USE OF TARGETED WEB-BASED INSTRUCTION TO ENHANCE LEARNERS' UNDERSTANDING OF ASTRONOMY CONCEPTS

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ABSTRACT – Primary school learners often use naïve ideas rather than normative notions to understand Astronomy concepts, because they rely on inadequate mental models to decipher the concepts. This paper reports on findings from the use of Targeted Web-Based Instruction (TWBI) to enhance Grade 4 learners' understanding of Astronomy concepts. Targeted instruction involves the identification of learners' different levels of understanding in order to provide them with information that is within their level or zone of proximal development. The TWBI involved the use of web-simulations, applications, search engines, and web links to multimedia to study Astronomy concepts that learners perceived as difficult. An online achievement pre- and post-test was used to collect quantitative data from 27 Grade 4 learners from a primary school in Johannesburg. In addition, a Web-Attitude Scale (WAS) and individual semi-structured interviews were used to collect qualitative data. The findings revealed a statistically significant improvement ($p<0,001$) in learners' post-test scores and in their attitude towards the study of Astronomy. We argue that the use of TWBI could enhance learners' understanding of Astronomy concepts.

Keywords: Web-based, Instruction, Astronomy, Targeted.

INTRODUCTION

In South Africa, Natural Science is a compulsory subject offered in the Intermediate Phase (Grades 4 to 6) curriculum (Department of Basic Education [DoBE], 2011), and it includes a learning unit titled Earth and Beyond (DoBE, 2011). In Grade 4, the Earth and Beyond unit focuses on the study of planet earth, the earth and the sun, and the moon (DoBE, 2011, p. 27-30). The existence of celestial bodies beyond the skies fascinates young people. Kallery (2000) asserted that this fascination with astronomical phenomena evokes numerous` enquiries and perplexities. When young learners are fascinated by seeing the sun 'set' or 'rise', and the moon appearing at night, they develop ontological 'big ideas' that guide their conceptions of these celestial bodies. Young learners tend to understand these phenomena by developing intuitive ideas based on naïve and causal theories that inform their interpretations (Kallery, 2000). Vosniadou and Brewer (1994) and Agan (2004) have established that learners often use inadequate mental models when learning Astronomy, mostly because they rely on naïve and causal ideas to construct their understanding of the relationship between the earth, moon, sun and the solar system in general. In this regard, Nthimbane, Ramsaroop and Naude (2017) suggested that 'like scientific theories, intuitive ideas are composed of a combination of causal laws and ontology that determine how various concepts interrelate' (p. 305). Although these are not scientifically proven notions, a young learner holds them to be true until a new theory that provides more conclusive evidence is taught or learned (Gopnik & Wellman, 2012).

In the South African context, the problems facing young learners beginning to learn Astronomy concepts is compounded by the fact that they are simultaneously transitioning from being taught in their native languages to being taught in English in Grade 4 (Pretorius, 2014; DoBE, 2011). Learners therefore face the dual challenge of learning complex Astronomy concepts in an unfamiliar language – English, which is a second or even third language to most South African learners (Snow, 2010).

Another challenge facing young Astronomy learners is that South African teachers predominantly use traditional methods to teach the topic, where teachers are seen as the main source of information, with limited use of technology. They also rarely emphasize the development of learners' prior knowledge. In this regard, Mnyamane and Naude (2016) have argued that 'teachers at the primary school level pay limited attention to their learners' prior-knowledge and to naïve theories about the natural world, when introducing scientific concepts' (p. 507). These authors further inferred that primary school teachers in South Africa ‘do not establish pedagogies that address these attributes in the instruction process’ (Mnyamane & Naude, 2016, p. 507).

Given these challenges, an instructional approach, which explicitly demonstrates the Astronomy concepts perceived as difficult by learners, could enhance their transition from naïve to normative understanding of the concepts. In South Africa, there is a dearth of literature on instructional methods for enhancing Grade 4 learners’ understanding of the Astronomy. It therefore became necessary to develop an instructional intervention that attempted to assist learners in the process of theory formation, refutation and change. The questions addressed in the study were:

1. How does TWBI affect learner achievement in an assessment on Astronomy concepts?
2. What are Grade 4 learners’ perceptions regarding the use of web-based instruction to learn about Astronomy concepts?

THEORETICAL BACKGROUND

The concept of constructivism was used to guide this study. According to Vygotsky (1934), cited in Liu, and Matthews (2005), ‘Learners are believed to be enculturated into their learning community and appropriate knowledge, based on their existent understanding, through their interaction with the immediate learning environment’. Based on the thinking of Vygotsky, it was assumed that learners could construct their understanding of abstract Astronomy concepts. Two features of constructivism are prominent, namely cognitive constructivism and social constructivism. This study was premised on the empirical work of cognitive constructivists such as McInerney and McInerney (2002), and Liu and Mathews (2005), who argued that knowledge is individually constructed through learner-centred and discovery-oriented learning processes. In line with cognitive constructivism, Grade 4 learners were provided with instruction that targeted the unique misconceptions or incorrect responses they produced in the pre-test. The learners were also individually engaged in mini research projects and virtual experiments to enhance their understanding of selected Astronomy concepts. The social context provided by peers functioned as motivation for individual cognitive development.

METHODOLOGY

Research design and sample

The study employed a sequential mixed methods research approach, involving a single group pre- and post-test experiment. Participants were selected using purposive sampling, because they were expected to study Grade 4 Astronomy topics stipulated in the CAPS document. The participants comprised 27 Grade 4 learners from an intact class in a school in Soweto, Johannesburg, enrolled for the 2018 school year. The class contained 16 male and 11 female learners, aged between 9 and 11 years.

Development of TWBI materials for intervention

In order to develop the TWBI materials, Astronomy concepts were identified based on learners not showing competence in them in a pre-test. These were then categorized into themes that included movements of the earth and the moon, features of the earth, moon and the sun, phases of the moon, the relationship between the earth, moon and sun, as well as the planets in our solar system. Concepts from these themes were incorporated into the TWBI materials used for the intervention. An experienced Grade 4 teacher and two primary school science education specialists reviewed and approved the TWBI materials.

Instrumentation

The instruments used to collect data were an Astronomy achievement test, a Web-based Attitude Scale (WAS), and a structured interview schedule. The researcher developed the achievement test instrument and a structured interview schedule in collaboration with an experienced Grade 4 science teacher and two specialists in the field of primary school science education and assessment. The WAS instrument was developed by Loyd & Gressard (1985), revised by Nash & Moroz (1997), and adapted for the South African context by the researcher. This adaptation by the researcher was done with the objective assistance of the experts who were involved in developing the test and interview schedule.

The involvement of primary school science education experts in the development of data collection instruments was meant to enhance their validity. These specialists were required to develop and review the instrument items to ensure that they were:

- related to the Astronomy topics under investigation
- in line with the South African Natural Science CAPS document
- clear, suitable and comprehensible to Grade 4 learners
- grammatically correct

All the instruments were also validated in a pilot study, using five Grade 4 learners who did not participate in the main study. After the pilot study, items in all instruments were revised, and those that did not meet the stated criteria were either discarded or modified.

The achievement test assessed learners' competence in Grade 4 Astronomy topics, while the WAS and the interview schedule were used to determine (i) learners' interest, access and attitudes towards the use of computers and the internet for teaching and learning purposes, and (ii) learners' knowledge of Grade 4 Astronomy concepts. The latter was done in order to triangulate the quantitative findings.

Research process

The achievement test, which consisted of 26 items, was administered to learners as a pre-test for two reasons. The first was to determine learners' baseline knowledge of stipulated Grade 4 Astronomy concepts. Secondly, it was used to identify Grade 4 Astronomy concepts that learners found difficult to understand. These, in turn, were used to guide the development of TWBI materials for the intervention. In addition, The WAS questionnaire was also administered prior to the intervention.

After the pre-test, learners were exposed to TWBI materials for seven 30-minute lessons, which took place over a period of three weeks. The intervention, which occurred during school time at the schools' computer centre, was meant to enhance participants' understanding of the identified difficult Astronomy concepts. Learners used web-simulations, applications, search engines and web links to multimedia, such as videos, animations, games and age-appropriate websites to learn about the earth, moon, sun, and the solar system. Learners were provided with research problems and web links, the latter of which were generic for all the lessons. However, unbeknownst to the learners, they received different solar system research problems to investigate, based on their performance in the pre-test.

Subsequently, the same achievement test and WAS survey were again given to the participants as a post-test. The purpose of this post-test was to determine the effect of the intervention on learner achievement and on their views about the use of computers and the internet for learning purposes. Out of the 27 learners who received the WAS questionnaire, only 21 learners completed it. The performance of learners in the pre-test and post-test, as well as in the WAS survey, was subsequently compared. Furthermore, five of the participants, comprising learners from the top 10% and bottom 10% of the post-test scores, were interviewed after the intervention.

Data analysis

Quantitative data from pre-test and post-test scores were compared using a histogram and paired sample t-test. These comparisons aimed to determine the effect of the intervention on the learners' achievement in Astronomy topics related to the learning unit Earth and Beyond. For the t-test, a level of significance equal to or less than 5% ($p \leq 0.05$) was considered a statistically significant difference.

Seidel's (1998) model of qualitative data analysis (QDA), was used to analyse the data from the WAS survey and interviews. Seidel (1998) postulated that the process of analysing qualitative data involves three parts, namely noticing, collecting and thinking. In accordance with the model, the researcher identified (noticed) and coded responses from the WAS questionnaire and interviews that were relevant to the study. The coded statements were then organised (collected) into themes. These themes were examined to make sense of the data, both within each theme and from the general collection of themes (thinking). The codes used to analyse the data consisted of four elements. For instance, the code “ivM3b” expresses the second statement (b) given by the third male learner (M3), under the fourth theme (iv).

Ethics considerations

Permission to involve learners in the study was sought from their parents, the principal, school governing body and the Department of Basic Education. Learners provided assent to participate in the study, after the purpose, nature, benefits and potential risks of the study were explained to them. The researcher informed learners of their right to refuse to participate or to withdraw from the study without repercussions. Learners were further informed that their performance in the assessments and their interview responses would be kept confidential, and that their right to privacy and anonymity were guaranteed. Finally, the research report was made available to the participants, their parents and their teacher, during a debriefing/closure session.

RESULTS

The study results are presented in two sections. The first section displays quantitative data from pre- and post-tests, comprising a histogram and inferential statistics. The second section presents qualitative data obtained from WAS survey and interviews.

Quantitative data

The displayed quantitative data pertains to the research question: ‘How does TWBI affect learner achievement in an assessment on Astronomy concepts?’ Pre- and post-test scores were initially compared using a histogram, and the results are shown in Figure 1.

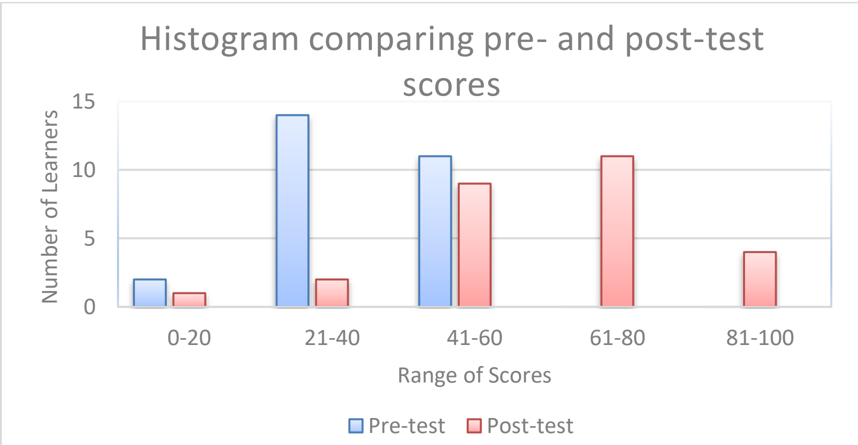

Figure 1: A histogram comparing learners’ pre- and post-test scores.

Figure 1 shows that most learners (25 out of 27) scored in the ranges of 21 to 40 and 41 to 60 in the pre-test. The mean score in the pre-test was 35.6%. After the TWBI, the majority of the learners (24 of 27) scored in the range of 41% to 100%, with a mean score of 60.7%, which is an improvement of 25.1% from pre-test mean score. The significance of the difference in learners’ pre- and post-tests mean scores was determined using a paired sample t-test, and the result of the comparison is displayed in Table 1.

Table 1: Paired sample t-test comparison of the performance of learners in the pre- and post-tests

Assessment	N	Mean score (%)	SD	Mean score difference (%)	*p*-value
Pre-test	27	35.6	11.06	25.1	0.001**
Post-test	27	60.7	17.98		

**p<0.05 (critical value)

The p-value of 0.001 in Table 1 reveals a statistically significant difference between the pre- and post-test mean scores. This quantitative result suggests that learners’ performance in an Astronomy achievement test improved significantly after the TWBI intervention.

Qualitative data

The second research question was 'What are Grade 4 learners' perceptions regarding the use of web-based instruction to learn about Astronomy concepts'? In order to answer this question, two themes were considered. The first theme involved determination of learners' attitudes toward the use of the computers and the internet for learning, and the second was an interrogation of learners' knowledge of Astronomy. The WAS survey and semi-structure interviews yielded the following results.

Theme 1: Learners' interest and attitudes towards the use of computers and the internet for teaching and learning purposes

Items from the WAS survey sought to determine, before and after the intervention, whether learners felt confident to use computers and the internet. The survey also aimed to determine whether the use of the internet makes learning easier, and whether the internet could enhance academic performance. The findings showed that learners were hardly exposed to computers and the internet during science lessons prior to the intervention. In addition, four of the five learners who participated in the interviews said they had not used the computer centre or the internet for teaching and learning purposes, prior to the intervention, in that academic year. Despite this deprivation, findings from the survey revealed that 57% of the learners felt confident to use computers and the internet.

After the intervention, 42.9% of the learners who participated in the survey indicated that the internet was relevant for teaching and learning purposes, and 48% felt that the use of the internet could enhance their academic performance. These sentiments were reiterated during the interviews, where all interviewed learners indicated that they enjoyed using computers and the internet to learn about the solar system. When asked what they found most interesting about learning in the computer centre, learners' responses included the following:

vF1a&b. *'When we played the games, making our solar system'.*

vM1a&b *'It helps you to know the solar system and how the internet works'.*

Additionally, all participants responded in the affirmative when asked if they think learning in the computer centre is useful in improving their academic achievement. Based on learners' responses to questions regarding the intervention, it is clear that they had a positive attitude towards the use of computers and the internet as learning devices and that they felt that these resources enhanced their knowledge of Astronomy concepts.

Theme 2: Learners' knowledge of Astronomy concepts

This theme was aimed at establishing learners' knowledge of Astronomy concepts, including the earth, moon and sun, after the intervention. Learners' responses suggest that they acquired basic knowledge of these celestial bodies. These assertions are evident in the following quotations; iF1a&b, '*What I have learned about the earth is that the earth has its own axis….'; iM2a, 'I've also learned that the features of the earth are water, land and air*'; iiM1a, *'I learned that the moon has rocks and it has, the holes are called craters'*. In addition, some learners thought that learning about these concepts had significance to future learning, as indicated in this quotation; iiiM2b, '*Yes, b-Because in other grades we need to make a book about the sun and it is important to remember the information'.*

From learners' responses, it appears that the majority of them held a normative understanding of the features of the sun, earth and the moon, and the movements of the latter two bodies, after the intervention. This finding corroborates the improvements observed in the quantitative data. However, despite these improvements, some learners did not seem to know the difference between certain Astronomy terms, such as rotation and revolution, as indicated in these statements; iF1a&b '*What I have learned about the earth is that the earth has its own axis and that the earth rotates around the sun'.* iiF2b *'We learned that the moon is it rocky and it is a sphere and it rotates around the earth'.* Learners' limited capacity to express themselves in English could account for this limitation.

DISCUSSION OF RESULTS

The quantitative results revealed that the use of TWBI to teach Grade 4 Astronomy concepts significantly enhanced learners' achievement in the topic, despite the fact that they had had limited exposure to tools (computers and the internet) used for the intervention. This improvement is not surprising as the TWBI used provided learners with control over the content taught, which could have enhanced their conceptual understanding. Learners are more likely to participate actively in, and to enjoy science lessons if they direct their learning (Thornman & Phillips, 2001). In addition, the use of a TWBI approach, which provided authentic visualisations of Astronomy phenomena, might have made difficult and abstract Astronomy concepts more concrete to learners. The authentic visualization of phenomena provided by web-based instruction may not be achieved using textbooks. This assumption is in line with the views of Vosniadou and Brewer (1994), as well as those of Agan (2004), that learning Astronomy concepts from textbooks can create inadequate mental models in learners, which may lead to the development of misconceptions. In a study involving the use of web-based educational technologies to rectify identified Astronomy misconceptions, Gurbuz (2016) found that the majority of the teachers who did not initially have a normative understanding of basic Astronomy concepts improved their scores with the aid of a web-based instruction. Similarly, the authentic visualization provided by the TWBI used in this study could have assisted learners to transition from a naïve conception of celestial bodies to a more normative understanding of the concepts.

The qualitative data showed that participating learners had limited exposure to computers and the internet prior to the intervention, although the majority of them indicated that they were interested in using these devices for the purpose of teaching and learning. Failure to expose learners to web-based instruction is disheartening, given the fact that the world is now operating within the fourth industrial revolution, which is characterized by the use of computers and the internet for knowledge acquisition, especially in the context of education (NASA, 2006). Learners indicated that their involvement in the TWBI improved their comprehension of Astronomy concepts. This declaration is in line with findings from Chumley-Jones, Dobbie and Alford (2002), who analysed 20 studies, on the link between Web-based learning and knowledge acquisition, all of which revealed substantial gains.

Despite learners' positive pronouncements about their comprehension of Astronomy concepts, some of them still could not differentiate between certain Astronomy concepts such as revolution and rotation. This could suggest a lack of proficiency in the language of instruction, which is English. This is particularly true for South African Grade 4 learners who transition from being taught in their native languages in the Foundation Phase, to being taught in English in Grade 4 (Pretorius, 2014; DoBE, 2011). Learners might therefore struggle to express themselves in English.

CONCLUSION

In conclusion, the TWBI used in this study enhanced learners' understanding of Astronomy concepts, and they showed positive attitudes towards the instructional approach. We therefore recommend the use of TWBI by practicing teachers, especially when teaching Astronomy concepts in Grade 4. We also propose an investigation into the feasibility of using smartphones to implement TWBI in science classrooms, in order to take advantage of the widespread availability of cell phones and their frequent use by learners. Furthermore, we recommend a longitudinal study to explore the long-term effects of TWBI on learner achievement in Astronomy. Finally, a study on the effect of TWBI on male and female learners is necessary to determine whether the instructional approach has gender bias.

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REFERENCES

Agan, L. (2004). Stellar Ideas: Exploring students' understanding of stars. *Astronomy Education Review*, 3 (1),77-97.

Chumley-Jones, H., Dobbie, A., & Alford, C. (2002). Web-based learning: Sound educational method or hype? A Review of the evaluation literature. *Academic medicine*, 77(10), 86-93.
Department of Basic Education-DoBE. (2011). *Curriculum and Assessment Policy Statement -CAPS*. Pretoria: Department of Education-Government Printing Works.
Gopnik, A., & Wellman, H.M. (2012). Reconstructing constructivism: Casual models, Bayesian learning mechanisms and the theory. *Psychological Bulletin*, 138 (6), 134-159.
Gurbuz, F. (2016). Physics Education: Effect of Micro-teaching Method Supported by Educational Technologies on Pre-service Science Teachers' Misconceptions on Basic Astronomy Subjects. *Journal of Education and Training Studies*, 4(2), 27-41.
Kallery, M. (2000). Children's science questions and ideas provide an invaluable tool for the early years' teacher. *Primary Science Review*, 61,18–19.
Liu, C., & Matthews, R. (2005). Vygotsky's philosophy: Constructivism and its criticisms examined. *International Education Journal*, 6(3), 386-399.
Loyd, B. H. & Gressard, C. (1985). Reliability and factorial validity of computer attitude scales. *Educational and Psychological Measurement*, 44(3), 501-505.
McInerney, D., & McInerney, V. (2002). *Educational Psychology: Constructing Learning* (3rd Ed.). Cambridge, MA, Prentice Hall.
Mnyamane, N., & Naude, F. (2016). Teachers skills in identifying children's' understanding of the natural world. *ISTE conference on Mathematics, Science and Technology*. Pretoria: Institute of Science & Technology Education, UNISA, 569-576.
NASA. (2006). Student Observation Network. Available at: http://www.nasa.gov/audience/foreducators/son/home/index.html: [Accessed March 13, 2018].
Nash, J. B., & Moroz, P. A. (1997). Computer attitudes among professional educators: The role of gender and experience. *Paper presented at the Annual Meeting of the Southwest Educational Research Association*, Austin, TX
Nthimbane, K., Ramsaroop, S., & Naude, F. (2017). The earth is flat! Exploring the mental models of the solar system in the foundation phase. *ISTE conference on Mathematics, Science and Technology Education*. Pretoria: Institute of Science & Technology Education, UNISA, 304- 312.
Pretorius, E.J. (2014). Supporting transition or playing catch-up in Grade 4: Implications for standards in Education and Training. *Perspectives in Education*, 32(1), 51-76.
Seidel, J. V. (1998). Qualitative data analysis. The Ethnography v5.0: A Users Guide. Appendix E. Colorado Springs, Colorado: *Qualis Research*. Available at: http://www.qualisresearch.com https: [Accessed November 12, 2018].
Snow, C. 2010. Academic language and the challenge of reading for learning about science. *Science*, 328(5977), 450- 452.
Thornman, CL., & Phillips, S. (2001). Interactivity in online and face-to-face sections of a graduate nursing course. *Techtrends*, 45 (1), 254-275.
Vosniadou, S., & Brewer, W.F. (1994). Mental Models of the day/night cycle. *Cognitive Science*, 18, 123-183