levels and game formats informing the discussion indirectly. The paper's theoretical contribution is a mapping of eight game-based learning characteristics to Bandura's four sources of efficacy information: mastery experiences, vicarious experiences, verbal persuasion and physiological and emotional states. Central to this mapping is the distinction between the experiences available during a lesson and the meaning pupils draw from them. Game design and teacher facilitation may provide opportunities to perform science tasks successfully, observe peers, receive credible feedback and respond to emotional challenges. Pupils' interpretations of these experiences may inform their capability judgments which may subsequently influence effort, choice and persistence. Act, Play and Do (A.P.D.) illustrates the proposed explanation in Malaysian Year 5 Moon-phase lessons through embodied simulation, cooperative card gameplay and manipulative modelling. This account extends the earlier design and validation of A.P.D. lesson plans by considering how participation in these activities may provide efficacy information. Curriculum alignment, equitable participation, opportunities to revise responses and task-specific assessment are discussed as considerations for implementation. Direct evidence concerning this application remains limited and empirical research is needed to examine the proposed relationships.

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Keyword:

Bandura's Self-Efficacy Theory, Moon Phases, Non-Digital Game-Based Learning, Primary Science Education, Science Self-Efficacy



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Introduction

Primary science education in Malaysia aims to develop scientific literacy by bringing together knowledge, inquiry, thinking skills, attitudes and values. The Kurikulum Standard Sekolah Rendah (KSSR) requires Year 5 pupils to explain reflected sunlight, simulate the Moon's rotation and orbit, represent the complete lunar-phase cycle according to the Qamari calendar and communicate their observations (Ministry of Education Malaysia, 2019). To understand Moon phases, pupils therefore need to connect illumination and movement with what they observe over time, beyond memorising the names of the phases.

Representations and classroom activities are particularly useful for this topic, which requires pupils to relate the Moon's changing appearance to the positions and movements of the Sun, Earth and Moon (Cardinot & Fairfield, 2022). Models, simulations and games can help pupils observe and discuss these spatial relationships (Alkan & Kurtoğlu, 2023; Cardinot & McCauley, 2024). An attractive representation, however, is no assurance of conceptual understanding. Teachers need to explain what each representation means scientifically and address the misconceptions that Moon phases result from changes in the Moon's physical shape or from Earth's shadow (Cardinot & McCauley, 2024).

Attention is also needed to how pupils judge their ability to carry out science tasks. Upper-primary pupils have reported lower self-efficacy for performing scientific skills than for answering science questions; mastery experience was the strongest predictor of scientific-skills self-efficacy (Carroll et al., 2024). Non-digital games may offer opportunities to manipulate representations, make decisions, explain answers, observe peers and revise responses without continuous internet access or a device for each pupil. Reviews have reported favourable findings for science knowledge, engagement, collaboration and self-efficacy, but the evidence has several limitations: small samples, little longitudinal research, insufficient attention to game mechanisms, high heterogeneity and differences in intervention contexts (Othman et al., 2025; Soriano-Sánchez et al., 2026). These findings justify further investigation without establishing that every non-digital game improves science self-efficacy.

The studies reviewed in this paper report outcomes such as science knowledge, engagement, collaboration and self-efficacy following game-based learning (Othman et al., 2025; Soriano-Sánchez et al., 2026). Less attention has been given to explaining how pupils interpret experiences during non-digital gameplay as evidence of their ability to perform specific science

tasks. This interpretive process is the focus of the present concept paper. Drawing on Bandura's four sources of efficacy information, it examines how successful performance, observation of peers, feedback and emotional experiences may inform primary pupils' judgments of their science capabilities. Direct evidence combining non-digital games, primary science, Moon phases and science-specific self-efficacy remains limited.

The authors' earlier A.P.D. work concerned the design and validation of lesson plans for teaching Moon phases (Subramaniam & Ishak, 2026). The present paper extends that work by using the sequence as an applied illustration of how instructional experiences may become efficacy information. Its specific conceptual contribution is a synthesis that connects non-digital game design and classroom facilitation with learning experiences, pupils' interpretations of competence, science self-efficacy, and subsequent effort, choice and persistence. Within this explanation, Act, Play and Do provide complementary forms of participation through embodied simulation, cooperative card gameplay and manipulative modelling. The contribution lies in explaining how these experiences may support science self-efficacy in a particular curriculum context, rather than in introducing new sources of self-efficacy or presenting another set of lesson plans. These proposed relationships provide a basis for classroom implementation and empirical investigation; they do not establish the effectiveness of A.P.D.

Conceptual Approach and Methodology

This paper uses conceptual theory synthesis to bring together literature on game-based learning, non-digital educational games and science self-efficacy. A conceptual paper goes beyond a summary of earlier studies by identifying relationships among concepts and developing a theoretically grounded explanation (Jaakkola, 2020). The approach taken here is interpretive and explanatory, with no claim to the exhaustive coverage of a systematic review or meta-analysis. It seeks to explain how experiences within non-digital game-based learning may become sources of efficacy information for primary pupils (Jabareen, 2009).

The literature was organised into four areas: game-based learning design; non-digital card, board and manipulative activities in science education; science self-efficacy and Bandura's four efficacy sources; and primary astronomy and Moon-phase instruction. Publications from 2021 to 2026 were prioritised, with earlier work retained where it provided foundational theory or established principles. The synthesis drew on theoretical and empirical studies, reviews, meta-analyses and official curriculum documents.

Each study was considered in relation to how closely it addressed the paper's focus. Research combining non-digital games, school science and science-related self-efficacy provided more direct evidence. Studies of motivation, engagement, collaboration and conceptual understanding informed the discussion of related learning mechanisms. Research in mathematics, nutrition, higher education and digital games was treated as indirect evidence, since outcomes may differ with the subject, educational level, game format, intervention duration and outcome measured.

The synthesis involved identifying recurring features of game design, comparing cognitive and affective outcomes, and mapping the resulting experiences onto Bandura's four efficacy sources. Successful science performance that pupils could interpret was associated with mastery experiences; observable peer strategies with vicarious experiences; credible, process-

focused feedback with verbal persuasion; and interpretations of enjoyment, tension and task manageability with physiological and emotional states. Together, these relationships formed the explanatory sequence: game design and classroom facilitation → learning experiences → pupils' interpretations of competence → science self-efficacy → subsequent effort, choice and persistence.

The A.P.D. lesson sequence illustrates how these relationships might operate in practice. Its lesson plans were previously designed and validated for teaching Moon phases in primary science (Subramaniam & Ishak, 2026). This paper does not analyse new participant data or test the sequence's effectiveness. The framework therefore sets out theoretically informed relationships for empirical examination, rather than a confirmed causal model.

Game-Based Learning

Game-based learning uses games deliberately within instruction to achieve specified learning outcomes. It differs from gamification, in which selected game elements, such as points, badges or rankings, are added to an activity that is not itself a game (Kalogiannakis et al., 2021; Plass et al., 2015). A learning game usually brings together goals, rules, challenges, player actions, interaction and feedback in an organised system. A novel object or an enjoyable classroom activity alone is therefore insufficient to constitute game-based learning.

Cognitive, motivational, affective and sociocultural processes interact during game-based learning (Plass et al., 2015). Learners engage cognitively when progress in a game requires them to apply knowledge, reason and solve problems. Motivational and affective engagement involves the challenge, interest, enjoyment or frustration experienced while playing. Sociocultural engagement develops through communication, collaboration and participation in a shared learning environment. The contribution of each process depends on the learners, subject, educational level and game design (Arztmann et al., 2023; Plass et al., 2015).

Entertainment alone does not give a game educational value. Learning is more likely when goals and player actions match the intended curriculum outcomes, feedback explains the consequences of pupils' decisions, and classroom facilitation connects gameplay with subject knowledge (Othman et al., 2025; Plass et al., 2015). Even an engaging game may lead to little learning if success rests mainly on luck, speed or familiarity with the rules rather than understanding the curriculum content.

Synthesised Design Characteristics of Game-Based Learning

The game-based learning literature offers no universally accepted framework of exactly eight principles. For this paper, eight recurring design characteristics were synthesised from theoretical and empirical work: cognitive engagement, feedback, motivation, emotional experience, social interaction, curricular and contextual alignment, safe exploration, and accessibility and flexibility (Arztmann et al., 2023; Othman et al., 2025; Plass et al., 2015). Whether these characteristics are present and effective depends on the game's design, its intended learning outcomes and the teacher's facilitation.

1. **Cognitive engagement** involves pupils in tasks that demand reasoning, decision-making, problem-solving and the application of subject knowledge. A game supports this form of engagement when pupils need to understand and apply the learning content

to participate successfully, rather than depend mainly on chance or speed (Arztmann et al., 2023; Plass et al., 2015).

2. **Feedback** provides timely, informative responses to pupils' actions and decisions during gameplay. It is effective when it helps pupils judge whether their responses are scientifically appropriate, understand their errors and adjust their strategies on later attempts (Othman et al., 2025; Plass et al., 2015).
3. **Motivation** concerns how game goals, achievable challenges, participation and opportunities to improve encourage pupils to begin and sustain their involvement in learning. Studies of card- and board-based science activities suggest that games can support motivational dimensions, although the strength of these outcomes varies with game design, subject and learning context (Lazarevic et al., 2024; Naaim & Karpudewan, 2024).
4. **Emotional experience** encompasses the enjoyment, interest, frustration, anxiety and satisfaction that pupils may feel during gameplay. Positive experiences can encourage participation and persistence. Competition, public comparison and excessive time pressure, however, may prompt negative responses in some pupils (Dondio et al., 2023; Plass et al., 2015).
5. **Social interaction** gives pupils opportunities to communicate, explain decisions, observe peers' strategies, negotiate rules and work together on learning tasks. Engagement and collaborative interaction were commonly reported in a systematic review of board games in science education, although these outcomes depend on equitable participation and appropriate classroom facilitation (Othman et al., 2025).
6. **Curricular and contextual alignment** requires game content, rules and tasks to match the intended curriculum standards and call on pupils to apply relevant subject knowledge. Without this alignment, pupils may become skilled at playing a game without understanding the scientific concepts it is intended to teach (Othman et al., 2025; Plass et al., 2015).
7. **Safe exploration** allows pupils to attempt tasks, make errors, receive feedback and revise responses without exclusion or public humiliation. Games can provide this space when errors are treated as part of learning and pupils have repeated opportunities to demonstrate improvement (Gee, 2007; Plass et al., 2015).
8. **Accessibility and flexibility** are practical affordances of non-digital games that use cards, boards and manipulatives. These activities can be adapted to different classroom arrangements without relying on digital devices or continuous internet access. Access still depends, however, on material costs, preparation time, clear instructions and pupils' ability to participate meaningfully (Balakrishna, 2023; Naik, 2015).

These characteristics are not outcomes that follow automatically from introducing a game. The proposed connections between these eight characteristics and Bandura's four sources of efficacy information are summarised in Table 1. Their educational value rests on the interaction of game design, curriculum alignment, teacher facilitation, peer organisation and pupils' interpretations of their experiences. Here, they provide a design basis for examining how the proposed Act, Play and Do lesson sequence may create experiences relevant to science self-efficacy.

Game-based learning can take digital or non-digital forms. Digital formats use computer-based platforms, mobile applications, simulations or video games; non-digital formats rely mainly on physical materials and face-to-face interaction. Either can include goals, rules, challenges, decisions, feedback and social participation. Educational effectiveness is not determined by the

medium itself. Outcomes depend more directly on how game mechanics, curriculum content, learner characteristics and instructional facilitation fit together (Arztmann et al., 2023; Othman et al., 2025; Plass et al., 2015). This paper focuses on non-digital game-based learning because the proposed lesson sequence combines physical gameplay with embodied and manipulative learning activities.

Non-Digital Game-Based Learning

Non-digital game-based learning uses games to achieve specified learning outcomes without digital devices or electronic platforms. Games may use cards, boards, tokens, puzzles and manipulatives, or structured verbal and physical interaction. An activity needs identifiable game features, such as rules, goals, challenges, player actions and feedback or outcomes, to qualify as game-based learning (Naik, 2015; Plass et al., 2015). Hands-on tasks, role-play and activities using physical materials are therefore not necessarily games. They may instead serve as simulations, models or supporting tasks within a broader game-based lesson.

Non-digital games have the practical advantage of requiring neither computers nor mobile devices nor continuous internet access. Working face to face with physical materials may also support direct communication, turn-taking and shared manipulation of those materials (Balakrishna, 2023; Othman et al., 2025). This does not make such games invariably inexpensive or accessible to everyone. Feasibility depends on material costs and availability, preparation time, class size, clear rules, teacher expertise and opportunities for every pupil to participate meaningfully (Naik, 2015; Othman et al., 2025).

Studies across subjects and educational levels offer supporting evidence, though much of it is indirect. Yusof and Shahrill (2021) reported favourable mathematical perspectives and achievement following non-digital game-based learning. Hamden Hamid et al. (2022) found improved achievement in isometric transformations among secondary-school students, while Balakrishna (2023) reported greater participation, engagement and peer interaction among students transitioning to higher education. These studies show that non-digital games can function as structured instructional activities. Differences in subjects, age groups and measured outcomes mean that they do not directly demonstrate improved science self-efficacy among primary pupils.

Othman et al. (2025) provide more closely related evidence through their review of 76 studies of paper-based and digital board games in science education. Physical board games were the most frequently studied format, and findings generally indicated benefits for science knowledge, engagement and collaborative skills. The review also identified small samples, insufficient longitudinal evidence, limited measurement of collaboration and inadequate investigation of the mechanisms behind the reported outcomes. These limitations suggest that a non-digital game's educational contribution depends on its design and implementation, beyond its format alone.

Non-digital game-based learning can thus be understood as an instructional approach whose value depends on context. It can organise opportunities for active participation, scientific reasoning, peer interaction, feedback and repeated practice. Such experiences may support science self-efficacy when pupils regard their performance, peer observations, feedback and emotional responses as credible evidence of growing competence. Direct empirical evidence connecting non-digital games, primary science and science-specific self-efficacy nevertheless

remains limited. This gap motivates the present conceptual examination of how a structured Act, Play and Do lesson sequence may support science self-efficacy when pupils learn about Moon phases.

Self-Efficacy in Learning

Self-efficacy is an individual's judgment of their capability to organise and carry out the actions needed to accomplish a particular task (Bandura, 1977). It is more specific than general confidence, self-esteem or a positive attitude towards learning. Within the same subject, a student may have high self-efficacy for one task and lower self-efficacy for another. Because the judgment concerns perceived capability, it may not correspond precisely to the student's actual knowledge or performance (Bandura, 1977; Schunk & Pajares, 2009).

Bandura (1977) identified four principal sources of efficacy information: mastery experiences, vicarious experiences, verbal persuasion, and physiological and emotional states. Mastery experiences involve how individuals interpret past performance, particularly success they attribute to effort, strategy or growing competence. Vicarious experiences arise when individuals use observations of others carrying out a relevant task to judge their own capabilities. Verbal persuasion consists of credible encouragement and feedback that help individuals recognise what they can accomplish and how to improve. Physiological and emotional states concern how individuals interpret reactions such as calmness, enjoyment, nervousness, tension or fatigue during a task (Bandura, 1977; Schunk & Pajares, 2009).

These sources neither operate independently nor affect self-efficacy automatically; their influence depends on students' interpretations. Completing a task successfully may do little to strengthen self-efficacy if a student credits the outcome entirely to luck or help from a more capable peer. An initial failure, in contrast, may not weaken self-efficacy if the student sees it as a correctable error and then succeeds by changing strategy. What matters is how students interpret performance, observation, feedback and emotional experiences, beyond simply taking part in an activity (Bandura, 1977; Hu et al., 2022).

Science Self-Efficacy in Primary Education

Science self-efficacy concerns pupils' judgments of their ability to undertake specific science-learning tasks: observing a phenomenon, conducting an investigation, interpreting evidence, answering a science question or explaining a scientific pattern (Carroll et al., 2024; Hu et al., 2022). Its task- and domain-specific nature means that confidence in answering factual questions differs from confidence in conducting an investigation or explaining relationships among scientific variables. Measures therefore need to match the science content and practices under examination (Carroll et al., 2024; Hu et al., 2022).

Theory links self-efficacy to the choices, effort and persistence students show when facing challenging learning tasks (Bandura, 1977; Schunk & Pajares, 2009). Believing they can perform a science task may make pupils more willing to attempt it, persist through initial difficulty and act on feedback. Science self-efficacy is nevertheless distinct from scientific knowledge and academic achievement. A confident pupil may hold an inaccurate scientific conception, while a knowledgeable pupil may feel unsure about applying that knowledge in an unfamiliar situation. Self-efficacy and achievement should therefore be treated as related but conceptually separate outcomes.

Research with upper-primary pupils shows why specific science tasks need attention. Carroll et al. (2024) examined the science self-efficacy beliefs of 260 Irish pupils aged 11–12 years. Self-efficacy was lower for performing scientific skills than for answering science questions, and mastery experience was the strongest predictor of scientific-skills self-efficacy. Pupils also reported few opportunities to take part in hands-on scientific investigations. These findings suggest that science self-efficacy depends partly on opportunities to carry out science practices and interpret performance as evidence of competence (Carroll et al., 2024).

Classroom conditions can constrain the development of science self-efficacy in several ways. Limited opportunities to carry out curriculum-relevant science tasks may restrict mastery experiences. Repeated difficulty without informative feedback may encourage pupils to view their performance as evidence of low capability. Although peers can offer useful models, comparisons with substantially more capable classmates may reinforce negative judgments. Nervousness or frustration may also weaken self-efficacy if pupils take these reactions to mean that they cannot manage a task (Bandura, 1977; Carroll et al., 2024; Hu et al., 2022). These conditions need not affect all pupils alike: interpretations depend on prior experience, perceived competence and the immediate learning context.

Enjoyable lessons alone are insufficient for developing science self-efficacy. Pupils need to perform meaningful science tasks, observe peer strategies they can understand, receive credible, process-focused feedback, revise responses and recognise improvement. These needs provide a theoretical reason to examine non-digital game-based learning. Well-designed games, supported by appropriate facilitation, may organise experiences corresponding to Bandura's four sources of self-efficacy. Whether pupils interpret those experiences as evidence of science competence still requires empirical investigation.

Discussion

Recent research supports a qualified link between game-based learning and motivational, cognitive and behavioural outcomes in STEM education (Arztmann et al., 2023). Non-digital games cannot be assumed to be inherently effective. Their contribution to science self-efficacy depends on game design, correspondence with the science curriculum, the quality of teacher and peer feedback, and students' interpretations of their performance.

Direct evidence connecting non-digital games, primary science and science-specific self-efficacy is less extensive than the wider literature on digital and non-digital game-based learning. The more defensible argument is that non-digital games can create conditions supportive of science self-efficacy. Participation by itself cannot be assumed to increase confidence.

Empirical Evidence Relevant to the Proposed Relationship

Few studies directly examine the relationship between non-digital game-based learning and science-specific self-efficacy among primary pupils. A relevant study by Cardinot and McCauley (2024) investigated non-digital educational games in astronomy with 474 post-primary students in Years 1–3 of Ireland's Junior Cycle. It used a mixed-methods, quasi-experimental design, with non-equivalent intervention and control groups assessed before and after instruction. The intervention group undertook astronomy-themed board-game activities

over six weeks, while the control group received comparable instruction without board games. Content covered the Earth–Sun–Moon system, seasons, gravity and the Big Bang.

Both cognitive and affective learning outcomes were examined. An astronomy knowledge diagnostic test assessed cognitive outcomes, and a survey measured enjoyment, motivation, astronomy self-efficacy and task value. The intervention group showed greater improvements in cognitive understanding and affective outcomes than the control group; gains within the intervention group reached statistical significance ($p < .001$). Focus-group discussions and classroom observations also suggested that students found the games enjoyable, interactive and supportive of peer engagement (Cardinot & McCauley, 2024).

These results do not directly establish effectiveness for primary pupils. Participants were post-primary students, instruction addressed several astronomy concepts, and astronomy self-efficacy formed one part of a broader affective survey. The study supports the potential of non-digital astronomy games to aid conceptual understanding and positive affective experiences. It does not show that a Moon-phases game will automatically improve primary pupils' science self-efficacy. This distinction strengthens the case for studying structured non-digital activities designed specifically for primary science, including the proposed Act, Play and Do sequence.

Providing Mastery Experiences

Pupils' interpretations of successful performance give rise to mastery experiences, generally the most influential source of self-efficacy information (Bandura, 1977). Winning a non-digital science game is not, by itself, mastery. Mastery develops when pupils' complete meaningful science tasks, attribute improvement to their effort or strategy and recognise the scientific appropriateness of their responses. For example, sequencing Moon phases becomes a mastery experience when pupils arrange and explain the sequence, correct an error and later complete a similar task with less help.

Non-digital games can divide difficult concepts into manageable challenges that support this process. Matching cards, sequencing, classifying and predicting give pupils repeated opportunities to retrieve information, test explanations, receive feedback and revise responses (Lazarevic et al., 2024; Othman et al., 2025; Plass et al., 2015). Repetition is useful when it calls for scientific reasoning and makes improvement visible. Its contribution to self-efficacy depends on pupils interpreting that progress as evidence of developing capability (Bandura, 1977).

Empirical findings offer cautious support for this relationship. Middle-school pupils using digital or non-digital science games reported stronger science performance and self-efficacy than those receiving lecture-based instruction; self-efficacy was higher in the digital condition (Wang & Zheng, 2021). A six-week physics memory-card intervention was associated with higher physics self-efficacy, active-learning strategies and perceived learning value (Lazarevic et al., 2024). The *STEM-PT Traveler* board game likewise improved several motivational dimensions and chemistry self-efficacy, although not every outcome differed significantly (Naa'im & Karpudewan, 2024). A nutrition board game improved nutritional self-efficacy among primary pupils, but this domain-specific finding does not establish an increase in general science self-efficacy (Çamlıbel & Tokatlı Demirok, 2026).

To support mastery, games should offer progressively challenging tasks, repeated opportunities to respond, informative feedback and teacher-guided discussion connecting gameplay to science concepts (Othman et al., 2025; Plass et al., 2015). Each pupil also needs to explain their understanding individually, since group success can reflect one knowledgeable participant's contribution without demonstrating mastery by everyone (Bandura, 1977; Schunk & Pajares, 2009).

Supporting Vicarious Experiences and Verbal Persuasion Through Peer Learning

Turn-taking, shared materials and discussion can make scientific reasoning visible to pupils playing a non-digital game together (Othman et al., 2025; Plass et al., 2015). A pupil who observes a similar peer using an understandable strategy may gain vicarious efficacy information. This depends on whether the pupil sees the peer model and strategy as relevant to their own performance (Bandura, 1977; Schunk & Pajares, 2009).

A systematic review covered 76 studies of paper-based and digital science board games. Findings generally indicated improvements in knowledge, engagement and collaboration, but the evidence was limited by small samples, little longitudinal research, and inadequate measurement of collaboration and individual game mechanisms (Othman et al., 2025). Research with first-year computing students also indicates that non-digital activities can support engagement, participation and peer interaction. These higher-education findings, however, do not transfer directly to primary science (Balakrishna, 2023).

Encouragement, explanations and feedback during peer interaction may serve as verbal persuasion. Such persuasion is most credible when it is specific, realistic and grounded in pupils' performance (Bandura, 1977; Schunk & Pajares, 2009). Feedback explaining why a science response is appropriate is therefore more useful than general praise. Collaboration does not always follow from working in a group: dominant pupils may control decisions, and public comparisons may weaken the judgments of less-confident pupils (Arztmann et al., 2023; Othman et al., 2025; Plass et al., 2015). Cooperative goals, rotating roles, structured turns and individual accountability help distribute participation and give each pupil personal evidence of competence.

Supporting Engagement and Managing Anxiety

The evidence for engagement through game-based learning is stronger than the evidence for consistent reductions in anxiety. Manipulation, decision-making and interaction in non-digital games can promote behavioural engagement, while tasks requiring scientific reasoning can promote cognitive engagement. Science board-game studies frequently report engagement, and school-based card- and board-game studies have found improvements in active learning and motivational outcomes (Lazarevic et al., 2024; Naa'im & Karpudewan, 2024; Othman et al., 2025).

Repeatable, low-stakes gameplay may feel less threatening when pupils can revise answers, ask for clarification and continue participating after errors (Dondio et al., 2023; Plass et al., 2015). Using an error to inform the next attempt may help pupils see difficulty as manageable, rather than evidence of low capability. This matters because pupils' interpretations of emotional and physiological reactions influence self-efficacy (Bandura, 1977). Low threat and opportunities to try again therefore require deliberate design.

Claims about anxiety need particular care. A meta-analysis found a small reduction in mathematics anxiety that was not robust in sensitivity analysis, although non-digital, collaborative and longer interventions yielded more favourable results (Dondio et al., 2023). Its relevance to science anxiety is indirect. Competition, strict time limits, rankings and elimination could instead increase tension for pupils with lower confidence or prior knowledge (Dondio et al., 2023; Plass et al., 2015). Cooperative objectives, adequate thinking time and non-punitive feedback are therefore needed to make games emotionally manageable (Othman et al., 2025). Enjoyment, engagement, anxiety, conceptual understanding and self-efficacy are distinct outcomes requiring separate assessment (Soriano-Sánchez et al., 2026).

Conceptual Link Between Game-Based Learning and Science Self-Efficacy

The eight design characteristics discussed earlier can be connected to Bandura's four sources of efficacy information through the learning experiences they make possible. Table 1 presents the proposed connections and illustrates their application within A.P.D. These relationships are not one-to-one: a characteristic may support several efficacy sources, while several characteristics may contribute to the same source. Whether an experience strengthens science self-efficacy depends on how pupils interpret it as information about their capability.

Table 1: Proposed Connections Between the Eight Game-Based Learning Characteristics and Bandura's Four Sources of Self-Efficacy

Game-based learning characteristic	Relevant efficacy source(s)	Proposed connection and A.P.D. illustration
Cognitive engagement	Mastery experiences	Reasoning and problem-solving may provide evidence of understanding when pupils complete science tasks successfully. In Play, accurately sequencing the Moon phases and explaining transitions may help pupils recognise their ability to apply scientific knowledge.
Feedback	Verbal persuasion; mastery experiences	Specific, credible feedback may help pupils recognise their capabilities and identify ways to improve. Successful revision can also provide mastery information. For example, the teacher identifies the effective reasoning a pupil uses when correcting a Moon-phase sequence.
Motivation	Mastery experiences, through sustained participation	Achievable goals and opportunities to improve may encourage continued effort and practice. In Play, working towards a complete, accurately explained phase sequence creates opportunities for successful performance. Motivation supports participation; the resulting performance may provide mastery information.
Emotional experience	Physiological and emotional states	Enjoyment, calmness or tension may inform capability judgments through pupils' interpretations of these reactions. Cooperative

completion and sufficient thinking time may help pupils experience the Moon-phase task as manageable, although enjoyment alone does not demonstrate competence.

Social interaction	Vicarious experiences; verbal persuasion	Observing a similar peer use an understandable strategy may help pupils judge whether they can perform the task themselves. In Play, watching a partner explain a phase transition provides a model, while realistic peer encouragement and feedback may offer verbal persuasion.
Curricular and contextual alignment	Mastery experiences, through relevant task performance	Alignment makes successful performance relevant to the science capability being judged. In A.P.D., identifying, sequencing, modelling and explaining Moon phases can provide evidence of curriculum-related understanding, beyond proficiency in handling cards or following game rules.
Safe exploration	Mastery experiences; physiological and emotional states	Opportunities to make errors and revise responses without humiliation may make difficulty feel manageable. Correcting an inaccurate sequence or model may also provide evidence of improvement when pupils attribute that progress to their effort or strategy.
Accessibility and flexibility	Mastery experiences; vicarious experiences, through participation opportunities	Accessible materials and adaptable activities may enable repeated attempts and observation of peers. Physical cards and suitable modelling alternatives can support participation in A.P.D. Accessibility itself is not efficacy information; it enables experiences from which pupils may judge their capabilities.

Source: This table represents the authors' conceptual synthesis, informed by Bandura (1977), Plass et al. (2015), Othman et al. (2025) and the A.P.D. lesson sequence (Subramaniam & Ishak, 2026). The proposed connections have not been empirically validated.

The mapping distinguishes the conditions that organise participation from the information pupils derive from their experiences. Motivation and accessibility mainly enable participation, while curriculum alignment makes successful performance relevant to the intended science tasks. These conditions may create opportunities for mastery, observation, persuasion and emotional interpretation, but do not constitute additional efficacy sources. The proposed explanatory link remains pupils' interpretations: completing a task, observing a partner or receiving feedback may support science self-efficacy when pupils regard the experience as credible evidence of their own capability.

Bandura's (1977) four sources of efficacy information provide an explanation for the relationship between non-digital game-based learning and science self-efficacy. Completing a curriculum-relevant task can offer a mastery experience when pupils take their success as evidence of competence (Bandura, 1977; Hu et al., 2022). Sequencing, modelling and

explaining lunar phases are examples of such tasks (Subramaniam & Ishak, 2026). This interpretation accords with improvements reported in non-digital puzzle and card-based science activities (Lazarevic et al., 2024; Wang & Zheng, 2021). Pupils may gain vicarious experiences by observing classmates apply relevant strategies (Bandura, 1977; Othman et al., 2025), and verbal persuasion through credible, process-focused feedback from teachers and peers (Bandura, 1977; Othman et al., 2025). Physiological and emotional states contribute when pupils take enjoyment, calmness and manageable challenge as signs that they can participate successfully (Bandura, 1977; Naa'im & Karpudewan, 2024). Positive associations between game-based science learning, self-efficacy and motivation vary with context and design (Soriano-Sánchez et al., 2026).

The sources fit within an explanatory process: game design and classroom facilitation → learning experiences → pupils' interpretations of competence → science self-efficacy → subsequent effort, choice and persistence (Bandura, 1977; Hu et al., 2022; Soriano-Sánchez et al., 2026). Games do not directly increase self-efficacy; they organise performances, observations, feedback and emotional experiences that inform pupils' capability judgments (Bandura, 1977; Othman et al., 2025). Prior performance, perceived competence and learning context may lead pupils to interpret the same game differently (Arztmann et al., 2023; Hu et al., 2022). Which efficacy sources become prominent therefore depends on equitable participation, peer organisation, constructive feedback and teacher facilitation (Naa'im & Karpudewan, 2024; Othman et al., 2025; Subramaniam & Ishak, 2026).

A recent meta-analysis in natural science reported a positive pooled self-efficacy difference of 0.72 between game-based and comparison conditions (95% CI [0.34, 1.10]). Heterogeneity was very high and evidence certainty was low. The review also combined digital and non-digital interventions spanning different subjects, educational levels, durations and measures (Soriano-Sánchez et al., 2026). Although the overall pattern was favourable, its applicability may differ across classrooms and game formats.

Measurement needs to match the intended outcome. A pupil's confidence in playing a game does not necessarily reflect confidence in explaining the science it involves. Instruments aligned with the topic and tasks should assess confidence in identifying, sequencing, predicting and explaining lunar phases, rather than general school confidence (Carroll et al., 2024; Hu et al., 2022). Non-digital games may support science self-efficacy by providing success that pupils can interpret visible peer modelling, credible feedback and manageable emotional experiences. Claims about these benefits should remain confined to the population, context, duration and construct studied.

Proposed Non-Digital Game-Based Learning (A.P.D. Lesson Sequence) for the Moon-Phases Topic

The proposed instructional framework is the A.P.D. lesson sequence: *Act*, *Play* and *Do*. It was designed and validated as a set of non-digital lesson plans for teaching Moon phases in primary science (Subramaniam & Ishak, 2026). The three stages are not each games in their own right. *Act* is primarily an embodied simulation; *Play* is a rule-based non-digital game and *Do* is a manipulative modelling activity. Together, they form a structured non-digital game-based lesson sequence, with embodied and model-based experiences supporting the gameplay.

Each stage offers a complementary form of representation. In Act, bodily movement and observation introduce changes in the Moon's visible sunlit portion. In Play, pupils identify, collect, sequence and explain representations of the eight Moon phases through a cooperative card game. In Do, they construct and compare physical representations of the complete sequence. The sequence's educational contribution depends on the conceptual connections between these stages, beyond using role-play, cards or cookies separately.

Act Stage: Embodied Simulation

In the Act stage, pupils represent changes in the Moon's appearance, as viewed from Earth, through head, hand and finger movements. The teacher first establishes a fixed position for the Sun and an observing position for Earth. Pupils use their face or head to represent the Moon and their fingers to outline its visible sunlit portion. Teacher guidance connects each bodily representation with the corresponding Moon-phase image and its place in the complete sequence (Alkan & Kurtoğlu, 2023; Ministry of Education Malaysia, 2019).

Waxing and waning should not be defined solely by whether the illuminated portion appears on the Moon's right or left side. The apparent orientation can vary with the observer's geographical position and the Moon's orientation in the sky. Waxing should instead be explained as an increase in the visible sunlit portion over successive observations and waning as a decrease. Once the sequence has been explained, "C" and reversed "C" finger shapes may offer supplementary visual cues. They should not replace explanations of the changing visible portion and the relative positions of the Sun, Earth and Moon. Teacher questioning should ask pupils to explain why that portion changes, beyond reproducing a finger shape.

Act stage gives pupils an opportunity to demonstrate understanding by representing a Moon phase and explaining its visible sunlit portion. Accurate performance could provide mastery information when pupils recognise it as evidence of their own capability. Observing a classmate's explanation may offer a vicarious experience, while teacher feedback linked to the pupil's reasoning may serve as verbal persuasion. Physiological and emotional states concern how pupils interpret their reactions during the demonstration. For example, guidance and opportunities to correct a response may help them regard nervousness as manageable. These proposed connections concern pupils' interpretations of the experience, rather than the bodily movements themselves (Bandura, 1977; Schunk & Pajares, 2009). Figure 1 illustrates the *Act* stage.



Figure 1: Act Stage: Embodied Representation Of Changes In The Moon's Visible Sunlit Portion

Source: Authors' photograph.

Play Stage: Cooperative Moon-Phase Card Game

The Play stage uses sixteen cards containing two identical sets of the eight Moon phases. Pupils work in pairs, taking turns to draw or exchange cards and build a complete phase sequence. To complete the game, both pupils must arrange their cards accurately and each must explain at least two transitions between phases. The teacher checks their responses and allows corrections. Completion depends on both pupils' understanding, with accuracy and explanation taking priority over speed (Othman et al., 2025; Plass et al., 2015).

Explaining a sequence accurately and correcting an error offer opportunity for mastery experiences when pupils recognise their progress as evidence of capability. A partner's explanation may provide a vicarious experience by making a useful reasoning strategy visible. Teacher and peer feedback may offer verbal persuasion when it is specific, credible and grounded in the pupil's performance. Cooperative completion and opportunities to revise are intended to make mistakes less threatening. Whether these arrangements support science self-efficacy through physiological and emotional states depends on how pupils interpret their reactions during the task (Bandura, 1977; Schunk & Pajares, 2009). Figure 2 depicts the Play stage. Figure 2 depicts the Play stage.



Figure 2: Play Stage: Cooperative Moon-Phase Sequencing Card Game

Source: Authors' photograph.

Do Stage: Manipulative Modelling

In the Do stage, pupils construct the complete Moon-phase sequence using eight Oreo cookies. The white cream represents the part of the Moon's sunlit half visible from Earth. Using a suitable tool, pupils shape the cream to represent the new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, last quarter and waning crescent. They arrange the eight models in sequence and compare them with the phase cards from Play (Ministry of Education Malaysia, 2019; Subramaniam & Ishak, 2026).

Teachers need to explain the cookie model's limitations explicitly. It represents the Moon's changing appearance from Earth but cannot on its own demonstrate the three-dimensional positions and movements of the Sun, Earth and Moon. The amount of cream must not be taken as the actual portion of the Moon illuminated by the Sun. Approximately half of the Moon receives sunlight except during a lunar eclipse; phases arise because observers on Earth see different proportions of that sunlit half. Teachers should also emphasise that Earth's shadow does not cause ordinary Moon phases. Discussion after the activity should connect the cookie models, embodied simulation and card sequence to help avoid reinforcing these misconceptions.

Do is a manipulative modelling activity, not a game in its own right: it has no independent game rules, player competition or game-based goal. Within A.P.D., it allows pupils to make their understanding visible and examine it after playing the card game. Paper circles, modelling clay or reusable discs can represent the phases where allergies, dietary requirements or school policy make food unsuitable.

The Do stage gives pupils a model they can inspect, correct and explain. Producing an accurate representation and explaining its scientific meaning could provide mastery information if pupils recognise the performance as evidence of their understanding. Observing how a classmate constructs or revises a model may offer a vicarious experience. Feedback that identifies what pupils have represented correctly and how they can improve may serve as verbal persuasion. The option to reshape the model also allows pupils to respond to mistakes. Its emotional significance depends on whether they experience frustration or uncertainty as

manageable difficulty, rather than evidence of inability. Enjoyment of the materials alone does not establish stronger science self-efficacy (Bandura, 1977; Schunk & Pajares, 2009). Figure 3 depicts the Do stage.



Figure 3: Do Stage: Manipulative Representation Of The Complete Moon-Phase Sequence

Source: Authors' photograph.

The three stages offer different opportunities to perform science tasks, observe peers, receive feedback and respond to difficulty. Table 1 summarises the proposed connections with Bandura's efficacy sources. These connections require empirical examination particularly whether pupils interpret their experiences as credible evidence of their science capabilities (Bandura, 1977; Othman et al., 2025).

Implications for Practice and Research

Implications for Practice

Curriculum alignment and classroom facilitation determine the instructional value of non-digital game-based learning. In A.P.D., reproducing finger movements, collecting cards and shaping cookie cream are insufficient on their own. Pupils should explain how each representation relates to the Moon's visible sunlit portion and the relative positions of the Sun, Earth and Moon. Teacher questioning and discussion after the activities are needed to connect Act, Play and Do with the intended learning standards (Ministry of Education Malaysia, 2019; Othman et al., 2025).

Classroom organisation should give pupils equitable access to materials, rotating roles, enough thinking time and opportunities to explain the science individually. Process-focused feedback and chances to revise errors can strengthen successful performance, peer modelling, verbal persuasion and manageable emotional responses (Bandura, 1977; Plass et al., 2015). The non-digital format may suit classrooms with limited devices or internet access, but implementation still depends on materials, preparation time, class size, pupil participation, food restrictions and teacher knowledge. Schools can help by providing reusable cards and non-food modelling materials, and by supporting teacher discussion of representational limitations. Curriculum planners should regard these activities as one option among inquiry, modelling and game-based strategies, without assuming universal effectiveness. Assessment should distinguish conceptual

understanding, engagement and science self-efficacy through content questions, individual explanations and task-specific confidence items on identifying, sequencing, predicting and explaining Moon phases (Carroll et al., 2024; Hu et al., 2022).

Implications for Research

Empirical studies are needed to test the proposed relationships. Future research should compare A.P.D. with an appropriate alternative condition, using curriculum-aligned pretests and post-tests of Moon-phase achievement and topic-specific science self-efficacy. Delayed post-tests should assess retention. Given the substantial variation in game-based outcomes across interventions, significance tests should be accompanied by effect sizes and confidence intervals (Soriano-Sánchez et al., 2026).

Research also needs to examine the process proposed to explain these outcomes. Observations, interviews and focus groups could explore whether pupils interpret gameplay as mastery experience, peer modelling, verbal persuasion or manageable emotional challenge. Implementation data should capture feedback, participation, revision and scientific explanation. Studies of individual components could establish whether Act, Play and Do make different contributions to conceptual understanding and self-efficacy, and whether the full sequence offers advantages over the card game alone. Prior knowledge, initial self-efficacy, language background and participation warrant attention because learner groups may experience different outcomes (Arztmann et al., 2023). Conclusions must stay within the educational level, topic, duration and efficacy construct examined. Evaluating transferability and sustainability will require larger, more diverse samples, varied school settings and longer follow-up periods.

Conclusion

The theoretical contribution of this paper is to connect eight game-based learning characteristics with Bandura's four sources of efficacy information in primary science. The mapping distinguishes the opportunities created by instructional design from the information pupils use to judge their capability. Successful performance, peer observation, credible feedback and interpretations of physiological and emotional reactions may inform these judgments, depending on how pupils understand their experiences. A.P.D. illustrates this explanation through embodied simulation, cooperative card gameplay and manipulative modelling of Moon phases. The paper extends the earlier lesson-plan design and validation work by examining how experiences across Act, Play and Do may become relevant to science self-efficacy. Its contribution is an explanatory synthesis that places pupils' interpretations of competence between instructional experiences and capability judgments. These proposed relationships do not establish that A.P.D. improves science self-efficacy.

This paper draws on a non-systematic conceptual synthesis, with limited direct evidence concerning non-digital games and science self-efficacy in primary Moon-phase lessons. Evidence from other subjects, educational levels and game formats informs the explanation but does not establish the effectiveness of A.P.D. Future studies should examine the proposed relationships using curriculum-aligned achievement measures, topic-specific self-efficacy instruments and pupils' accounts of their learning experiences.

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