THE EFFECT OF USING COMPUTER SIMULATIONS ON GRADE 11 LEARNERS' PERFORMANCE IN PLANTS BIODIVERSITY IN SOUTH AFRICA

Israel Kibirige,
Kgashane Bethuel Bodirwa

Abstract. *Teachers use different pedagogies to improve learners' performance. The study explored the effect of Computer Simulations (CS) on Grade 11 learners' performance when taught Plants Biodiversity. A Solomon Four-Group design was used to cater for internal and external validity. Sixty-six learners were assigned to two Control Groups (CG) taught using CS and 66 learners to two Experimental Groups (EG) taught using Talk and Chalk Method (TCM). The pre-test was administered to EG1 and CG1, while post-tests were administered to all four groups. Focus Group Discussion Interviews (FGDI) were conducted with 12 learners: six from EG and six from CG. Quantitative data were analyzed using a T-test, Analysis of Variance (ANOVA), while qualitative data were analyzed using thematic analysis. The results show that EG outperformed CG (T-test; ANOVA; p < .05). Boys' and girls' performance in EG did not differ significantly, suggesting that CS favour both gender to perform well. CS positively influenced EG learners' attitudes towards Biodiversity topic, but not CG. Thus, CS is an effective tool for enhancing learners' performance.*
Keywords: *computer simulations, Solomon Four-Group Design, learners' performance, Talk and Chalk Method (TCM)*

**Israel Kibirige,
Kgashane Bethuel Bodirwa**
University of Limpopo, South Africa

Introduction

Improving learners' performance is a goal in teaching science subjects. Science teachers have diverse knowledge to teach different topics (Shulman, 1986). The teachers' knowledge to teach different topics is Pedagogical Content Knowledge (PCK) (Deidre, 2015; Shulman, 1986). PCK is distinct knowledge exclusive to teachers, distinguishing them from the subject content specialists (Shulman, 1986). Although researchers in teacher education have ignored PCK, Hill, Ball and Schilling (2008) report that the PCK teachers use can improve teaching and learning. Educational research shows that teachers' creativity in teaching affects students' learning (Kleickmann et al., 2013). Teachers direct special attention toward science topics: Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) (Sickel & Friedrichsen, 2017). Both types of knowledge affect teachers' instructional practices and student learning (Baumert et al., 2010; Hill et al., 2008). Shulman (1986) states that PCK is a cognitive construct representing an idea embedded in the teachers' beliefs. It is more than teaching content knowledge to learners since learning is not absorbing information for reproduction in the exams.

PCK is the fusion of content with methods of teaching (1986, 1987). This knowledge is not the same for all teachers, but it is explicit knowledge within a teacher's idiosyncratic practice. Thus, teachers can choose different teaching tools to assist them to enhance learning. According to Lowther et al. (2012) projectors, televisions, and computer laboratories are forms of technology to enhance learning. Using computers in teaching science is popular in the developed world and is slowly picking momentum in the developing world. Technology stimulates learning and more so, learners can manipulate objects using different devices (Kirkley & Kirkley, 2005). Also, teachers employ technology in numerous ways to address learners' needs (Koh et al., 2018). One approach is to use computers, which motivate learners. Also, teachers use Computer Simulations (CS) for teaching and for updating their content knowledge.

CS engage learners in understanding artificial as well as natural systems (Ramat & Preux, 2003). During simulations, students are the test subjects. CS contribute to the 'learners-play-to-learn' process where learners create

knowledge through playing (Mavhunga & Kibirige, 2018), increases learners' interest (Yildirim & Sensoy, 2018) and enhances learners' knowledge retention (Popil & Dillard-Thompson, 2015). CS improve learning outcomes in the science classroom (Akpan, 2001) and are essential in research and investigations (Samsonau, 2018). Hannel and Cuevas (2018) reviewed teachers' use of CS and found that they assist learners in time management because less time was devoted to setting up apparatus. Besides, in EG learners changed variables to allow stating and testing hypotheses. In this context, a learner becomes active and improves in formulating questions, hypothesizing, collecting data, and revising theories. Interactive CS provide learners with a sense of ownership and thus increase content understanding as well as content retention (Ramos et al., 2016). Simulations allow learners to reproduce and envisage actual world processes that would take a long time or perilous processes in a high school laboratory context (Akpan, 2001).

Limniou et al. (2007) contend that replacing some laboratory lessons with cooperative pre-laboratories simulation increases learners' knowledge. Similarly, Dalgarno et al. (2009) used a 3-dimensional Virtual Laboratory (VL) and a Real Laboratory (RL) to acquaint learners with the long- term structure of laboratory apparatus. They concluded VL was effective for familiarisation with laboratory background. However, several studies opine simulations should not substitute physical laboratories (Limniou et al., 2009; Sypsas & Kalles, 2018). CS motivate learners to interact with real-life issues. Using CS, the teachers can regulate parameters to achieve the best learning outcomes (Hertel & Millis, 2002). Learners engage with simulations to alter parameters, and practice solving specific tasks. Thus, CS can be incorporated into learning to discover hypothetical situations. Learners can compare the information from CS with textbooks and notes from lectures to solve problems in a realistic mode to minimise learning difficulties (Samsonau, 2018).

Research Problem

Teachers use Pedagogical Content Knowledge (PCK) for specific topics and different contexts. This knowledge defines them as teachers. Sanders, Borko, and Lockard (1993) assert that experienced teachers have affluent PCK, while Chan and Yung (2018) indicate teachers' previous experiences may promote or hinder their new PCK development. Studies confirm teachers seldom use technology in addition to their PCK as Technological Pedagogical Content Knowledge (TPACK) to improve learning (Mavhunga et al., 2016). Teachers spend a long time talking in class and ask low order questions (Carlsen, 1993). Some teachers cannot identify learners' misconceptions (Hashweh, 1987) and consequently choose incongruous strategies to teach content. One strategy to improve learners' performance is to use CS. The effect of using CS on learners' performance has not been well studied, particularly in developing countries, where learners-to-computer ratio varies. For example, in Zambia, the learners to computer ratios were as high as 143:1 (Chaamwe, 2017; Sossa et al., 2015) and 17:1 in South Africa (Kibirige & Hodi, 2019). It should be noted that in South Africa as a developing country, learners are challenged in two aspects: 1) lack of access to the use a computer, learners cannot afford to own one (Habibi et al., 2018), and 2) learners have limited time to practice on the computer because they typically access the computer during school hours (Tarman & Chigisheva, 2017). Some content cannot be taught using hands-on activities in the classroom because of its abstract nature. In such instances, CS can be viewed in the classroom to minimize misconceptions on a specific topic. After all, misconceptions are context and topic-specific, making this study unique because, to the best of our knowledge, no studies used CS to teach a Plant Biodiversity topic in a rural school context in South Africa. This is a knowledge gap this study aimed to fill. Thus, the study investigated the effect of CS on learners' performance in Plant Diversity compared to the learners taught using (TCM).

Research Focus

The research focuses on the effect of CS, which engage learners in active participation more than the Talk and Chalk Method. The research contributes to literature from developing countries on learners' experiences of using CS to improve their understanding of science. CS assist learners to improve their attitudes and interests, and cognitive achievements in science (Tüysüz, 2010; Yildirim & Sensoy, 2018). Considering the vast majority of teachers using TCM in schools, which results in learners' poor conceptualisation and poor attainment in sciences, CS would change the paradigm and actively engage learners, especially during the COVID-19 era where face-to-face interaction is minimal. Thus, the findings from this study can benefit Life Science teachers, learners, curriculum, and material designers in chemistry to incorporate CS in the teaching of Life Sciences.

Research Aim and Research Questions

Due to the scarcity of computers in schools in South Africa, many learners are assigned to one computer to access during their free time. The effect of using CS to improve learners' performance in Life Sciences in developing countries with limited computers is not well studied. Thus, the purpose of the study was to explore the effect of CS on Grade eleven learners' performance in a Plant Biodiversity topic. The study was to answer one question: What is the effect in learners' performance of teaching Grade 11 learners Plant Biodiversity using CS? The study addressed three hypotheses: 1) Pre-test learners' scores vary in EG and CG; 2) EG learners taught using CS perform better than CG learners taught using TCM; 3) There is no statistically significant difference in learners' performance between boys and girls in EG.

Research Methodology

General Background

The researchers used Solomon Four-Group Design (Cambell & Stanly, 1963) because of its robustness. It deals with internal validity, where one considers alternative causes, and external validity, where the results can apply to the entire population (Kirikkaya & Başgül, 2019). The design assists in 1) identifying the cause and effect of CS intervention. 2) The researcher can determine whether the administration of a pretest affected the dependent variable (Abaniel., 2021). Thus, this study differs from earlier quasi-experimental designs (Tlala et al., 2014), which did not cater for these two threats and hence results were not conclusive of the cause and the effect regarding the use of Predict-Observe-Explain (POE). The current design addressed the effect of Computer Simulations using a Biodiversity topic in rural South African schools during 2018. The research design is represented in Table 1.

Table 1
A Solomon Four-Group Design (EG$_1$; CG$_1$ pretested and EG$_1$; CG$_1$; EG$_2$; CG$_2$ post-tested)

Randomized Group	Pre-tested	Intervention	Post-tested
EG$_1$	Yes	Yes	Yes
CG$_1$	Yes	No	Yes
EG$_2$	-	Yes	Yes
CG$_2$	-	No	Yes

The target population was 200 Grade 11 Life science learners aged between 15 and 17 years with an average age of 16 years were purposively selected (Creswell, 2013) from four schools based on the availability of computers. The Raosoft Software sample calculator provided a sample of 132 learners, with a 6.95% margin of error at a Confidence Interval (CI) of 95%. This implies the sample was a representation of the population and therefore suitable for the study. 132 Grade 11 learners were randomly assigned to four groups: two groups with 33 per group as EG and two groups with 33 per group as CG. The researchers considered 33 learners per group adequate (Mugenda & Mugenda, 1999).

Instruments and Procedures

Pre- and post-tests and Focus Group Discussion Interviews (FGDI) were used to collect data.

The tests were checked for face validity by two lecturers and piloted to 20 learners from one school with a similar environment, which was not part of the study. For reliability, a Cronbach Alpha coefficient of .85 was obtained, which is acceptable because it is above .7 cut-off line (Muijs & Reynolds, 2011). The interview schedule questions were checked for face validity by two lecturers, and their recommendations were addressed before data collection.

EG_1 and CG_1 were pre-tested, EG_2 and CG_2 were not pre-tested (Table 1), and the post-test was administered to all the four groups EG_1, EG_2, CG_1 and CG_2. Pre-post-test learners' scores were the independent variables. EG_2 learners were taught using CS to influence outcomes to assist researchers in assessing the impact of the treatment. Learners were taught during the usual school periods to avoid school curriculum disruption. The researcher accessed simulations from Physics Education Technology (PhET) online. Although the name appears as physics, the simulations include other subjects like Biology, Chemistry and Earth sciences. The topic was the main groupings of living organisms and their diagnostic features such as bryophytes, pteridophytes, gymnosperms and angiosperms. Although the regular class teachers were present during the teaching, they did not participate in the teaching. The researchers led the class in discussions and in answering questions regarding the simulations.

Four steps were followed during the lessons: 1) general introduction of the content - learners wrote their predictions on what Kingdom or Division the organism belong; 2) screening of Computer Simulations - learners observed; 3) reflections on the simulations - learners wrote explanations and discussed within the class; 4) wrapping up the lesson- the teacher clarified a few misconceptions and highlighted main ideas of the lesson. After an introduction, learners wrote their predictions following teachers' guides. During simulations they observed and identified different plants and classified them into their Divisions. For example, Bryophytes, learners predicted if the plant according to the structure was vascular or non-vascular; Pteridophytes - Spores but no seeds, Spermatophytes- Seed Plants, and Gymnosperms - naked seeds. The above content was in line with the Grade 11 curriculum. The study lasted for five weeks, where one week was used for acclimatization. Due to the shortage of computers in the schools, the learners-to-computer ratio was limited to four or five learners per computer and learners accessed computers at their opportune time after classes. Focus Group Discussion Interviews (FGDI) with 12 individuals (6 per group) were employed to collect the views on learners' attitudes before and after teaching. Each interview lasted approximately 30 minutes and was audio recorded. Four sessions were held, and the interviews ended when there was no extra information gained from the discussions.

Data Analysis

Quantitative data were analysed using means, standard deviations, T-test, and Analysis of Variance (ANOVA). Levene Test for Equality of Variances was applied to the pre-test scores to determine if the two groups (EG and CG) were equal. T-test was used on pre-test to detect equality of the two groups, and pre- and post-tests mean differences between EG and CG, and the gender differences in performances in EG. A 2 x 2 ANOVA test on four post-test scores (EG_1, CG_1, EG_2 and CG_2) was used to determine differences between the CG and EG. Finally, qualitative data were analyzed thematically using six steps of Braun and Clake (2006): reading line by line through the transcripts to be conversant with the texts, creating tentative codes, looking for themes, revising the themes, defining themes, and finally writing the themes.

Ethical Issues

The Education Department granted permission to carry out the study. All learners consented to participate, and their parents signed consent forms. During data collection, anonymity and confidentiality of participants were ensured throughout the entire study. To minimize learners' discrimination from a worthwhile teaching method, the other two classes taught without CS were given extra classes after the five weeks of intervention to experience the CS approach

Research Results

The results show that EG taught using CS performed better than CG, which was taught without CS. Levene Test for Equality of Variances $F = 1.64$, $p > .05$) showed no significant differences between the pre-test scores of EG and CG. The statistics related to equal variances were assumed, and hence the use of the t-test.

The results of pre-tested EG_1 and CG_1 using an independent T-test are presented in Figure 1 a-b.

Figure 1 a-b

a) T-test results for pre-test for EG$_1$ and CG$_1$ groups before intervention.
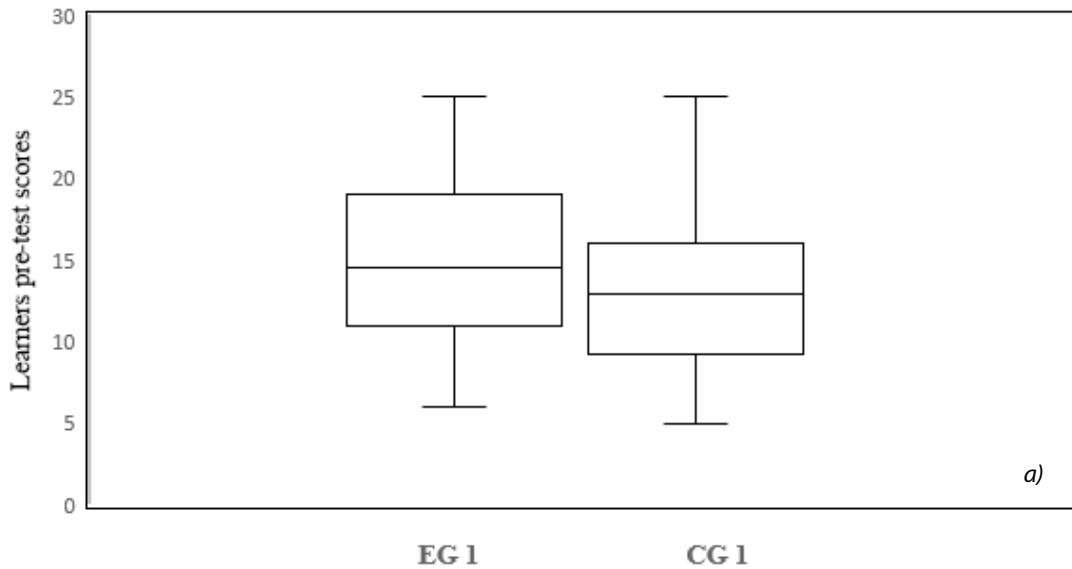
b) T-test results for post-test for both EG$_1$ and CG$_1$ groups after intervention.
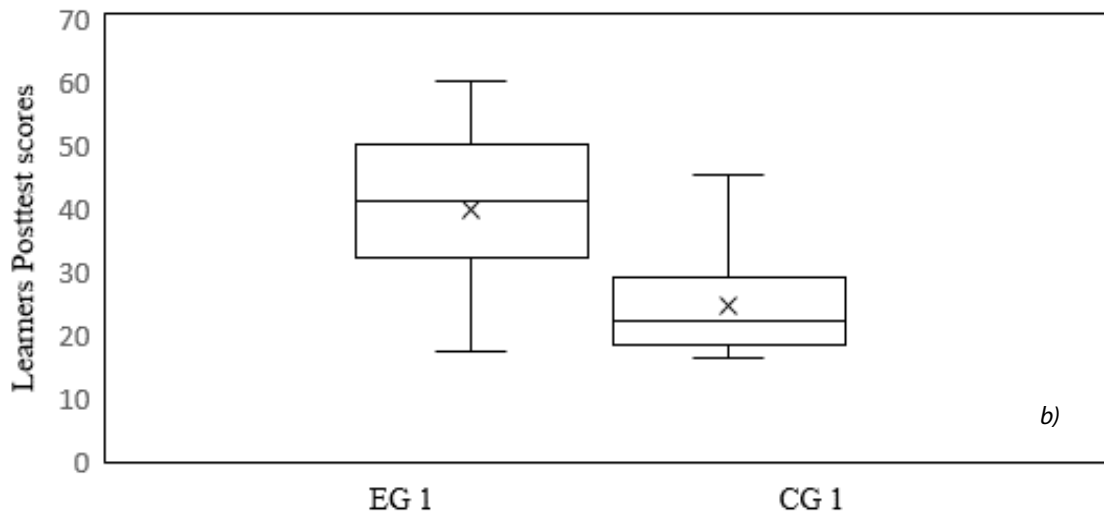
In Figure 1 a) pre-test results for CG ($M = 12.94$, $SD = 4.90$) and EG ($M = 14.07$, $SD = 3.78$) showed no significant differences *T*-test, $t(64) = 1.14$, $p > .05$). Thus, the learners had a similar understanding of science concepts before the intervention. Therefore, we reject Hypothesis one, which states that learners' scores vary in the pre-test.

After teaching for four weeks, the post-test results of EG$_1$ and CG$_1$ performances were compared using a T-test. Figure 1 b) shows results of the post-test scores for both EG$_1$ ($M = 38.53$, $SD = 11.19$) and CG$_1$ ($M = 22.32$, $SD = 6.87$) differed significantly after intervention *T*-tests, $t(64) = 7.19$; $p < .05$). Also, Cohen *d* results for EG$_1$ and CG$_1$ show a huge effect size of 2.02 for the EG$_1$ group compared to 1.6 for the CG$_1$. Effect size between the EG$_1$ and CG$_1$ .42 suggesting EG$_1$ performed better than the CG$_1$. Therefore, Hypothesis two, stating learners' performance does not vary in EG$_1$ and the CG$_1$ after intervention is rejected.

Figure 2
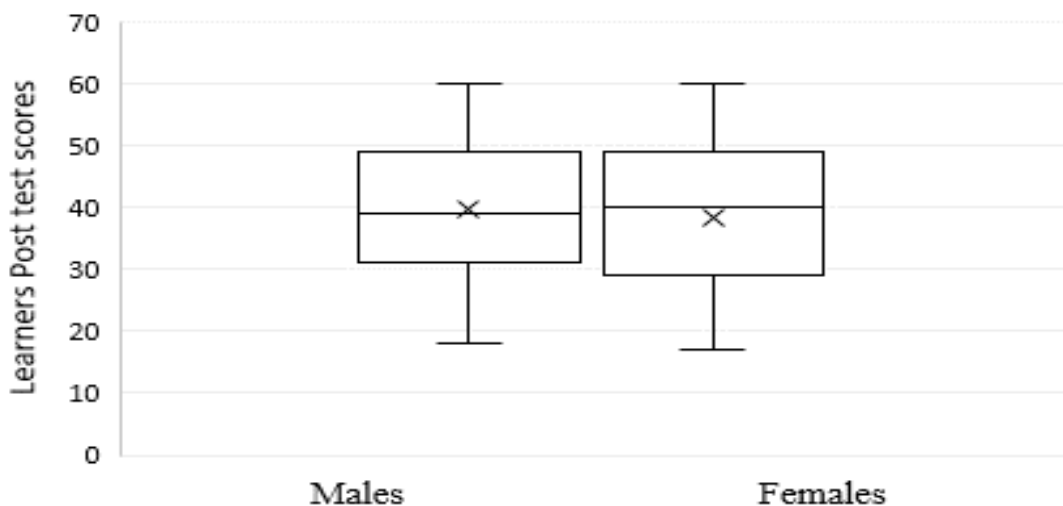*T-test Results for Post-test for Males and Females in EG after Intervention*

Figure 2 shows mean scores were ($M = 39.63$, $SD = 11.52$) for males and ($M = 38.67$, $SD = 12.08$) for females. No statistically significant differences were found among the two groups using a *T*-test, $t(64) = (.39)$; $p > .05$. Therefore, hypothesis three stating scores vary between boys and girls in EG after intervention is rejected.

ANOVA results of the treatment are represented below in Table 3.

Table 3
ANOVA Representing the Main Effect Test between EG and CG

Solomon Four Group	Type III SS	df	MS	F	p
Treatment versus No treatment	7592.86	3	2559.55	25.80	.01
Pre-tested versus Not Pre-test	86.11	1	124581.97	1255.71	.01
Treatment versus pretest	7.21	1	86.11	.87	.35
Error	7686.18	1	7592.86	76.53	.01
Total	144378.00	127	99.21	.07	.79
Corrected Total	20278.58	131			

In Table 3, the significance level (*p*-value) corresponding to treatment*pretest is .35, which is more than the .05, suggesting there is no interaction effect. The *p*-values corresponding to the Pre-tested versus Not Pre-tested and Treatment versus Not treatment are less than $p = .05$. Thus, there is a main effect between CG_1 and EG_1, and between pretested and not Pre-tested groups. Also, between groups variance is not greater than within groups variance because the $F = .87$ value is small.

In the qualitative results, three themes emerged from FGDI: 1) interest in learning, 2) acquisition of knowledge, and 3) finishing tasks in time. Each theme is presented below using learners' narratives.

Theme 1: Interest in learning

The main excerpts describing learners' attitudes and interests consisted of words such as: boring, not fun, easily forgettable, and difficult. Learners' verbatim quotes are presented here below:

Journal of Baltic Science Education, Vol. 20, No. 4, 2021

THE EFFECT OF USING COMPUTER SIMULATIONS ON GRADE 11 LEARNERS' PERFORMANCE
IN PLANTS BIODIVERSITY IN SOUTH AFRICA
(PP. 612-621)

ISSN 1648–3898 /Print/

ISSN 2538–7138 /Online/

FGDI 1: "Learning Life Sciences in boring and it is not an interesting subject". CG

FGDI 3: "The subject is boring. We study for a pass only, and it is not even fun." CG

FGDI 4: "This time I found Life Sciences interesting since we learnt Plant Biodiversity using simulations." EG

Theme 2: Acquisition of knowledge

From the discussions, learners indicated learning using CS assisted them to comprehend Plant Biodiversity concepts better than before. Learners could replay simulations at their own time to master the content.

FGDI 1: "I discovered Life Sciences interesting, I remember everything regarding the content in the class using CS."EG.

However, learners had challenges in remembering the taught content.

FGDI 2: "We forget the taught content, and are unable to share the content we learnt" CG

Theme 3: Finishing tasks on time

When learners were asked to comment on the strategy used in teaching, the following direct quotes from FGDI are presented here below:

FGDI 3: "I enjoyed Life Science lessons because I spend more time studying Life Sciences" EG

FGDI 4: "We do not cover all expected topics as specified in the pacesetter and it is hard for us preparing to write exams." CG

Discussion

This study explored the effect of CS on Grade 11 learners' performance in Plant Biodiversity. The results show learners in the EG_1 achieved significantly higher scores than learners in the CG_1. The study showed statistically significant differences in the performance between learners taught using CS compared to those taught using TCM. This suggests hypothesis one stating learners in the EG taught using CS perform better than those in the CG taught using TCM is accepted. Our findings agree with Ragasa (2008), who showed computer-assisted teaching and learning is more effective than TCM. When teaching using CS, learners are accountable for their learning. Learning occurs through different levels where learners assess themselves and concentrate on meaningful learning. This observation agrees with the constructionists' theory, where learners use their environment to enhance their existing knowledge to learn effectively (Vygotsky, 1978). In fact, Gonczi et al. (2017) stated that CS teaching is twice as effective compared to TCM. It is no wonder learners using CS performed better than learners taught using TCM.

The results show EG learners taught using CS scored higher than CG learners taught using TCM (Figure 1 a). EG learners worked together to enquire, improve their cognition, and interact with their peers to study Plants Biodiversity. This observation agrees with the social constructivism theoretical framework where learners interact with objects and their peers to learn. Similarly, the technology used blended well with the pedagogy and content knowledge in teaching EG using CS. Technology also offered a conducive learning environment that facilitated interest, collaboration, and social construction of knowledge. Learners in EG scheduled their time to access CS on the school premises, so learners self-regulate their learning. It is a unique finding because no studies on high school biodiversity have been reported in the South African context.

There were no statistically significant differences in mean scores of male and female learners (Figure 2). It can be concluded that both boys and girls achieved similar conceptual understanding when taught using CS. Thus, hypothesis three which states that boys' and girls' performances in EG vary is rejected. The findings concur with the studies by Okwuduba et al. (2018) and Mihindo et al. (2017), who investigated the impact of computer simulations on gender and found no significant differences among male and female secondary school learners' performance in stoichiometry. They attributed the improvement to computers used in the activities. Fraser and Walberg (2005) contend that using technologies in teaching improves learners' performance.

Learners in CG did not perform as well as EG because they might have lacked the enthusiasm to learn Life Sciences as it was rated as boring. Conversely, learners from EG found CS very interesting. These observations agree with Yildirim and Sensoy (2018), who indicated dynamic interactive visual representations are necessary to enhance academic performances and learners' interests. They further alluded that attitude is one of the critical factors determining learners' performance in science. EG group learners regarded the lessons as interesting and remembered what they had learnt using CS. This account was clear when learners shared information among themselves after the lesson presentations. The improvement in conceptual understanding corroborates with Popil and Dillard-Thompson (2015), who found simulations enhanced learners' knowledge acquisition. On the one hand, EG learners indicated that using CS helped them cover a wide scope quickly, giving more time for revision. On the other hand, learners from CG were frustrated because they did not complete the curriculum. Popil and Dillard-Thompson (2015) highlight using TCM limits learners' academic success by depending on teachers. If the teacher is not at school, learners study nothing during that time. Besides, teachers may hamper the academic performances of gifted learners. It is unlikely that teachers would revise all the content with learners.

Comments from EG show learners were excited about the use of CS to cover the scope with confidence. The excitement may have increased their desire to do more and achieve more. These results support the TPACK theoretical framework where instruments' interaction with social beings yields high performance (Koehler et al., 2014). Few studies in education used the Solomon Four Design in a developing country like South Africa. Learners scheduled their time to access CS on the school premises, so it can be concluded that learners developed Self-Regulated Learning (SRL). This study is unique because no studies on biodiversity at high school have been reported in the South Africa context. This study contributes to encouraging teachers with technology phobia to gain the courage to use ICT to teach science. Teachers in developing countries may adopt the use of CS to teach science like their counterparts in the developed countries. This is very vital, especially during the COVID-19 pandemic and possibly post COVID-19 era, where virtual learning is inevitable.

In the developed countries, each learner has a computer to use during studying. It is not the case in developing countries like South Africa, where a computer is shared among many learners. While using CS increased learners' performances with four to five learners sharing a computer, it is unclear how many learners per computer will be needed before compromising the positive effects. The effect of many learners sharing one computer was not investigated but may interest researchers. Also, a comparative study of the use of CS between the developed and developing countries needs further studies. The limitations of the study were: 1) few learners 33 per group may not be a true representation of the population, and thus there is a need for studies with larger samples for more reliable results; 2) learners were from one geographical region which may have limited the level of performance; 3) the simulations could not be done individually due to lack of home computers; and 4) the time for the study was short, which may have disadvantaged slow learners.

Conclusions and Implications

Learners taught using CS performed better than their counterparts taught using TCM. It has been established that CS are effective tools for enhancing learners' performance. The study confirmed CS did not discriminate against gender because both males and females in the EG performed equally well, but not learners taught using TCM. These results imply that the Department of Education should equip schools with computers and build teachers' capacities to embrace simulations in science teaching. When learners are provided with computers, they can develop interest and autonomy in science learning and this is relevant when considering the online teaching in the New Normal during and after the COVID-19 pandemic. These results may provoke other researchers to extend the study by involving larger samples from diverse geographical representations and use simulations in different subjects and topics. In addition, teachers' attitudes towards CS and a comparative study regarding the effect of learner-computer ratio may need further study.

Acknowledgements

Declaration of Interest

Authors declare no competing interest.

References

Abaniel, A. (2021). Enhanced conceptual understanding, 21st century skills and learning attitudes through an open inquiry learning model in physics. *Journal of Technology and Science Education*, *11*(1), 30-43. https://doi.org/10.3926/jotse.1004

Akpan, J. P. (2001). Issues associated with inserting computer simulations into biology instruction: A review of the literature. *Electronic Journal of Science Education*, *5*(3), 233-245 https://ejrsme.icrsme.com/article/view/7656

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., & Tsai, Y. M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, *47*(1), 133-180. https://doi.org/10.3102/0002831209345157

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101. http://doi.org/10.1191/1478088706qp063oa

Cambell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for MA*: Houghton Mifflin.

Carlsen, W. S. (1993). Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms. *Journal of Research in Science Teaching, 30*(2), 471-481. https://doi.org/10.1002/tea.3660300506

Chaamwe, N. (2017). A review on the challenges that hinder sustainable implementation of ICT as a subject in rural Zambia. *International Journal of Learning and Teaching*, *3*(3), 217-221. https://doi.org/10.18178/ijlt.3.3.217-221

Chan, K. K. H., & Yung, B. H. W. (2018). Developing pedagogical content knowledge for teaching a new topic: more than teaching experience and subject matter knowledge. *Research in Science Education*, *48*(2), 233-265. https://doi.org/10.1007/s11165-016-9567-1

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.

Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood Jr, D. R. (2009). Effectiveness of a virtual laboratory as a preparatory resource for distance education chemistry learners. *Computers & Education*, *53*(3), 853-865. http://doi.org/10.1016/j.compedu.2009.05.005

Fraser, J. B. & Walberg, H. J. (2005). *Improving academic performance*. Academic press.

Gonczi, A., Maeng, J., & Bell, R. (2017). Elementary teachers' simulation adoption and inquiry-based use following professional development. *Journal of Technology and Teacher Education*, *25*(2), 155-184. https://www.learntechlib.org/primary/p/172142/

Habibi, A., Mukminin, A., Riyanto, Y., Prasojo, L. D., Sulistiyo, U., Sofwan, M., & Saudagar, F. (2018). Building an online community: Student teachers' perceptions on the advantages of using social networking services in a teacher education program. Turkish *Online Journal of Distance Education*, *19*(1), 46-61. https://doi.org/10.17718/tojde.382663

Hannel, S. L., & Cuevas, J. (2018). A study on science achievement and motivation using computer-based simulations compared to traditional hands-on manipulation. *Georgia Educational Research, 15*(1), 3. https://doi.org/10.20429/ger.2018.15103

Hashweh, M. Z. (1987). Effects of subject matter knowledge in the teaching of biology and physics. *Teaching and Teacher Education, 3*(2), 109-120. http://doi.org/10.1016/0742-051X(87)90012-6

Hertel, J. P., & Millis, B. J. (2002). *Using simulations to promote learning in higher education*. Stylus Publishing, LLC.

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic specific knowledge of students. *Journal of Research in Mathematics Education, 4*(39), 372-400. https://www.jstor.org/stable/405393

Huck, S. W., & Sandler, H. M. (1973). A note on the Solomon 4-group design: Appropriate statistical analyses. *The Journal of Experimental Education*, *42*(2), 54-55. http://dx.doi.org/10.1080/00220973.1973.11011460

Kibirige, I. & Tsamago, H. (2019). Exploring Grade 10 learners' Conceptual development using Computer Simulations. *Eurasian Journal of Mathematics, Science & Technology Education, 15*(7), 1-17. https://doi.org/10.29333/ejmste/106057

Kirikkaya, E. M., & Başgül, M. Ş. (2019). The effect of the use of augmented reality applications on the academic success and motivation of 7th grade students. *Journal of Baltic Science Education*, *18*(3), 362-378. https://doi.org/10.33225/jbse/19.18.362

Kirkley, S. E., & Kirkley, J. R. (2005). Creating next generation blended learning environments using mixed reality, video games and simulations. *Technical Trends*, *49*(3), 42-53. http://Kirkley-Kirkley2005_Article_CreatingNextGenerationBlendedL%20(3).pdf

Kleickmann, T., Richter, D., Kunter, M., Elsner, J., Besser, M., Krauss, S., & Baumert, J. (2013). Teachers' content knowledge and pedagogical content knowledge: The role of structural differences in teacher education. *Journal of Teacher Education*, *64*(1), 90-106. http://doi.org/10.1177/0022487112460398

Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. In *Handbook of Research on Educational Communications and Technology* (pp. 101-111). Springer.

Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2018). Teacher professional development for TPACK-21CL: Effects on teacher ICT integration and student outcomes. *Journal of Educational Computing Research*, *55*(2), 172-196. http://doi.org/10.1177/0735633116656848

Limniou, M., Papadopoulos, N., Giannakoudakis, A., Roberts, D., & Otto, O. (2007). The integration of a viscosity simulator in a chemistry laboratory. *Chemistry Education Research and Practice*, *8*(2), 220-231. http://oliverotto.de/images/papers/limniou_ce2007.pdf

Limniou, M., Papadopoulos, N., & Whitehead, C. (2009). Integration of simulation into pre-laboratory chemical course: Computer cluster versus WebCT. *Computers and Education*, *52*(1), 45-52. https://doi.org/10.1016/j.compedu.2008.06.006

Lowther, D. L., Inan, F. A., & Ross, S. M. (2012). Do one-to-one initiatives bridge the way to 21st Century knowledge and skills? *Journal of Educational Computing Research*, *46* (1), 1-30. https://doi.org/10.2190/EC.46.1.a

Mavhunga, F., & Kibirige, I. (2018). Tapping the tacit knowledge of playfield swings to learn physics: A case study of childhood reflections by pre-service teachers. *African Journal of Research in Mathematics, Science and Technology Education*, *22*(2), 221-230. https://doi.org/10.1080/18117295.2018.1479620

Mihindo, W. J., Wachanga, S. W., & Anditi, Z. O. (2017). Effects of computer-based simulations teaching approach on learners' achievement in the learning of chemistry among secondary school learners in Nakuru sub county, Kenya. *Journal of Education and Practice*, *8*(5), 65-75. http://doi.org/iiste.org/Journals/index.php/JEP

Mugenda, M. O., & Mugenda, A. G. (1999). *Research methods. Qualitative and quantitative approaches.* CTS Press.

Muijs, D., & Reynolds, D. (2011). *Effective teaching: Evidence and practice* (3rd ed.). Sage.

Okwuduba, E. N., & Okigbo, E. C. (2018). Effect of teaching methods on students' academic performance in chemistry in Nigeria: Meta-analytic review. *Bulgarian Journal of Science and Education Policy*, *12*(2), 418-434. http://doi.org/10.13189/ujer.2018.060516

Popil, I., & Dillard-Thompson, D. (2015). A game-based strategy for the staff development of home health care nurses. *The Journal of Continuing Education in Nursing*, *46*(5), 205-207. http://doi.org/10.3928/00220124-20150420-14

Ragasa, C. Y. (2008). A comparison of computer-assisted instruction and the traditional method of teaching basic statistics. *Journal of Statistics Education*, *16*(1), 1-10. https://doi.org/10.1080/10691898.2008.11889556

Ramat, E., & Preux, P. (2003). "Virtual laboratory environment" (VLE): A software environment-oriented agent and object for modeling and simulation of complex systems. *Simulation Modelling Practice and Theory*, *11*(1), 45-55. https://doi.org/10.1016/S1569-190X(02)00094-1

Ramos, S., Pimentel, E. P., Marietto, G. B., & Botelho, W. T. (2016). Hands-on and virtual laboratories to undergraduate chemistry education: Toward a pedagogical integration. In *IEEE Frontiers in Education Conference (FIE)*, 1-8. https://doi.org/ieeexplore.ieee.org /abstract/document/7757580/

Samsonau, S. V. (2018). Computer simulations combined with experiments for a calculus-based physics laboratory course. Princeton International School of Mathematics and Science, USA. *arXiv preprint arXiv:1804.09264.*

Sanders, L. R., Borko, H., & Lockard, J. D. (1993). Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. *Journal of Research in Science Teaching, 3,* 723-736. https://doi.org/10.1002/tea.3660300710

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *2*(15), 4-14. http://doi.org/abs/10.3102/0013189x015002004?journalCode=edra

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57,* 1-22. http://doi.org/10.3102/0013189X015002004

Sickel, A. J, & Friedrichsen, P. (2017). Using multiple lenses to examine the development of beginning biology Teachers' Pedagogical Content Knowledge for teaching natural. *Selection* Simulations. *Research in Science Education, 48*, 29-70. http://doi.org/10.1007/s11165-016-9558-2

Sypsas, A., & Kalles, D. (2018). Virtual laboratories in biology, biotechnology, and chemistry education: a literature review. In *Proceedings of the 22nd Pan-Hellenic Conference on Informatics* (pp. 70-75). https://doi.org/abs/10.1145/3291533.3291560

Sossa, S. F., Rivilla, A. M., & González, M. L. C. (2015). Digital inclusion in education in Tarija, Plurinational State of Bolivia. https://repositorio.cepal.org/bitstream/handle/11362/38833/RVI115Farfan_en.pdf

Tarman, B., & Chigisheva, O. (2017). Editorial for Special Issue: transformation of educational policy, theory and practice in post-soviet social studies education. *Journal of Social Studies Education Research*, *8*(2), 1-4. https://doi.org/dergipark.org.tr/en/pub/jsser/issue/32450/360860

Tlala, B., Kibirige, I., & Osodo, J. (2014). Investigating Grade 10 learners' achievements in photosynthesis using Conceptual Change Model. *Journal of Baltic Science Education, 13*(2), 155-164. https://oaji.net/articles/2015/987-1437062876.pdf

Tüysüz, C. (2010). The effect of the virtual laboratory on students' performance and attitude in chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37-5. https://doi.org/10.13189/ujer.2018.060516

Vygotsky, L. S. (1978). Internalization of higher psychological functions. *Mind in Society: The Development of Higher Psychological Processes*, 52-57. https://scholar.google.com/citations?user=L4S0dT0AAAAJ&hl=en&oi=sra

Yildirim, H. I., & Sensoy, O. (2018). Effect of science teaching enriched with technological practices on attitudes of secondary school 7th Grade students towards science course. http://doi.org/10.13189/ujer.2018.060516

Israel Kibirige
(Corresponding author)

PhD, Professor, University of Limpopo, Department of Mathematics Science and Technology Education (DMSTE P/Bag x 1106, Sovenga, South Africa.
E-mail: Israel.Kibirige@ul.ac.za
ORCID: https://orcid.org/0000-0002-6908-2361

Kgashane Bethuel Bodirwa

MEd, Department of Mathematics Science and Technology Education (DMSTE University of Limpopo, P/Bag x 1106, Sovenga, South Africa.
E-mail: kgashanebodirwa@gmail.com
ORCID: https://orcid.org/0000-0003-2916-7210