Developing Science Process Skills Using Augmented Reality

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ABSTRACT

concerns about Malaysia students' performance in international assessments have highlighted the need to strengthen Science Process Skills (SPS), this study aimed to identify primary school students' existing SPS levels, and try to implement and evaluate the effectiveness of augmented reality (AR) in improving these skills, and examine how students used AR during science learning. A primary school in southern Malaysia was selected through simple random sampling and classes were selected through cluster random sampling. The study involved 150 students: 100 completed an initial SPS assessment, and a separate group of 50 participated in a two-week marker-based AR intervention incorporating the 5E inquiry model. The initial assessment group demonstrated a moderate SPS level (M = 50.14). In the intervention group, the reported mean increased from 58.12 in the pre-test to 85.26 in the post-test. The reported paired-samples t-test indicated a statistically significant difference, ($t = 22.199$, $p < .005$). Interviews provided information about how students interacted with AR. All interview respondents reported viewing objects from different directions through 360-degree manipulation, while 83.33% reported examining specific parts of animal models more closely. The findings suggest that AR can support the development of SPS, particularly classification, by enabling students to observe and compare features of three-dimensional models. Further research using comparison groups would help establish the contribution of AR to the observed improvement.

Keywords: science process skills; augmented reality; primary science education; classification; inquiry-based learning

INTRODUCTION

The Malaysia Education Blueprint 2013–2025 set out a programme of educational transformation intended to strengthen the national education system and achieve internationally competitive educational standards. The historical performance of Malaysian students in TIMSS 2007 and PISA 2009 raised concerns about achievement in mathematics and science. These concerns provide the background to the present study rather than a description of current national performance. Effective teaching and learning are central to addressing such challenges. The Malaysian school quality standards emphasise the teacher's role in creating an enjoyable and stimulating learning environment (Inspectorate and Quality Assurance Division, 2004).

The Science Curriculum emphasises scientific skills, comprising SPS and manipulative skills. SPS enable learners to obtain, organise, and interpret information about the scientific world. They involve mental processes that support critical, analytical, and systematic thinking. Mastery of these skills enables students to identify questions and investigate problems systematically, progressing from relatively simple to more complex processes (Curriculum Development Division, 2010). SPS are closely associated with thinking and inquiry in science (Gagné, 1965; Aydoğdu et al., 2012). They are used in scientific investigation (Mutlu & Temiz, 2013) and are associated with attitudes towards science (Opateye, 2012).

SPS are important to scientific literacy (Harlen, 1999; Espinosa et al., 2013), which contributes to participation in contemporary society (Turiman et al., 2012). Ewers (2001) argued that scientific literacy requires more than reading and listening: learners must also develop competence in the processes through which scientific knowledge is investigated. Aktamış and Ergin (2008) likewise examined the educational importance of developing scientific process skills. Ferreira (2004) highlighted the importance of SPS in science teaching.

Accordingly, science instruction should deliberately incorporate opportunities to develop these skills (Saat, 2004; Yakar, 2014).

Integrating SPS into primary science lessons can be challenging. Science teachers therefore require professional development, whether centrally organised or provided within schools, to plan learning activities that explicitly incorporate SPS. Such instruction should emphasise the development of skills alongside the acquisition of scientific facts and principles. Wellington (1994) argued that the value of these skills extends beyond the retention of particular factual knowledge. Observation is fundamental to the development of SPS.

Millar (1990) discussed the role of processes in science education, while Haury (2002) emphasized observation as a foundational scientific skill. Although observations are constrained by the limitations of human perception, they remain central to developing and testing scientific ideas. Classification is also an important process for primary school learners. Ferreira's (2004) study, which addressed classification, observation, and inference among fifth-grade students, illustrates the value of deliberately designed activities and classroom dialogue in supporting these skills.

Science Process Skills and the Educational Potential of Augmented Reality

Previous Malaysian research has raised concerns about students' mastery of SPS. Ismail Jusoh (2001) reported difficulties in science teaching and scientific reasoning. More directly, Ong and Bibi Hazliana Mohd Hassan (2013) found that primary school students did not reach the two-thirds mastery criterion for basic SPS. Their findings indicated that difficulties occurred across individual skills and highlighted differences associated with school location. These findings support the need to examine students' existing SPS and investigate instructional approaches that can provide more effective opportunities for observation and classification.

Recent research has examined the integration of AR and gamification in education. These approaches are related but should be distinguished: AR combines digital information with the physical environment, while gamification introduces game elements into learning activities. AR can also be used within a complete educational game. Lampropoulos et al. (2022) reviewed research on AR and gamification and reported benefits associated with engagement, motivation, participation, and learning outcomes. They also emphasised appropriate educational strategies and attention to learners' characteristics. These findings provide a rationale for considering the educational design of AR activities rather than assuming that the technology alone will improve learning.

Volioti et al. (2022) developed three gamified AR applications for teaching physics at primary and secondary school levels. Their evaluation involved 314 participants, including pupils, teachers, and computer science students. The findings indicated favourable usability and teachers' interest in classroom implementation. This study supports the practical application of gamified AR in science education, although it does not directly establish improvements in science process skills. Czok et al. (2023) compared AR and game-based conditions in a science learning environment involving 203 pre-service teachers. Their results highlighted the potential of AR to support motivation and engagement, while the game-based versions did not improve learning outcomes in that particular context. Because their participants were in higher education, the findings cannot be transferred directly to primary school students. Nevertheless, they reinforce the need to align technological and game features with learning objectives and evaluate their effects rather than assume benefits. Taken together, these studies support the investigation of AR as an educational approach while identifying gamification as a possible area for subsequent instructional development. In thin study, researcher specifically want to examined on how students used marker-based AR within a 5E inquiry approach to develop and enhance SPS. Three research objectives involves which is:

1. To identify primary school students' existing SPS levels.

2. To examine the effectiveness of AR in improving primary school students' SPS.

3. To investigate how students used AR to support the development of their SPS.

RESEACH METHODOLOGY

The study used a pre-experimental design. A primary school in southern Malaysia was selected through simple random sampling. After the school had been selected, classes were chosen through cluster random sampling. A total of 150 students participated. Of these, 100 completed an initial assessment of existing SPS using a researcher-developed test. A separate group of 50 participated in the AR intervention.

Although the intervention participants were selected through cluster random sampling, the following conditions had to be met:

1. Students agreed voluntarily to participate.
2. Students owned a suitable device and knew how to operate it.
3. School administrators granted conditional permission for devices to be used at school for learning and research.
4. The classroom had adequate Internet access.

Intervention

The intervention group used marker-based AR for two weeks to learn classification, an SPS taught at primary school level. The researcher incorporated the 5E inquiry model into the learning process. Questions were used to prompt students to investigate and construct answers. Table 1 presents the questioning approach used during the intervention.

TABLE (1). How questioning been used to apply 5E model during SPS learning with AR supported

5E phase	Description	Examples of questions and prompts
E1-Engage	Stimulate interest in learning and introduce the relevant concepts.	What do you see?
	Show interest towards topic.	What similarities can you identify?
		Why might this happen?
E2-Explore	Students got experience by investigating the phenomenon.	Describe your observations and ideas. Provide evidence to explain why this happens.
E3-Explain	Teacher can guide students towards a deeper understanding.	Refer to the previous activity. Explain your view.
		Group the animals according to their shared characteristics.
E4-Elaborate	Students can apply their understanding in a new situation or context.	Construct a tree map to classify the animals. Support your conclusion using the information obtained.
		Explain your current view based on what you have learned.
E5-Evaluate	Assess students' understanding.	Show why this statement is incorrect. Write down your understanding about this topic.

Students completed a pre-test before using AR. After the intervention, they completed a post-test, and selected students were interviewed. Interview participants were chosen randomly. The SPS assessment, pre-test, and post-test were examined for reliability. A pilot study involved 10 students who did not participate in the main study. The reported Cronbach's alpha coefficient was .658. The instruments were reviewed for validity by a head of the science panel with 10 years of teaching experience. Each test carried a maximum score of 100. Students completed the tests on paper and were allowed 30 minutes for each assessment. The researcher marked the tests using a predetermined answer scheme.

FINDING DAN RESULTS

The initial assessment of 100 students indicated a moderate level of SPS, with a mean score of 50.14. The

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minimum score was 40 and the maximum was 90. The findings indicated that SPS mastery required further development among the assessed students.

Table 2 presents the individual scores reported for the 50 students who participated in the intervention.

Table (2). Reported individual pre-test and post-test scores

Participant	Pre-test	Post-test	Participant	Pre-test	Post-test
S1	56	90	S26	50	80
S2	60	92	S27	54	90
S3	58	88	S28	76	95
S4	44	74	S29	90	90
S5	60	89	S30	54	86
S6	84	94	S31	48	78
S7	56	88	S32	76	90
S8	54	78	S33	56	90
S9	54	76	S34	44	76
S10	48	78	S35	64	86
S11	50	85	S36	54	96
S12	76	94	S37	56	76
S13	42	82	S38	78	93
S14	58	87	S39	70	91
S15	54	82	S40	42	80
S16	58	78	S41	76	90
S17	66	90	S42	42	84
S18	72	96	S43	58	90
S19	44	68	S44	54	88
S20	50	85	S45	58	78
S21	40	84	S46	66	80
S22	44	76	S47	72	95
S23	64	89	S48	44	85
S24	58	83	S49	50	78
S25	56	86	S50	58	86

The original analysis reported a pre-test mean of 58.12 and a standard deviation of approximately 11.55. The post-test mean was 85.26, with a standard deviation of 6.61. The higher post-test mean indicated improvement in SPS performance following the AR intervention. Table 3 conclude the descriptive statistics for the pre-test and post-test.

Table (3). Reported descriptive statistics for the intervention group

	n	Range	Minimum	Maximum	Mean	SD	Variance	Median
Pre-test	50	48	42	90	58.12	11.5523	133.455	56
Post-test	50	28	68	96	85.26	6.61418	43.747	86

To examine the effectiveness of AR in enhancing SPS, the researcher conducted a t-test to identify the differences between pre-test and post-test performance. The reported results are presented in Table 4.

Table (4). t-test results

	Mean difference	**SD of differences**	**t**	**df**	**p**
Post-test minus pre-test	27.14	8.64495	22.199	49	0

The reported analysis indicated a statistically significant increase in scores, t = 22.199, p = .000. The change was consistent shows that AR improved SPS performance. Interview data provided further information about students' experiences of using AR. Table 5 summarises the responses reported in the original study.

Table (5). Summary of interview findings

Theme	**Sample responses**
Ways of using AR	Using smartphones, manipulating images through 360 degrees, examining specific parts of animal models more closely.
Advantages of AR	Viewing features that were obscured in static pictures, identifying more animal characteristics, observing dangerous animals or animals not found in Malaysia at close range through virtual models.
Limitations of AR use	Restrictions on using smart devices at school.
Views on using AR in learning	supporting students' imagination, should use AR in more topics

DISCUSSION

The initial assessment indicated a moderate level of SPS among the 100 students assessed. This finding supports the need to strengthen the teaching of these skills in primary science. Earlier Malaysian research also identified difficulties in basic SPS. Ong and Bibi Hazliana Mohd Hassan (2013), for example, found that primary school learners did not achieve a two-thirds mastery criterion across the basic SPS assessed. The present findings are therefore consistent with concerns about the need for more deliberate opportunities to develop observation and classification skills.

The curriculum context is important to this interpretation. The six basic SPS emphasized in the relevant primary science curriculum are observing, classifying, measuring and using numbers, inferring, predicting, and communicating (Curriculum Development Division, 2012). These skills require students to work with evidence and make distinctions between relevant features. AR can provide an additional means of presenting such features, particularly when static illustrations do not show all sides of an object.

For the intervention group, the reported increase in mean scores from 58.12 to 85.26 suggests improved performance after students used AR within the 5E inquiry activities. Recent literature provides support for examining such technology-supported learning opportunities. Lampropoulos et al. (2022) identified educational benefits associated with AR and gamification, while emphasizing the role of learner-centered implementation and appropriate instructional strategies. Their review offers a broad educational rationale rather than direct evidence that the present intervention improved classification skills.

Chaipidech et al. (2024) provide a closer comparison in terms of age group and technology. Their study involved primary school students using marker-based AR gamification in science and reported improved conceptual understanding. Their findings support the potential of interactive AR activities for younger learners. However, differences in scientific topic, assessment, and instructional design mean that the two studies should not be treated as equivalent. In particular, the present study assessed SPS through an AR-supported 5E approach and did not isolate the effect of game elements.

The interview findings help explain how students used the AR application. Viewing animal models through 360 degrees enabled them to examine different perspectives, while closer inspection helped them identify details that might be difficult to see in a static image. The ability to observe more characteristics could support the comparison of similarities and differences required for classification. The reported use of tablets also suggests that screen size influenced the clarity of the viewing experience. These interpretations are grounded in

participants' descriptions; the study did not separately measure the contribution of screen size or model manipulation to test performance.

Gamification provides a relevant direction for improving the design of future AR learning activities. For example, classification tasks could be organised around progressively challenging questions, immediate feedback, or clearly defined learning goals. These would be proposed additions rather than features established by the current methods. Lampropoulos et al. (2022) provide a basis for considering such design choices, while Chaipidech et al. (2024) illustrate their application in primary science learning.

At the same time, educational improvement should not be assumed merely because AR and game features are combined. Czok et al. (2023) found that game-based versions of a science learning environment did not produce the expected benefits in their higher education sample, despite evidence of motivational and engagement benefits associated with AR. This contrasting finding strengthens the case for evaluating the fit between game features, learning objectives, and learners' needs. It also supports maintaining a clear distinction between engagement, conceptual understanding, and SPS as different outcomes.

The findings of the present study should be interpreted in relation to its pre-experimental design. The intervention combined AR, inquiry activities, teacher guidance, and two weeks of learning. Without a comparison group, the observed change cannot be attributed exclusively to AR or gamification. Nevertheless, the score improvement and students' accounts indicate that AR merits further investigation as a means of supporting observation and classification in primary science.

CONCLUSION

The initial assessment indicated a moderate level of SPS among the participating students. Following the two-week AR-supported intervention, the intervention group demonstrated an increase in reported test scores. Interview respondents also described ways in which AR supported their learning, particularly through viewing animal models from different perspectives and examining specific features more closely.

The findings suggest that AR can provide useful opportunities for developing SPS within science lessons, especially when visual exploration is supported by purposeful questioning and inquiry activities. Students' responses also indicated interest in extending AR to additional topics. Effective implementation requires cooperation between teachers and school administrators, including suitable arrangements for device use and access.

Recent literature from 2022–2024 provides a relevant basis for considering gamification as a future enhancement to AR-supported science learning. Such development should be guided by clearly defined educational objectives and evaluated through appropriate measures of SPS, conceptual understanding, and engagement. Further studies using comparison groups would help determine the specific contribution of AR and any added game elements to students' learning.

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