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ACHIEVING SUSTAINABLE DEVELOPMENT GOALS THROUGH EFFECTIVE TEACHING OF SCIENCE EDUCATION IN NIGERIA TERTIARY INSTITUTIONS

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ABSTRACT

This study examined into the role of science education at the tertiary level of education in achieving the SDGs' science and technology-related goals. Descriptive research design was adopted for this study. Three hundred and fifteen (315) respondents were randomly selected in the School of Science, Adeyemi College of Education, Ondo. Two research questions and hypotheses were answered and tested for acceptance or rejection. A structured and well-validated questionnaire was used to obtain data for this study. The data collected were analyzed using frequency count, mean score, and t-test statistics. Findings revealed that effective teaching of science education at the tertiary level of education will significantly boost the achievement of science and technology-related goals of the SDGs. This study concludes that science education has evolved to be the backbone of the sustainable development of any nation since its teaching will result in scientific and technological advancements, which is the soul of the development of any nation. It was recommended that the government should devote greater resources to the teaching of science education at both the secondary and tertiary levels of education.

KEYWORDS

Science-education, SDGs, sustainable, development.

Introduction

Sustainable development is an important issue in preparing the global community to face the emerging challenges of environmental changes globally. By the start of the UNESCO Decade of Education for Sustainable Development (2005–2014) (UNESCO 2014), universities had adhered to several approaches to rethinking sustainable development. A major transformation in higher education needs to occur across all disciplines and levels of study (González, Jiménez-Fontana, Azcárate-Goded, and Cardeñoso, 2017). As Boron, Murray, and Thomson (2017) indicate 'The ultimate purpose of academic teaching programs orientated around 'sustainability' is to support the practical attainment of a sustainable future for industry, business and society'. More than ever higher education institutions and their stakeholders, that is, students, staff, scholars, administration and management, research communities, alumni, businesses, social movements, consumer organizations, governments, and professional associations (Jongbloed, Enders, and Salerno, 2008), need to rethink the notion of Higher education for sustainable development in alignment with the Sustainable Development Goals (SDGs) which are both an approach to sustainable development and a tool for addressing global problems in a collaborative (United Nations 2015; and Saito, Managi, Kanie, Kaufman, and Takeuchi, 2017).

The Sustainable Development Goals (adopted by the United Nations General Assembly in September 2015) run from 2016 to 2030 and are formally the goals of the United Nations in transforming our world. The 2030 Agenda for Sustainable Development is an agenda that sets out the vision, principles, and commitments to a fairer and more sustainable world for all. The Global Goals are a set of objectives within a universal agreement to end poverty, protect all that makes the planet habitable, and ensure that all people enjoy peace and prosperity, now and in the future. The Goals were adopted by all member states of the United Nations formally in 2015, for the period 2016 - 2030 to address the overwhelming empirical and scientific evidence that the world needs a radically more sustainable approach.

The Millennium Development Goals (MDGs) Report 2015 stated the practical and political importance of the SDGs, and the challenges associated with them, can only be truly appreciated by understanding what preceded them (MDGs). The Millennium Development Goals (MDGs) were in place from 2000 to 2015 and consisted of eight international development goals. The first three goals covered poverty, education, and gender equality; the next three goals addressed health outcomes covering child mortality, maternal health, and HIV/AIDS, malaria, and other diseases. The remaining two goals addressed environmental sustainability and global partnership for development. The sustainable developmental goal refers to five areas of critical importance; sometimes known as the 5 'P's, these are People, Planet, Prosperity, Peace, and Partnerships The goal is made up of 17 goals{No Poverty (goal 1) (Goal 2), Good Health and Well-being (Goal 3), Quality Education (Goal 4), Gender Equality (Goal 5), Clean Water and Sanitation (Goal 6), Affordable Clean Energy (Goal 7), Decent Work and Economic Development (Goal 8), Industry, Innovation, and Infrastructure (Goal 9), Reduce Inequalities (Goal 10), Sustainable Cities and Communities (Goal 11), Responsible consumption and production (Goal 12), Climate Action (Goal 13), Life below Water (Goal 14), Life on Land (Goal 15), Peace, Justice and Strong Institutions (Goal 16), Partnerships for the Goals (Goal 17)} which will help make the world habitable for its habitants.

Science Education

According to Wang, Zhou, & Ye (2021), science education plays a critical role in preparing students for the challenges of the 21st century. It provides them with the necessary tools to navigate complex scientific issues, such as climate change and genetic engineering, and empowers them to participate in scientific debates in society. The authors argue that science education should be inclusive, engaging, and relevant to students' lives to promote curiosity, creativity, and critical thinking. Similarly, Hameed, Somers, Croft, & Lortie (2021), emphasize the importance of science education in building a scientifically literate society. They suggest that science education should go beyond the transmission of knowledge to cultivate scientific attitudes, habits, and values, such as curiosity, skepticism, and ethical responsibility.

Science education aims to grow scientifically literate individuals who have an understanding of scientific content, can conclude scientific issues, and know how to evaluate scientific cases (Wang & Schmidt, 2001) in (Karaarslana and Teksöz, 2016). During the early years of the 20th century, SE was influenced by the education philosophers like John Dewey, because of the influence of Dewey's educational perspective, it was accepted that SE and education in general were more related to social life (Deboer, 2000) in (Karaarslana and Teksöz, 2016). Thus the role of SE was set to teach individuals to be effective in a social world; in other words, the target of SE was to integrate scientific knowledge into real-life activities. The focus of SE changed through science and technology education to meet the needs of daily life and society.

The focus of SE continued to change in line with the developments in science and technology and people's concerns (Deboer, 2000). Today, industrial and economic developments in digital technologies have been influencing SE. Therefore, the aim of SE is described as to develop scientifically and technologically informed citizens. As stated by Carter (2008), science has changed in recent decades with economic and technological developments and the effects of globalization.

Science Education and Sustainable Development

The great idea of science Education for Sustainable Development is to equip students with interdisciplinary sustainable competencies to improve the national development of any nation through student-centered and innovative strategies, such as inquiry teaching method, discovery teaching method, and project method. Despite the importance of science education to national development, Nigeria lacked sustainable science education since its independence and as a result, science education has not been able to move the country into industrialization and above the poverty level.

Despite the importance of science education to national development, Nigeria lacked sustainable science education since its independence and as a result, science education has not been able to move the country into industrialization and above the poverty level (Obianuju, Obiajulu& Francis, 2013). According to Momeke (2007), science education has failed to produce skilled human resources needed for transformation into national prosperity due to the misplacement of priority. This implies that most of Nigeria's development in the direction of modernization has been haphazard leading to the acquisition of obsolete technology. As a result, the development of sustainable science education constitutes a catalytic process for social education, training, and public awareness - the values, behaviors, and lifestyles essential for a sustainable future. For any nation, including Nigeria, to achieve sustainable development, scientific education must be recognized as a priority field of education for its inhabitants.

William and Desmond (2020) emphasized the Independent Group of Scientists appointed by the Secretary-General (2019) position that the challenge of achieving sustainable development is to secure human well-being in ways that are not only safe, in terms of not threatening the Earth system with irreversible change, but also just. Ultimately then, sustainable development should be pursued in the spirit of finding pathways that enable a good life for all, leaving no one behind, while safeguarding the environment for future generations and ensuring planetary justice (p. 2). The authors consider "how science can best accelerate the achievement of the Sustainable Development Goals" and they argue "in favour of sustainability science as a new way for science to contribute directly to sustainable development (p. 2). The Report presents a scientific view of integrated ways to accomplish the transformation of the planet. The authors identify six essential entry points, where the interconnections across the SDGs and targets are suitable for accelerating the necessary transformation. The six entry points are:

- Strengthening human well-being and capabilities;
- Shifting towards sustainable and just economies;
- Building sustainable food systems and healthy nutrition patterns;
- Achieving energy de-carbonization with universal access to energy;
- Promoting sustainable urban and peri-urban development; and
- Securing the global environmental commons.

Considering these global initiatives, where are the voices of science educators? Science educators ought to be at the forefront of ensuring the education discourse is oriented toward the goals, aspirations, desires, and needs of all Nigerians and the world at large.

Statement of the Problem

Nearly a decade after the world's fifteen-year sustainable development goals (SDGs) were implemented by United Nations, Nigeria has made little or no progress toward meeting the Sustainable Development Goals, with none of the seventeen targets having been met. This is evident from widespread poverty, lack of clean water and sufficient food, dilapidated infrastructure, high electricity tariffs, massive unemployment, lack of industrial revolution, high incidence of diseases, excessive debt burden, inflation; persistent loss of lives due to insurgencies by various terrorist organizations among others. This study looks into how effective science education can be employed in achieving science-related targets among the United Nations' sustainable development goals such as Zero Hunger (Goal 2), Good Health and Well-being (Goal 3), Clean Water and Sanitation (Goal 6), Affordable Clean Energy (Goal 7), Industry, Innovation and Infrastructure (Goal 9), Responsible consumption and production (Goal 12), Climate Action (Goal 13).

Objectives of the study

The broad objective of this study is to investigate how science education can be used in achieving science and technology-related goals of the United Nation's SDGs in Nigeria. Specifically, this study sought to investigate;

a. How effective teaching of science education at the tertiary level of education by science educators can be used to improve the student's science and technological ideas.

b. If the appointment of experts in the field of science and technology companies into the teaching of science education will enhance the production of graduates with innovations and invention ideas.

Research Questions

The following questions were raised to guide the investigation:

a. Will the effective teaching of science education at the tertiary level of education by science educators, improve the student's science and technological ideas?

b. Will the appointment of experts in the field of science and technology companies into the teaching of science education enhance the production of graduates with innovations and invention ideas?

Research Hypothesis

The following hypothesis was generated for the study:

H_0: There is no significant difference between effective teaching of science education at the tertiary level of education and the achievement of science and technology-related goals of the SDGs.

Methodology

This study was a descriptive survey in nature. The sample consisted of three hundred and fifteen respondents, of which 45 respondents were randomly chosen from the seven departments in the School of Science Adeyemi College of Education, Ondo. A structured questionnaire was used to obtain information on how science education can be effectively utilized in achieving science and technology-related SDGs. The items on the research instrument were generated after the careful observation of the level teaching of science education in the tertiary institution selected as a case study. The questionnaire was structured on four (4) Likert rating scales (Strongly Agree, Agreed, Disagreed, and Strongly Disagreed), while 1 point, 2 points, 3 points, and 4 points were assigned to the scales respectively. The benchmark for acceptance or rejection of the stated research questions was mean=2, when the calculated mean is equal to or higher than 2, the stated research question is accepted or otherwise. The research instrument was validated by three experts in test and measurement, while the reliability test was a coefficient of 0.68 using Kuder-Richardson 20 (KR20). The collected data were analyzed using mean score and t-test statistics.

Findings and Discussion

Research question 1: Will the effective teaching of science education at the tertiary level of education by science educators, improve the student's science and technological ideas?

Table 1: Effective teaching of science education at the tertiary level of education and improvement in the student's science and technological ideas.

S/N	Effective teaching of science education at the tertiary level of education and improvement in the student's science and technological ideas	SA (%)	A (%)	D (%)	SD (%)	MEAN	REMARKS
1	Adequate use of technologically advanced laboratory equipment in science teaching will improve students' science and technological ideas	99 33.0	108 36.0	52 17.3	41 13.7	2.88	Accepted
2	The competence of the science educators does not necessarily determine the level of science students' science and technological ideas.	21 7.0	24 8.0	99 33.0	156 52.0	1.70	Rejected

3	Effective use of innovative strategies in teaching science will boost their critical thinking to foster new scientific ideas	147 49.0	104 34.7	36 12.0	13 4.3	3.28	Accepted
4	Explicit modification of the science education curriculum will enhance the productive scientific ideas of the students	129 43.0	113 37.7	27 9.0	31 10.3	3.13	Accepted
5	Updating the objectives of science education to tackle the nation's contemporary issues does not necessarily enhance its productivity	22 7.3	41 13.7	89 29.7	148 49.3	1.79	Rejected
6	The appointment of more competent science educators will have a positive influence on the scientific ideas of the students.	109 36.3	98 32.7	56 18.7	37 12.3	2.93	Accepted
	Total	527 29.3	488 27.1	359 19.9	426 23.7	2.62	Accepted

Table 1 reveals the responses of the participants to the stated question "Will the effective teaching of science education at the tertiary level of education by science educators, improve the student's science and technological ideas?" On item (1) which states that Adequate use of technologically advanced laboratory equipment in science teaching will improve students' science and technological ideas, 33.0%, 36.0%, 17.3%, 13.7% were obtained strongly agreed, agreed, disagreed, and strongly disagreed, respectively, while the mean is (=2.88). Item (2), which states that the Competence of the science educators does not necessarily determine the level of science students' science and technological ideas, 7.0% of the responses of respondents were for strongly agreed, 8.0% was for agreed, 33.0% was for disagreed, while 52.0%, strongly disagreed and the mean is (=1.70).

Item (3), states that Effective use of innovative strategies in teaching science will boost their critical thinking to foster new scientific ideas. The respondents' responses indicated 49.0%, 34.7%, 12.0%, and 4.3% for strongly agreed, agreed, disagreed, and strongly disagreed respectively, while the mean is (=3.28). On item (4), which states that Explicit modification of science education curriculum will enhance the productive scientific ideas of the students, 43.0% of responses were obtained strongly agreed, 37.7% agreed, 9.0% disagreed, and 10.3% were obtained strongly disagreed, while the mean is (=3.13).

Item (5) which states that Updating the objectives of science education to tackle the nation's contemporary issues does not necessarily enhance its productivity, 7.3% of the responses from respondents was for strongly agreed, 13.7% agreed, 29.7% was for disagreed and 49.3% was for strongly disagreed, while the mean is (=1.79). On item (6), which states that the Appointment of more competent science educators will have a positive influence on the scientific ideas of the students, 36.3% responses were obtained for strongly agreed, 32.7% for agreed, 18.7% disagreed, and 12.3% was obtained for strongly disagreed, while the mean is (=2.93).

Finally, table 1 above shows the Average mean of the total responses from the respondents as (=2.62) which makes it to be accepted that the effective teaching of science education at the tertiary level of education by science educators, will improve the student's science and technological ideas. This buttressed the (Ogunmade, 2006) position that, for any nation including Nigeria to attain

sustainable development, there is a need to recognize science education as a priority area of education for her citizens, because Science education has evolved worldwide as a prerequisite in technological development.

Research question 2: Will the appointment of experts in the field of science and technology companies into the teaching of science education enhances the production of graduates with innovations and invention ideas?

Table 2: Appointment of experts in the field and the production of graduates with innovations and invention ideas.

S/N	Appointment of experts in the field and the production of graduates with innovations and invention ideas	SA (%)	A (%)	D (%)	SD (%)	MEAN	REMARKS
1	The appointment of experts from the field of science and technology companies may not motivate students to learn efficiently	22 7.3	31 10.3	104 34.7	143 47.7	1.77	Rejected
2	The teaching of practical-oriented concepts by experts from science and technology companies may not yield the production of critically thinking science graduates	17 5.7	22 7.3	110 36.7	151 50.3	1.68	Rejected
3	Taking the student on field trip to science and technology companies will motivate them to see possibilities in the invention of new scientific ideas and technological devices.	108 36.0	89 29.7	75 25.0	28 9.3	2.92	Accepted
4	Giving students innovative and inventive group project work will motivate them to do more	95 31.7	103 34.3	82 27.3	20 6.7	2.91	Accepted
5	Governments, schools, and science education experts support big innovative ideas from students will motivate them to engage in more innovative works	98 32.7	99 33.0	56 18.7	47 15.6	2.83	Accepted
6	The establishment of competition on innovation and invention by science education experts will enhance the production of technological instruments	121 40.3	86 28.7	62 20.7	31 10.3	2.99	
	Total	461 25.6	430 23.9	489 27.2	420 23.3	2.52	Accepted

Table 2 reveals the responses of the participants to the stated question "Will the appointment of experts in the field of science and technology companies into the teaching of science education enhance the production of graduates with innovations and invention ideas?" On item (1) which states that The appointment of experts from the field of science and technology companies may not motivate students to learn efficiently,7.3%, 10.3%, 34.7%, 47.7% were obtained for strongly agreed, agreed, disagreed, and strongly disagreed, respectively, while the mean is (=1.77). On item (2), which states that The teaching of practical oriented concepts by experts from science and

technology companies may not yield the production of critically thinking science graduates,5.7% of the responses of respondents were for strongly agreed, 7.3% was for agreed, 36.7% disagreed, while 50.3%, strongly disagreed and the mean is (=1.68).

Item (3), states that taking the students on a field trip to science and technology companies will motivate them to see possibilities in the invention of new scientific ideas and technological devices. The respondents' responses indicated 36.0%, 29.7%, 25.0%, and 9.3% strongly agreed, agreed, disagreed, and strongly disagreed respectively, while the mean is (=2.92). On item (4), which states that Explicit modification of science education curriculum will enhance the productive scientific ideas of the students, 31.7% of responses obtained strongly agreed, 34.3% agreed, 27.3% disagreed, and 6.7% obtained strongly disagreed, while the mean is (=2.91).

On item (5) which states that Governments, schools, and science education experts support big innovative ideas from students will motivate them to engage in more innovative works, 32.7% of the responses from the respondents was for strongly agreed, 33.0% agreed, 18.7% were for disagreed and 15.6% was for strongly disagreed, while the mean is (=2.83). On item (6), which state that the Establishment of competition on innovation and invention by science education experts will enhance the production of technological instruments, 40.3% responses were obtained for strongly agreed, 28.7% agreed, 20.7% disagreed, and 10.3% was obtained for strongly disagreed, while the mean is (=2.99).

Finally, table 2 above shows the Average mean of the total responses from the respondents as (=2.52) which makes it to be accepted that the appointment of experts in the field of science and technology companies into the teaching of science education will enhance the production of graduates with innovations and invention ideas. This is in line with the report prepared by the National Science Teacher Association (NSTA, 2003) which described that science teachers at all levels should hold competencies related to the necessary knowledge, and skills, motivating students to engage in topics related to science, technology, nature of science, inquiry, and scientific issues. And also per a study conducted by (Bybee, 2014) addressed that in addition to basic competencies for STs such as subject matter knowledge, and pedagogical practices, personal qualities like personal relations with students or willingness to teach science are also essential competencies for science teachers.

Research Hypothesis

H_0: There is no significant difference between effective teaching of science education at the tertiary level of education and the achievement of science and technology-related goals of the SDGs.

Table 3: Difference between effective teaching of science education at the tertiary level of education and the achievement of science and technology-related goals of the SDGs.

Variables	N	Mean	SD	DF	Tcal	Tvalue	Remark
Science Education	6	184.8	938.76	10	0.510	1.812	Accepted
Achievement of science and technology-related goals of the SDGs	6	115.2	680.94				

Table 3 shows the analysis of the collected data for testing the generated hypothesis: The formulated hypothesis stated that "There is no significant difference between effective teaching of science education at the tertiary level of education and the achievement of science and technology-related goals of the SDGs" was accepted, because the calculated value 0.510 is less than the table value of 1.812, at the alpha level of significance of 0.05. This implies that the great idea of science Education for Sustainable Development is to equip students with interdisciplinary sustainable competencies to improve the national development of any nation through student-centered and innovative strategies. This affirmed Carter's (2008) position which stated that the purpose of SE in the 21st century has been set to help students make critical judgments about science and increase their engagement to work for a more socially just, equitable, and sustainable world.

Conclusion

It is undeniable that Nigeria is currently confronted with formidable challenges. Clean water shortages, outdated medical facilities, living insecurity, extreme poverty, and hunger continue to be a problem. New diseases are surfacing, while old ones are still unabated. Food security, quality education, a stable energy supply, and good governance are all things that the country is far from achieving. Based on the findings of this study, it was concluded that science education can be an effective tool in reversing the country's dire situation; however, many leaders are misled into believing that advancing economy is the only means by spending funds is the only means of improving the sustainability of the nation, despite the importance of science education in achieving sustainability. Science may provide the country with an essential avenue via which it might address its problems.

Recommendations

Based on the results of the findings, the following recommendations were made for improvement in the teaching of science education in tertiary institutions:

1. Policies and programs should be devised to address the difficulties of sustainable development, and all stakeholders in education should be included.
2. To facilitate effective science instruction at both secondary and tertiary levels of education, the government should hire more qualified and competent science instructors.
3. Governments should be inclined to endorse a variety of innovative projects undertaken by schools and students.
4. The goals of science education should be oriented toward achieving a sustainable developed nation through science education.
5. The schools should have clearly stated goals for graduating students who are capable of developing new scientific methods and achieving long-term development goals.
6. Establishing Effective inter-school innovation and invention competitions to encourage the development of new technological tools.

REFERENCES

Boron S, Murray K.R., and Thomson, G.B. (2017) Sustainability education: towards total sustainability management teaching. Handbook of Theory and Practice of sustainable development in higher education, vol 1, pp 37–52.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. Journal of Science Teacher Education, 25(2), 211-221. doi 10.1007/s10972-014-9381-4

Carter, L. (2008). Globalization and science education: Implications of science in the new economy. *Journal of Research in Science Teaching* 45(5), 617-633. doi:10.1002/tea.20189.

Deboer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37(6), 582- 601.

Franco, I., Saito, O., Vaughter, P., Whereat, J., Kanie, N., and Takemoto, K. (2018). Higher education for sustainable development: actioning the global goals in policy, curriculum, and practice. United Nations University Institute for the Advanced Study of Sustainability, 5 Chome-53-70 Jingumae, Shibuya, Tokyo 150-8925, Japan.

García-González E, Jiménez-Fontana R, Azcárate-Goded P, and Cardeñoso JM., (2017). Inclusion of sustainability in university classrooms through the methodology. In: *Handbook of theory and practice of sustainable development in higher education*. Springer, Cham, pp 3–19.

Hameed, I., Somers, M., Croft, N., and Lortie, M. (2021). Science education for a scientifically literate society. *Canadian Journal of Science, Mathematics and Technology Education*, 21.2:129-135.

Jongbloed B, Enders J., and Salerno, C. (2008) Higher education and its communities: interconnections, interdependencies, and a research agenda. *High Educ* 56(3):303–324.

Karaarslanab, G. and Teksözb, G., (2016). Integrating Sustainable Development Concept into Science Education Program is not enough; We Need Competent Science Teachers for Education for Sustainable Development – Turkish Experience. *International Journal of Environmental & Science Education*, VOL. 11, NO.15, 8403-8424.

Millennium Development Goals Report 2015. United Nations, New York, 2015. http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf

Momeke, C. O. (2007). 'Effects of the learning cycle and Expository instructional approaches on Students' learning outcome in Secondary Biology' is An unpublished Ph.D. thesis submitted to the School of postgraduate studies, University of Benin, Benin City.

NSTA (2003).Standards for science teacher preparation. National Science Teacher Association. Retrieved (January, 2023).

Obianuju, O.S., Obiajulu, A.N. & Francis, A.E. (2013). Science Education for Sustainable Development in Nigeria: Challenges and Prospects. *Academic Journal of Interdisciplinary Studies*. Vol 2 No 6, pp 159-165.

Ogunmade, T.O (2006). And Quality of Secondary Science Teaching and Learning of Secondary Science Teaching And Learning Of Secondary In Lagos State, Nigeria. An Unpublished Doctoral Thesis, Edith Cowan University, Perth, Western Australia.

Pauw JB, Gericke N, Olsson D, and Berglund T. (2015).The Effectiveness of Education for Sustainability Development. *Sustainability*, 7(11): 15693-15717.

Saito O, Managi S, Kanie N, Kaufman J, and Takeuchi K (2017). Sustainability Science and implementing the sustainable development goals. *Sustain Sci* 12(6):907–910.

Sustainable Development Solutions Network: (2015). Getting Started with the Sustainable Development Goals – A Guide for Stakeholders. December 2015. http://unsdsn. org/resources/publications/sdg-guide-getting-started-withthe-sdgs/ (Accessed, March 2023).

United Nations (2015) Transforming our World: the 2030 agenda for sustainable development. United Nations, New York.

United Nations General Assembly (2021). Critical milestones towards coherent, efficient, and inclusive follow-up and review at the global level.

Wang, H. A., & Schmidt, and W. H. (2001). History, philosophy, and sociology of science in science education: Results from the third international mathematics and science study. Science and Education, 10, 51-70. doi 10.1080/08832323.2010.505254.

Wang, L., Zhou, J., and Ye, S. (2021). Science literacy for the 21st century: Challenges and opportunities in science education. *Science & Education,* 30.3:791-799.