Negative Impacts of the Current COVID-19 Crisis on Science Education in Kenya: How Certain Can We Be about the Efficacy of the Science Learning Framework Online?

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Recently, there has been a significant interest in the possibility of continued disruption to school learning due to the spiraling COVID-19 crisis worldwide. Consequently, online learning has been widely adopted. However, in the least- and medium-developed countries like Kenya, the digital learning models used particularly for science-based courses have either been superficial or ambiguous, making it difficult for students to properly grasp concepts. Conducting online lectures of STEM subjects, without providing simulations and experimental learning experiences, is defective, since such an approach does not appreciate the inherent uncertainty concerns in science education. Besides, delivering only theoretical virtual lectures without integrating students' ideas may be ineffective. The approach masks certain skills that are important for proper interpretation of scientific concepts. This paper presents a framework to examine the detrimental impacts of the COVID-19 crisis on science education and also an out-of-class learning framework that addresses some of the uncertainties. The proposed framework consists of four blocks: (i) a theoretical virtual lecture model that impacts the basics of the scientific concept to be studied; (ii) simulation model to stimulate the understanding of the experimental concept; (iii) a home-based experimental model that propagates the understanding between (i) and (ii); and (iv) an interactive feedback model attributed to the proportion of the home-based experimental activity outcomes to model assumptions and objective values. This structure can be of great benefit to students as it incorporates key tenets of interest to the future for learning of science outside the classroom.

INTRODUCTION

On 15 March 2020, the Government of Kenya (GK) ordered the closure of all educational institutions as part of public health initiatives to control the spread of the novel coronavirus. As reported by the British Broadcasting Corporation (1), the Ministry of Education (MOE) of the (GK) was later to declare that the 2020 academic year was considered lost and that the learning institutions would reopen in 2021. As in other countries, there was immediate advocacy pressure from various stakeholders to develop online learning plans to address the school emergency closure and learning needs at all levels of schooling during the related lockdown interventions. The MOE in response issued guidelines for out-of-class basic learning activities through the Kenya Institute of Curriculum Development (KICD) to be delivered through radio, TV, and online (2). However, these guidelines were generally opaque and not synthesized to enhance efficacy especially on science subjects. Moreover, reports indicated that a multitude of obstacles have been encountered by the introduction of the online learning experiences, with only fewer than 50% of learners being able to access the lessons (3). The low acceptance of the intended transformative learning interventions could be attributed to several factors, including the likelihood of most students being outside the broadcast range, lack of appropriate technology, students' reluctance and demotivation (4).

The essential factors that should have been considered during the rollout of the out-of-class learning include: unequal access to technology; learners' obligations as part of their homes and communities activities; access to secure and supportive learning spaces; and accessibility for peers and/or adults to facilitate learning, sensitivity, and efficiency (5). The GK developed the content and guidelines for out-of-class learning (Appendix 2). Yet, in science subjects, how compelling and sustainable are these guidelines to students? It may be argued that the approaches implemented in Kenya are either vague or simplistic when it comes to interpreting scientific concepts. It is insufficient to provide online classes on STEM subjects without integrating the experimental learning model. Such an approach does not acknowledge the intrinsic need for understanding of the external and internal transformation that comes with the
disruption of school learning setup. Also, the methods adopted in Kenya, for example, which mimic the class as usual and simply delivered in a virtual environment, could instead contribute to the student dissatisfaction and significant loss of interest. An experimental approach at home may be able to significantly bridge the understanding between the online teaching of abstract scientific concepts and provide a framework for better comprehension and dissemination of the concepts. This paper explores an outline of such a framework, whose primary objectives are to:

(i) Provide effective and more constructive delivery of out-of-school science learning to students at the secondary school level

(ii) Enhance students’ experience in science through interactive platforms for online learning

(iii) Help students focus on and create their experimental solutions based on the home environment setup.

The strategies to accomplish these objectives would concentrate on creating an organized and scalable online learning framework, incorporating purposeful and interactive teaching and learning programs, as well as structuring experimental learning for home-based activities, while increasing the engagement of students in the learning process.

Conceptual framework for uncertainties in science education due to prolonged school closure

Before explaining the proposed teaching and learning framework, we must first consider our ideal outcome, namely, an interactive online science learning activity with a commensurate experimental experience at home. To achieve this, it is crucial to first scientifically model and understand the potential uncertainties associated with prolonged school closures on science education. Since we are interested in the extremes of the emerging COVID-19 crisis, such as prolonged staying at home without the academic psycho-social support within the school environment, the best approach to out-of-class learning should be balanced by varying the learning time that includes an extension for reflection rather than majorly assuming a rigid form of schedule, as in a school classroom learning scenario.

Various approaches to recognizing the uncertainties of long-term school closure on STEM subjects have been proposed (6–8). The level of uncertainty associated with spiraling social problems associated with COVID-19, however, far exceeds that of the effects of the schools’ current closure (9). This is due to the great uncertainty about the overall challenges at the tipping points of the school closure and the reaction of students at the basic education level to these challenges. This growing confusion, linked to the spiraling COVID-19 crisis, needs careful attention. To measure the overall uncertainty and assign it to the various pathways to increase the theoretical narratives from the current models, a reasonable hypothetical mathematical model is suggested. The theoretical hypothetical framework for the impact on science learning as a result of the prolonged school closure could be framed from the probability density function (PDF) concept (10). Appendix 6 shows schematically the hypothetical change in a time-varying PDF of the maximum of prolonged school closure effects on learning loss as it changes over time with continuing COVID-19 crisis. It is presumed in this figure that learning loss rises substantially over time as a result of extended school closure, with the effect moving significantly to the right during the period. The science education will be influenced by the change in the progression of learning loss, which can be measured by an effect-response relationship principle. Figure 1b illustrates such a relationship schematically. The y axis is the negative effects on science education, illustrated by learning loss in this context, and the x axis is the degree of influence. This relationship is defined by the uncertainty zone (Appendix 6) due to the potential variability in the effect-response relationship during a prolonged break. In this area between the lower and upper curves, the variance in the relationship is captured. For example, the lower and upper curves could reflect the 95% confidence interval around the correlation’s primary approximation.

Fig. 1 depicts schematically the relational routes between the long break and the impacts on science education through several obstacles (C1 to Cn), such as deficient supportive learning environment, inaccessibility to regular meals, limited study space, erratic power, threats of dropping out, unwanted pregnancy, and indulgence in drugs, etc. The magnitudes of these uncertainties on learning in general in Kenyan context have been reported by HRW (11). The assumption in this schematic illustration is that the current COVID-19 crisis will lead to a very large-scale change in the affective, psychomotor, and cognitive domains that will eventually have massive effects on science education. The figure shows examples of negative impacts on learning, including disinterest in subjects, negative shifts of attitude toward education, decreased ability to focus, impaired physical well-being, etc. Some of these impacts were exacerbated by the remote learning approaches adopted by the government. For example, the problem of learning loss could be attributed to less learning due to limited accessibility to the Internet and the wide digital divide (12). As there are numerous drawbacks of a prolonged school closure period (Fig. 1), to explain the overall implications on science learning we can borrow from the mathematical principle functions of additivity. The overall impacts could be additive, subadditive, or supra-additive (11), depending on whether the challenges occur independently or correlate linearly or nonlinearly. The science learning impacts \( L(C1 + C2) \) will be additive if the challenges \((C)\) of extended school closure occur independently at different times. If, however, the challenges \((C1, C2)\) arise simultaneously, their aggregate impact on science education would be subadditive if the combined effects were less than or equal to the amount of the impacts of the two challenges if they occurred independently at separate times instead \([L(C1 + C2) ≤ L(C1) + L(C2)]\). If the two challenges occur concurrently and their aggregated effect is greater than or equal to the amount of their effects independently at different times, the impact could be supraadditive \([L(C1 + C2) ≥...

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L(C1) + L(C2)] To illustrate these hypothetical principles, let us consider a learning environment with an inadequate supply of power and limited access to proper nutrition. If a student is faced with these twin challenges, the overall impact on education is likely to be additive. By contrast, if the two events occur concurrently, then the overall impact on education is likely to be supra-additive, because one of the deficient conditions will have already affected the education. Finally, if there is a psychological adaptation to a repeated occurrence of the challenges over a prolonged period, for example, if the students adapt to cope with repeated intermittent electricity and/or hunger over time, leading to loss of interest in learning, the impact is likely to be subadditive.

The conceptual pedagogical framework

Present pedagogical approaches to the management of online science education holistically discuss the uncertainties of school closure without objectively connecting the effects on science education, such as no laboratories, no Internet connectivity, and demotivation (12, 13). This gives a false impression of STEM subjects being taught and weakens the interest of students in them. We propose a paradigm shift in content delivery approaches, with considerations for the perspective of the hypothetical mathematical analysis of the dynamics of the challenges (Fig. 2). Four building blocks of initiatives derived from different pedagogical models (Appendix 3) constitute the proposed conceptual pedagogical framework:

(i) a dynamic theoretical lecture framework that flexibly focuses on key areas of the targeted topic with flexible objectives delivered through a guided presentation
(ii) a purposeful virtual simulation solution designed to allow significant interaction between instructor and student to enhance the theoretical exposure in (i)
(iii) an experimental framework that typifies the premises in (i) and (ii), that propagates the correlation between (i) and (ii) that can be self-conducted safely at home.
(iv) a student-centered two-way system for feedback from the results of activities at (iii)

Often, there has been an effort to replicate a typical classroom environment at home in the ongoing online learning events, where content is delivered normally albeit virtually through radio, TV, and other digital platforms without due consideration to the uncertainties as conceptualized. The deliveries are characterized by theoretical racing with the planned scope and content through these channels, which may be ineffective in the prevailing circumstances of uncertainty.

The proposed framework for characterizing and propagating an empirical experimental online learning approach (iii) begins with the setting of flexible objectives and development of structure for the theoretical learning while in the Block (i).

Block (i): Structured and scalable online theoretical lectures

This is the preliminary stage based on the lecture pedagogical model (I4). Goal setting takes place at this stage. The
set goals should ultimately focus on the generation of activities for Block (iii). The approach should be provocative to stimulate interests and consider prior learning (15). Tools such as the school syllabus, textbooks, and revision kits are required at this stage. Possible initiatives may include:

1. The selection of learning topic or concept. The teacher purposefully identifies certain learning targets that can primarily generate activities that can be carried out at home with limited dependence on the use of technology or the internet.
2. Drafting of concrete objectives. The teacher is expected to build smart goals from the chosen concepts.
3. Virtual classroom creation. The teacher is then intended to design and schedule using suitable technology a virtual classroom. Invite students to attend the virtual lesson, the technology preferred should be used to generate an invitation link.
4. Theoretical virtual lectures. The teacher delivers theoretical virtual lecture where all targeted students are required to attend synchronously.

The initiatives are then propagated in Block (ii) through the application of the systematic online interactive simulations.

Block (ii): Interactive, purposeful online animation

This is essentially a stage for sense-making where the ideas conveyed at Block (i) are schematically expanded. It is based on a simulation model (16) which may take the form of computer animation or a game (17). This may include initiatives such as:

1. Hypothetical problem-solving session. The instructor challenges the students to complete a design schematic project that is graphically illustrated and displayed on a screen.
2. Coaching and feedback session. The instructor is required to provide feedback, guidance and coaching. He/she is also expected to provide an opportunity for feedback from the other participants.
3. Self-reflection. The instructor facilitates students’ self-reflection on what they have learned from (i) and (ii). The instructor guides and encourages students to explore their interests in the various concepts of the topic discussed.

Block (iii): Authentication of the learnt concepts at home

The teacher is expected to guide the students to relate the concepts of Blocks (i) and (ii) to household activities, such as...
cooking, repairing items, or farming activities, etc., based on an experimental learning model \((18)\) involving knowledge acquisition from a combination of the grasp and conversion experience \((19)\). Initiatives suggested should include:

1. The instructor probes and offers students the opportunity to identify specific kinds of situations at home with the simulations from Block \((ii)\). The teacher should design a provisional list of possible home-based activities based on the outlines of the activities from the preceding Block \((ii)\). This will guide the students to link and select the most plausible activity depending on his/her set up.

2. Extraction and packaging of the areas of interest of the student. The teacher should isolate and package the areas of interest per student into practical and achievable tasks and projects that can be carried out safely within the home setup. The teacher should be guided by the level syllabus, need to consider holistic contexts, cost effectiveness, and availability of materials \((20–22)\).

3. Developing and uploading worksheets and activities. The teacher develops and uploads worksheets and activities to be explored within the students’ home setup on the online platform. Alternative means of sending packs may be used to cater for those students who may not be able to download for some reason.

4. Designing the cycle of activities. Teacher guides and directs students to design a cycle of experimental activities at home that can address the defined concepts of interests \((23, 24)\).

5. Exploration of the concepts of interest. Teacher helps students to explore the concepts of interest in depth through investigation to develop comprehension over time using the resources available at home.

6. Family and social group engagement. The teacher should encourage students to engage with their friends, peers and communities in the experimental activities at home.

**Block (iv): Presentation and feedback**

This stage involves presentation of the results from the home-based activity by the student and the provision of feedback. Initiatives may be composed of:

1. Presentation of the results. The teacher offers the student’s adequate time to share their results from the home activity online.

2. Feedback. The teacher, the student and the other participants provide the presenter with feedback.

3. Harmonization and wrap-up. The teacher will harmonize the concepts learned and presented. The teacher points out the differences between the outcome presented and the expected and concludes.

Those students who are unable to identify an appropriate task in line with their home conditions or are unable to proceed through Block \((iii)\) initiatives for some reasons should be given an optional opportunity to connect virtually at a variety of times with teachers and peers.

**DISCUSSION AND CONCLUSION**

It is imperative that, as a result of extended school closures, the negative effects of COVID-19 on science learning be mitigated by online learning activities. The proposed framework offers a structured approach that is sufficiently straightforward for student-centered online learning of science. Each of its elements, the theory, simulation, and the home-based experimental models, stands on its own merits and can be adopted and changed when appropriate \((Appendices 4 and 5)\). Theories on the additivity or nonadditivity features of the complexities of prolonged closure impacts should be taken into account in case of modifications. For example, the Block \((iii)\) initiatives can be enriched by integrating certain concepts from Andresen et al. \((25)\), who described the criteria for experience-based learning as well as the concepts from Koole’s \((26)\) criteria for the mobile learning theory \((Appendix 3)\).

Policymakers and teachers were subjected to uncertainties facing learners during the prolonged school closure that eventually affected science learning without recourse to how to use them to help decision-making. The proposed framework can be integrated into the decision analytical framework for addressing negative impacts in a clear way. For instance, during the lockdown, the Kenya Basic Education COVID-19 Emergency Response Plan \((2)\) was used for general out-of-class learning planning in Kenya. Policymakers may prioritize measures by linking this framework that offers reliable and trustworthy uncertainty bounds to the core estimates of the impacts of science learning. By the learner conceptualizing and conducting their own home-based experiences regarding what they have learned, this would certainly induce a combination of psychomotor, cognitive, and affective behaviors. This provides students with options on how they participate, what they study, or how they illustrate science learning. It is intended to assist students in content grasping and self-reflection to improve their learning experience. The proposed structure, therefore, offers opportunities for equity, value, and efficiency, which can be of benefit to students once adopted.

**SUPPLEMENTAL MATERIALS**

Appendix 1: Significance of the perspective and anticipated output
Appendix 2: Key components of the Kenyan government out-of-class learning guidelines
Appendix 3: Teaching and learning theories and models on which the proposed model is based
Appendix 4: Key guides in the implementation of the online learning framework
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References

1. BBC. 2020. Coronavirus: Kenyan schools to remain closed until 2021. https://www.bbc.com/news/world-africa-53325741. Retrieved on 15 September 2020.
2. MOE. 2020. Kenya Basic Education Sector COVID-19 Emergency Response Plan, 2020. Nairobi, Kenya. https://www.education.go.ke/images/Kenya_basic_Education_COVID-19_Emergency_Response_Plan-compressed.pdf. Retrieved 17 September 2020.
3. United Nations Children’s Fund (UNICEF). 2020. Learning from home in Kibera, during COVID-19. https://www.unicef.org/kenya/stories/Learning-from-home-in-Kibera-during-COVID-19.
4. Areba GN. 2020. COVID-19 Pandemic Impact on Kenyan Education Sector: Learner Challenges and Mitigations. J Res Innov Implic Educ 4:128–139.
5. UNESCO. 2020. How to plan distance learning solutions during temporary schools closures. UNESCO. Retrieved from https://en.unesco.org/news.
6. Reiss MJ. 2020. Science education in the light of COVID-19. The contribution of history, philosophy and sociology of science. Sci & Educ 29:1079–1092. https://doi.org/10.1007/s11191-020-00143-5.
7. OECD. 2020. Education and COVID-19: focusing on the long-term impact of school closures. https://www.oecd.org/coronavirus/policyresponses/education-and-covid-19-focusing-on-the-long-term-impact-of-school-closures-2ca926e/.
8. Saavedra J. 2020. Educational challenges and opportunities of the Coronavirus (COVID-19) pandemic. Worldbank Blogs. https://blogs.worldbank.org/education/educational-challenges-and-opportunities-covid-19-pandemic. Accessed 28 November 2020.
9. Gouëdard P, Pont B, Viennet R. 2020. Education responses to COVID-19: shaping an implementation strategy. OECD Education Working Papers, No. 224. https://doi.org/10.1787/8e95f977-en.
10. Grinstead CM, Snell JL. 2009. Conditional probability – discrete conditional. Grinstead & Snell’s introduction to probability. Orange Grove Texts.
11. Human Rights Watch. 2020. Impact of COVID-19 on children’s education in Africa. 35th Ordinary Session. https://www.hrw.org/news/2020/08/26/impact-covid-19-childrens-education-africa#. Retrieved 28 January 2021.
12. Operation Eyesight (OE). 2020. The impact of school closures in Kenya goes beyond education. https://operationeyesight.com/the-impact-of-school-closures-in-kenya-goes-beyond-education/. Accessed 28 January 2021.
13. György P, Gábor S. 1976. Problems and theorems in analysis, volume I. Springer-Verlag, New York, NY.
14. Masanja N. 2020. Re: what are the disadvantages of online/virtual learning and teaching? https://www.researchgate.net/post/What_are_the_Disadvantages_of_Online_Virtual_Learning_and_Teaching/506c66f79da7729bc66b556/citation/download. Retrieved 5 December 2020.
15. Varvel V, Lindeman M, Stovall IK. 2003. The Illinois online network is making the virtual classroom a reality: study of an exemplary faculty development program. J Asynchron Learn Netw https://doi.org/10.24059/olj.v7i2.1857.
16. Daphne K. 2012. What we’re learning from online education. https://blogs.worldbank.org/education/educational-challenges-and-opportunities-covid-19-pandemic. Accessed 28 January 2021.
17. Twigg CA. 2003. Improving learning and reducing costs: new models for on-line learning. http://www.educause.edu/ir/library/pdf/erm0352.pdf. Retrieved 7 February 2021.
18. Michelson J. 2015. How to help teachers find an area of focus. https://blog.k-12leadership.org/instructional-leadership-in-action/how-to-help-teachers-find-an-area-of-focus. Retrieved 7 February 2021.
19. Audu EE, Ojekudo N. 2016. Application of real-world simulation: a bridge between theory and practice in higher education in Nigeria. IOSR J Res Meth Educ 6:59–70. https://doi.org/10.9790/7388-0604055970.
20. Millenbah K, Campa H, Winterstein S. 2004. Models for infusing experiential learning into the curriculum. http://www.snr.missouri.edu/meetings/uenr/millenbah.pdf. Retrieved 20 September 2020.
21. Oxendine C, Robinson J, Willson G. 2004. Experiential learning. In M. Orey 403 (ed), Emerging perspectives on learning, teaching, and technology.
22. Andersen L, Boud D, Cohen R. 2000. Experience-based learning. p 225–239. In Foley G, Understanding adult education and training, 2nd ed, Allen & Unwin, Sydney, Australia.
23. Koole ML. 2009. A model for framing mobile learning. p 38. In Ally M (ed), Mobile learning: transforming the delivery of education and training. AU Press, Edmonton, Canada.