Development and Validation of Instructional Package for Teaching and Learning of Genetics in Senior Secondary Schools

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Abstract

The sound knowledge of Biology is, to date, is a strong prerequisite to study many Biological and Life Sciences, examples of which include Physiology, Forensic Science, Pharmacy, Medicine, Nursing, Biochemistry, to mention a few. These fields, amongst others, rely on a very important aspect of Biology known as Genetics, which is the study of heredity and variation in living organisms. The field of Genetics intersects with many other life sciences. However, students' attempts of questions on Genetics in internal and external examinations in senior secondary schools in Nigeria have been very poor over the years because they find the concepts of Genetics hard to understand. The need, therefore, arises to look for ways of dealing with this prolonged problem. This study, therefore, attempted to develop an institutional package and also surveyed the extent to which it is adequate for instructional delivery. The Instrumentation design describes the processes of package development based on the Waterfall Model. The package was validated by thirty (30) Biology teachers who were randomly selected from ten schools in Ijebu-Ode Local Government Area, Ogun State, Nigeria. "Package Adequacy Scale (PAS)" was developed and used for validation purposes. Two research questions were raised in the study and the data collection was analyzed using descriptive statistics of median scores and standard deviation. The result showed that the package was adequate (3.00) for instruction in Genetics due to its quality in terms of lesson contents, graphics, sound, and others. It was suggested, among others, that students should be supplied with modern instructional packages which can aid the teaching and learning of Genetics.

Keywords: Development, Validation, Instructional Package, Genetics

INTRODUCTION

In late 2019, a disease known as the novel coronavirus disease or COVID-19 was reported in Wuhan, China. The Coronavirus disease later spread rapidly to over 198 countries of the world, Nigeria inclusive. As of March 2020, the Nigeria Government declared a national lockdown in a bid to control the spread of the disease being a highly infectious disease. Due to the severity of the disease, it was declared a global pandemic by WHO on the 12th of March, 2020. The COVID-19 disease which is primarily a public health concern later affected other areas of human lives including but not limited to economic, social, and importantly, the education aspect. Despite the low rates of infection among children, school closure was necessitated as a means of social distancing to curb the spread of the disease. In February 2020, the Federal Government of Nigeria declared that all schools – primary, secondary and post-secondary institutions should be locked when it was discovered that the virus has found its way into the country through an Italian man who was on a business trip to Nigeria. According

to Akhtar, Hussain, Afzal and Gilani (2019, the period of COVID-19 pandemic is a typical example of times when conventional teaching methods could not work in schools due to lockdown, most especially when teachers and their students were separated due to social distancing rules, therefore barring physical contacts. As a result of the closure of schools for over 6 months, teaching and learning were badly affected except for few State governments who reached a lower percentage of their students online through teachers with some levels of Information and Communication Technology (ICT) skills. The question which readily comes to kind is, in this age of ICT and several opportunities for online learning, should a pandemic locked all teachers and students far away from each other for months thereby disrupting teaching and learning activities?

The roles science and technology play in all nations all over the world cannot be overstressed. It is important to also point out that without the knowledge of Science, Nigeria like other concerned nations might be left out of the numerous gains of scientific and technological developments being witnessed in many developed nations (Okonjo, 2012). Given this, the Nigerian government, because of its plans for national development through scientific and technological means made the knowledge of Science to some extents, compulsory for its citizens (FRN, 2013). No country can claim to be developed without massive deployment and application of science and technology. According to Olasehinde and Olatoye (2014), Science education is considered an important part of education in nations that wish to develop scientifically, technologically and economically because it is designed to guide the world towards a scientifically literate society. This position brings to mind one science subject of importance, Biology.

The word *Biology* was coined from the Greek words *bios* (life) and *logos* (study of). It is therefore defined as the "study of life". Some of the branches of Biology included but not limited to Zoology, Botany, Anatomy, Ecology, Parasitology, Marine Biology, Biochemistry, Forensic Science, and Genetics. There is no gainsaying in the fact that a sound knowledge of Biology is essential for the study of Medicine and other medical related sciences. Given this, any nation that wishes to develop medically to be able to take care of the health of its citizens must not joke with the teaching and learning of Biology. The field of Biology provides students with important knowledge of life science concepts, scientific skills, environment and natural phenomena just as it also provides students the opportunity to be aware of living things around them without which they cannot exist as human beings. The relevance of Biology is recognized in the National Policy on Education (NPE) which stated the objectives of teaching Biology to include the inculcation of relevant field and laboratory and skills in students; acquisition of skills for the application of scientific processes and knowledge in daily living and also in the areas of personal, community health and in Agriculture, among others (NPE, 2014).

Genetics is a branch of biology that studies heredity and variation in living organisms. Being a field that studies cells at complex levels, it generally intersects frequently with many other life sciences. However, as interesting as the field is, it is one of the few aspects of Biology considered abstract, complex, and hard to learn by students. It has been reported severally that students' attempt of questions bothering on Genetics in external examinations was generally very poor (WAEC Chief Examiner's Report, 2002, 2003, 2004, 2005, 2010, 2011, 2012 & 2015). This is because when Genetics concepts are not well understood by students, they tend to shy away from answering questions on it during their terminal examinations West African Examination Council (WAEC), National Examination Council (NECO), and National Business and Technical Examination Board (NABTEB). One reason that has been attributed to students' poor understanding of Genetics concepts is the use of irrelevant or poor teaching methods by Biology teachers. The traditional or conventional method of teaching Biology has long been criticized because it only affords students the opportunity to memorize concepts instead of concrete understanding (Zheng, Lawhorn, Lumley & Freeman, 2008). Also, many researchers (Yu-Chien, 2008; Lewis & Leach, 2004; Schwartz, Lederman & Graford, 2004; Lewis & Wood-Robinson 2000) have reported the problem of the teaching and learning of Genetics over the years to be due to the use of wrong teaching methods, especially the use of the traditional or conventional teaching methods. They reported that Genetics concepts require abstract thinking and therefore must be taught using concrete means which are made available by Information and Communication Technology (ICT) and other modern teaching methods/approaches for students to fully understand the concepts of the subject.

According to the Association for Educational Communications and Technology (AECT)

(2007), solutions to existing educational challenges have been on the rise as several efforts are being taken to address the various problems encountered by teachers and students in teaching and learning processes. In this solution quests, Educational Technology which is all about imparting knowledge through the use of ICT tools has been of help as the field has stressed the development of new instructional technologies or packages including web-based instruction, mobile learning, game-based learning, and so on. These have shifted the teacher-centered learning environments to a more preferred student-centered learning environment. The use of computer software for teaching and learning, especially for personalizing learning for students has dominated educational fields in the world. The inclusion of ICT in education plays an essential role in the achievement of learning objectives in any subject area as stated by Hirsh et al. (2015) so far the appropriate educational software is included and utilized in the appropriate educational situations (Lee, 2009). The use of this software is complemented by many other gadgets and devices all of which are collectively known as ICT. It is now possible to develop packages or programmed instructions for students of varying ages and levels which they can use for private study in the absence of the teacher. This does not completely exclude the teacher from the teaching and learning platform but is expected to act as a facilitator of learning. In an attempt to ensure students are not locked out of the classroom completely during national or global crises coupled with the need to ensure that students learn effectively, ICT and software development for meeting academic needs could be used. These could help in the event of another pandemic or other disasters which may shut teachers and students out of the physical classrooms for months or years (AECT, 2007).

The development of instructional packages considers the learner, learning tasks, and cognitive processing of information among others (Cassarino, 2003). Also, to support learning, the design and development of instructional packages require that there must be a shift from content-delivery to a beneficial task-based instructional approach that allows learners to reflect on their learning and which also allows them to collaborate (Singh, 2009). The development of the package in this study followed a software development model known as the Waterfall Model. The development of software or packages for teaching and learning involves all the processes from the conception of the idea to the final development of the software (Okorie, 2010). The development of software might include new developments, existing modifications, or re-engineering among other activities that will result in the final production. The design process of software entails the need for it and the eventual inculcation of those needs into the final product. Several software models exist. The developer follows one or more of these models which describe tasks procedures that will eventually give rise to the final product. This study considers the Waterfall model. This model (Waterfall model), according to Royce (1970), organizes various stages of development in a linear order which systematically progresses from one stage to the next in a downward manner, hence, the name waterfall. The phases of the model are requirements, design, implementation, verification, and maintenance as shown in figure 1.

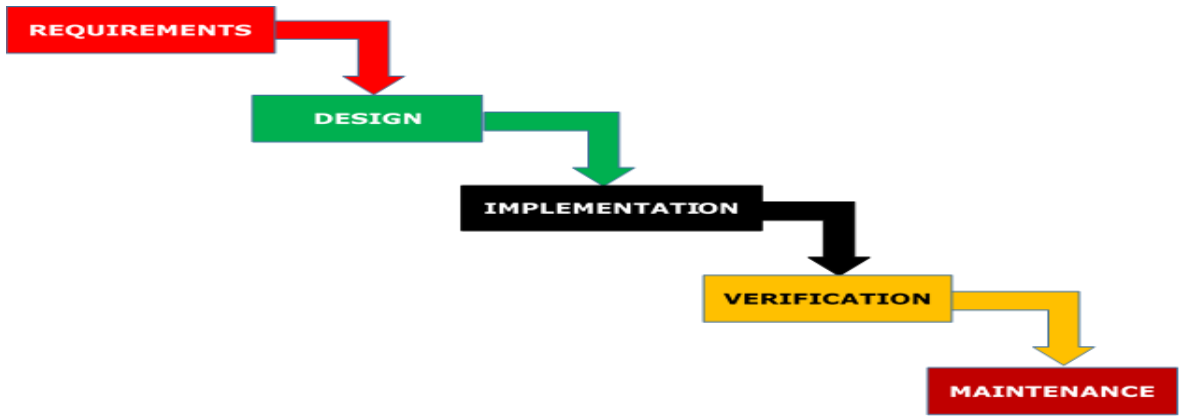

Figure 1. The waterfall model of software development

PREVIOUS STUDIES

Some literature has reported the relevance of using packages for teaching and learning Biology. Kim et al. (2021) reported that there are several advantages to using ICT-based devices in the teaching and learning processes. Some of these gains include availability and ease of use of the devices; stimulus and motivation from using the devices, connectivity, and so on. The ICT-based devices assist learners to take advantage of trending learning platforms and use them for developing new knowledge by performing activities that are related to their immediate interests and real-life scenarios in learning domains (Papadakis et al., 2021). Terzić and Miljanović (2009) stated that the use of ICTs for teaching and learning Biology showed much more effective compared with the traditional method in terms of quality, durability, and applicability of knowledge. Therefore, using digitalized media affords students the opportunity the media presents lessons in graphics, and this aids students' multiple sensory modalities, thereby motivating them to pay better attention to the contents presented. Also, Biology teachers and their students need highly interactive teaching and learning tools which can motivate students into complex thinking and problem solving (McLaughlin & Arbeider, 2008). In addition, Ahmad (2010) found that multimedia in education assists teachers to present concepts through the meaningful process by making use of varied elements of media. Furthermore, effective use of content and color; structure, and mode of navigating the package are effective for gaining students' attention as reported by Fakomogbon et al. (2012), from their study on design, development, and validation of a web-based instructional package. This agrees with Özkök (2013) who also reported that the CAI was valid reliable in assisting students to learn effectively. Vera et al. (2013) also reported that CAI embraces multimedia techniques and its use of attractive animations with a blend of the right colors and sound can capture, hold and also provide students with opportunities to learn effectively and get immediate feedback which prevents incorrect learning concepts. They reported further that CAI eliminates rote learning so that meaningful learning can occur.

The covid-19 pandemic locked out millions of teachers and students out of the classroom for months. At present, teaching and learning activities are still being done based on social distancing rules. In a world where ICT has permeated almost every sphere of human lives, especially the educational setting, lockdown instituted by any infection or disease shouldn't be. This is because ICT-based packages for teaching and learning either in the physical classrooms or online are numerous. Hence, pandemics or natural disasters need not lockdown teachers and students at home as the application of ICTs could bridge the gap. Also, the abstract nature of Genetics, a core Biological field, can be eliminated through the use of relevant ICT gadgets. These gadgets or packages can assist students to learn at their own pace and their comfort at home and can also assist teachers in facilitating students online. Hence, the rigors teachers and students pass through, including the use of conventional/traditional teaching methods, shortage of time in the physical classroom, lack of instructional aids, the rear position of Genetics in the Biology curriculum and so on might be reduced drastically while leveraging on ICT. Given the foregoing, this study objectively describes how an instructional package was developed for learning Genetics and also determined the extent of adequacy of the instructional package for instructional delivery.

Since students can now learn anywhere in the world from the comforts of their home and regardless of any pandemic resulting in a lockdown of schools, it becomes imperative to design, develop and validate a software package for learning Biology (Genetics) effectively. The objective of this was to design, development and validate a personalized package for learning Genetics in secondary schools. Specifically, the study attempted to (i) develop an instructional package for teaching and learning Genetics in senior secondary, and (ii) determine the adequacy of the instructional package for teaching and learning Genetics.

METHOD

This study adopted the instrumentation design. The instrumentation design involves the creative making of tools or instruments to meet a specific need or to solve a specific problem (Okorie, 2014). In making the package, the Waterfall Model that was proposed by Royce (1970) was used. In the development of effective instructional packages, instructional designers usually follow instructional design models some of which include but are not limited to Kemp's Instructional Design Model, Dick and Carey Model, ADDIE Model, and so on. Educators use developmental models to develop instructions that are systematically guided (Khodabandelou & Samah, 2012). The Waterfall model considered in this study

is a step-by-step model which progresses in a downward flow based on predetermined stages that must be followed to ensure a successful instructional package design. The waterfall model is made up of some consecutive stages each of which must be completed before moving to the next stage as depicted in Figure 1 above. To validate the package developed, thirty (30) Biology teachers were randomly selected from ten schools in Ijebu-Ode Local Government Area, Ogun State. A research instrument titled Package Adequacy Scale (SLPAS) was developed and used for validation purposes. The instrument contained 19 closed-ended items with a four-option response format of 'Not at all (1)', 'To an extent (2)', 'To a large extent (3)', and 'To a very large extent (4)'. The instrument was adapted from Yilmaz (2008). Two research questions were raised and answered in the study. The data collected were analyzed using descriptive statistics of frequency counts, percentages, Median scores, and standard deviation.

RESULTS

Research Question One - How was the package developed?

In developing the package used in this study, the "Waterfall Model" (Royce, 1970) of software development was adopted. This was adopted because it is a model that is easy to adapt in the development of educational software. The waterfall model was proposed by Winston W. Royce in 1970 to describe a possible software engineering practice (Bassil, 2012).

All the above stages are related in that one leads to the other. In this way, the next stage only comes on board after the first one at the top has been completed. The following were carried out to develop the package:

Requirement Gathering and Analysis

In this stage, all relevant materials, Biology curriculum and syllabus (Federal Republic of Nigeria), Biology textbooks, online resources, and media (sound, videos, pictures, texts, etc.) were gathered. In addition, other software, for example, MS PowerPoint, flash players, etc. that were to form part of the package were sourced. All possible requirements of the package were catered for at this stage and recorded in the specification file.

System Design

In this second stage, the requirement specifications from the first phase were effectively studied and the relevant ones were singled out for the final preparations. Based on the relevant information and units that have been adequately retrieved from those collected in the first stage, the package design was prepared. The package was designed to incorporate videos, animations, and non-media content all of which are meant to aid students' easier learning of Genetics. Preparing the package design helped in specifying hardware and other package requirements and also helped in defining overall package architecture as desired by the developer (researcher).

Implementation

Based on the inputs from the package design in the second stage, the package was first differentiated into small chunks referred to as units, that is, the package was developed unit by unit. Each unit was based on the six units into which Genetics is broken down into in the senior secondary schools thus: (i) Genetics Terms (ii) Transmission and Expression of Characteristics in Organisms (iii) Chromosomes: the Basis of Heredity (iv) Probability in Genetics (v) Linkage, Sex Determination, and Sex-Linked Characters, and (vi) Application of the Principles of Heredity in Agriculture and Medicine. It was at this stage that interface architecture, structures, and functions were fully designed and implemented. Also, Unit Testing, which involved assessing and testing each unit developed was for its functionality was carried out in this stage.

Verification

At this fourth stage of the package development, the units put together at the implementation stage were

fully inculcated into a whole after carrying out Unit Testing of each of the six units making up the package. Also, the package was examined for faults/failures that may hamper its effective utilization by the end-users, post-integration. It was at this stage that the whole package was fully developed and made ready for full utilization. After functional and non-functional testing have been done, the package was ready for testing in the school setting.

Maintenance

As common with all software or packages, issues do come up when testing software in the client environment. Therefore, when the package was first tested in a school setting, functional issues that came up were dealt with according before the package was finally deployed for use in the study. Maintenance, the last stage, was carried out to deliver the changes in the end-user environments. The whole process took more than 5 months to accomplish.

Research Question Two - To what extent is the instructional package adequate for instructional delivery?

Table 1. Median and standard deviation indicating adequacy of the instructional package for teaching and learning of Genetics.

S/N	Items	Median	SD	Decision
1.	The contents of the package meet the current objectives of Genetics concepts in Biology.	2.00	.73	To an extent
2.	The contents of the package meet the objectives of the Biology curriculum (FBN & WAEC).	3.00	.95	To a large extent
3.	The content of the package is appropriate for the SS III Biology students.	3.00	.79	To a large extent
4.	The content of the package is accurate and detailed.	4.00	.73	To a very large extent
5.	The content of the package presents Genetics concepts in an interesting, lively, and compelling way.	3.00	.77	To a large extent
6.	The package offers a range of difficulty levels.	3.00	.69	To a large extent
7.	The content of the package is adequate in communicating Genetics concepts effectively to students in less time.	3.00	.64	To a large extent
8.	The package is adequate in terms of instructional delivery.	4.00	.81	To a very large extent
9.	Students can rely on the package in learning the concepts of Genetics effectively.	3.00	.71	To a large extent
10.	The package is highly effective in terms of content per unit time.	3.00	.79	To a large extent
11.	The package promotes higher-level thinking.	3.00	.79	To a large extent
12.	The lessons in the package adequately personalize Genetics concepts appropriately.	3.50	.83	To a large extent
13.	The assessments and activities in the package are appropriate.	3.00	.61	To a large extent
14.	The lessons, activities, content, and procedures in the package are effective in motivating students to acquire Genetics knowledge.	3.00	.75	To a large extent
15.	There is a balanced use of graphics, text and sound which are appealing to the sense of sight in the package.	3.00	.51	To a large extent
16.	The multimedia used are clear, simple to understand and effective in communicating the concepts of Genetics to students.	3.00	.62	To a large extent
17.	The colours and background are appealing and captivating.	3.00	.64	To a large extent
18.	The use of animations is well positioned and appropriate.	3.00	.69	To a large extent
19.	The package is easy to navigate and the directions given on the opening screens are easy to follow.	4.00	.51	To a very large extent

Mode of the Median score = 3.00

Based on the result (Mode of the Median score = 3.00) in Table 1, the multimedia self-learning package on Genetics was adjudged adequate to a large extent by the Biology teachers who rated the package. Disaggregating the results item by item, the package was adequate to a large extent (Median 3.00) in offering a range of difficulty levels to content. To a very large extent (Median 4.00), the package was adequate for easy navigation and understanding to follow the directions given on the opening screens. The teachers claimed that to a very large extent (Median 4.00), the content of the package is accurate and detailed. Also observed by the teachers was that to a large extent (3.00), the package is highly effective in terms of content per unit time just as it promotes higher-level thinking (3.00). Similarly, the teachers observed that to a large extent (3.50), the lessons in the package depict personalized instruction on Genetics. The observation of the teachers further depicts that the package is adequate to a very large extent (Median 4.00) in terms of instructional delivery while at the same time, they submitted that to a large extent (3.00), students can rely on the package in learning the concepts of Genetics effectively. Also, to a large extent (3.00), the teachers observed that the lessons, activities, content, and procedures in the package are effective in motivating students to acquire knowledge of Genetics. The teachers claimed that to a large extent (3.00), the graphics, text, and sound used were adequate. The adequacy of the package in terms of color and background is to a large extent (3.00) appealing and captivating. In like manner, the use of animations to a large extent (3.00) is well-positioned and appropriate. The teachers also observed that to a large extent (3.00), the content of the package is appropriate for SS3 Biology students. The package was equally adjudged to a large extent (3.00) adequate in terms of communicating Genetics concepts effectively to students in less time and also presents Genetics concepts in an interesting, lively, and compelling way. To a large extent (3.00), the assessments and activities in the package are appropriate and the contents of the package also meet the objectives of the Biology curriculum. The adequacy of the multimedia package was to a large extent (3.00) strong in terms of clarity, simple and effectiveness in communicating the concepts of Genetics to students. Lastly, the teachers observed that to an extent (2.00), the package meets the current objectives of Genetic in Biology.

DISCUSSION

The study developed an instructional package for teaching and learning Genetics based on the principles of inclusion of ICT in education. The package was validated by giving it to teachers of Biology for verification to ensure its suitability for teaching and learning Genetics. The findings of the study showed that the carefully designed and developed instructional package is suitable for the teaching and learning of Genetics in senior secondary schools. Over the years, researchers have shown that the inclusion of ICT in education plays an essential role in the achievement of learning objectives in any subject area (Hirsh et al., (2015) so far the appropriate educational software are included and utilized in the appropriate educational situations (Lee, 2009). The finding also corroborates McLaughlin and Arbeider (2008) who reported that Biology teachers and their students need highly interactive teaching and learning tools which can motivate students into complex thinking and problem-solving.

Papadakis et al. (2021) reported that there are several advantages to using ICT-based devices in the teaching and learning processes. Some of these gains include availability and ease of use of the devices; stimulus and motivation from using the devices, connectivity, and so on (Kim et al., 2021). The ICT-based devices assist learners to take advantage of trending learning platforms and use them for developing new knowledge by performing activities that are related to their immediate interests and real-life scenarios in learning domains. Similarly, Ahmad (2010) found that multimedia in education assists teachers to present concepts through the meaningful process by making use of varied elements of media. Effective use of content and color; structure and mode of navigating the package are effective for gaining students' attention as reported by Fakomogbon et al. (2012), from their study. Also, the study agrees with Özkök (2013) who conducted a study designed to test the validity and reliability of CAI. The findings revealed that the CAI used was valid and also reliable. According to Vera et al. (2013), CAI embraces multimedia techniques and its use of attractive animations with a blend of the right colors and sound can capture, hold and also provide students with opportunities to learn effectively and get immediate feedback which prevents incorrect learning concepts. They reported further that CAI

eliminates rote learning so that meaningful learning can occur.

CONCLUSION

The study achieved its objectives of describing the procedure of instructional package design and testing it for suitability to teach and learn Genetics. The study developed and validated an instructional package for teaching and learning Genetics in senior secondary schools, using the waterfall model of instructional package design. The study has further contributed to knowledge by proving that carefully designed and validated instructional packages could be used to not just motivate learners and stimulate learning but also that their learning could also be significantly through the use of ICT-based instructional packages. While Genetics is seen as a difficult subject by Biology students, the study has shown that it could be easily learned and students' fear removed by leveraging on the advantages of ICT in education. While the Covis-19 lockdown still ravages worldwide and resulting in the closure of schools in some countries, yet students can still learn and interact with their teachers through ICT devices. Finally, the personalized instructional package for learning Genetics as developed in the study is effective for assisting students to learn the concepts of Genetics from the comfort of their homes, even in the event of schools lockdown.

RECOMMENDATIONS

Concerning the findings of the study, it was suggested that students should be supplied with modern software which can aid the learning of Biology both at home and in school. Having uniform software will ensure that students are following the same syllabus or curriculum and being able to use the software at home will help to assure that even at the outbreak of any pandemic, learning continues at home undisturbed. Also, Biology teachers should be trained and regularly retrained by the government on the utilization of ICT packages for instructional delivery. The use of CAI by students need teachers as facilitators. Sequel to this, Biology teachers need to be trained on becoming effective and efficient facilitators for better student guidance. Finally, science education software developers in the country are advised to involve Biology teachers, curriculum developers, computer programmers, educational technology experts, and Biology students in particular in the development and validation processes of multimedia learning packages to ensure high quality, relevant software which is highly interactive and user-friendly.

As the covid-19 pandemic continues with no end in view, researchers in Educational Technology and allied fields need to keep developing packages to making teaching and learning more enjoyable for teachers and students of not just Science but in other fields of learning as well. As ICT has permeated every part of education, its advantages must be embraced by educators all over the world to ensure that educational goals are easier to attain such that sustainable citizens are trained all over the world. The pandemic or natural disasters need not bar students from learning and teachers from reaching and teaching their students.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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