# ASSESSING GENDER DIFFERENCES IN NANOTECHNOLOGY AWARENESS, EXPOSURE AND MOTIVATION AMONG PHYSICS UNDERGRADUATES IN OYO STATE

BY

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## Abstract

*Advances in nanotechnology have drawn attention to nanotechnology education. The study assessed gender differences in nanotechnology awareness, exposure and motivation among physics undergraduates. The study was guided by three hypotheses. The population of this study comprises all undergraduate physics students of Ekiti State university affiliated with Emmanuel Alayande College of Education, Oyo, during 2022/2023 academics session. Data was collected using a questionnaire titled Nano-Awareness, Exposure, and Motivation Questionnaire (NAEMQ) and presented using frequency counts, simple percentage, mean and chi-square. The findings of the study reveal that: the participants have good awareness of, exposure to, and motivation for nanotechnology and the level of awareness of, exposure to, and motivation for nanotechnology was dependent on genders of respondents. Based on the results of findings, it is recommended that physics education programs should capitalize on the existing awareness, exposure, and motivation of undergraduate students towards nanotechnology, and enhance their curriculum to include more nanotechnology-related content, particularly in areas where gender disparities were identified.*

***Keywords: Physics Students, Nanotechnology, Awareness, Exposure, Motivation and Gender***

## Introduction

Nanotechnology is one of the most important technologies of our time and has become one of the most important fields in the field of science because of its profound impact in various aspects including environmental sustainability, which is to be based on the activation of nanotechnology in our scientific and practical public life as well as the preservation of the environment (Boras et al., 2018). The concept of nanotechnology has become linked to the development of the educational system as it is a contemporary type of technology, which is based on the integration of many disciplines that must be integrated into the educational system and take advantage of its applications (Alqahtani, 2020). Nanotechnology is a broad applied area as it directly and indirectly enters all human needs and scientific and environmental developments (Ayad, 2017). Economists have estimated that nanotechnology will accomplish development aims in diverse fields by 2025 as an emergent technology and new industrial revolution, leaving its mark on the 21st century (Roco et al., 2011).

It is therefore essential that students be aware of this field of technology to keep up with the developments as it has become a requirement to meet the challenges of the times (Darwish & Abu , 2018). Yawson (2012) argued that nano consciences need to be integrated into curricula for students to become more aware of, and have a better understanding of nanotechnology, i.e. there is an urgent need for them to be aware of developments and developments related to nanotechnology and its effects on environmental sustainability and the so-called "nanoring" or "nano-enlightenment'' (Yawson,2012). Adegboyega et al (2023) studied determinants of awareness levels of Physics teachers about nanoscience and nanotechnology (NSNT) in senior secondary schools and concluded that majority of the participants have awareness about nanoscience and nanotechnology and the level of awareness of the physics teachers was independent of their genders.

Although modern nanotechnology is well-established, the current generation of science teachers typically has little exposure to nanoscience and nanotechnology (NSNT), and few opportunities to understand the basic concepts of NSNT (Pas et al., 2019). Therefore, undergraduates will experience a maximal NSNT exposure, with risks in learning abstract and complex NSNT concepts, thus necessitating an improved introduction to NSNT. Ekli & Şahin (2010) emphasized conveying advantages of NSNT to undergraduates, and other authors have maintained that NSNT education may start early at pre-school level, continuing to undergraduate education (Alpat et al., 2017; Roco & Bainbridge, 2005; Sagun-Gɩkɩz & Akaygьn, 2013). Furthermore, exposure to science develops positive attitudes, which can be pursued and further developed in a formal way (Ban & Kocijancic, 2011; Alpat et al., 2017; Saidi & Sigauke, 2017; Andina et al., 2019), contribute to analytical thinking (Winkelmann & Bhushan, 2016) and produce next generation scientists and researchers firmly grounded in the discipline. Harthorn (2010) has noted that women are less familiar with nanotech, less enthusiastic about it, and less willing to tolerate nano-related risk. One method of increasing students' motivation to pursue nanotechnology as a field of study or career is to provide opportunities for awareness and exposure to it (nanotechnology). Because of the growing demand for nanotechnology experts, it is clear that many students are needed. In order to satisfy the pipeline requirements for a trained workforce, it is critical to determine if the programs or courses put in place have an effect on students' awareness, exposure, and motivation to study nanotechnology. In the present study, the researcher assesses gender differences in nanotechnology awareness, exposure and motivation among physics undergraduates, believing that the study would contribute towards promoting NSNT as a next generation topic for undergraduates.

## Statement of the Problem

The need to raise students' awareness, exposure and motivation about Nanotechnology (NT) has been assessed in a variety of studies. Ban & Kocijancic (2011) highlighted the need to integrate nanotechnology into educational system to enhance students' motivation and interest. Khan (2016) stressed the importance of promoting students' awareness and understanding of nanotechnology to prepare them for future careers. Mammino (2012) argued that educational programs should focus on raising student' awareness and interest in nanotechnology to address the shortage of skilled professionals in the field.

However, none of these researchers probed into the expertise of the level of awareness, exposure and motivation on Nanotechnology among physics undergraduate, particularly in relation to gender differences. Nigeria a developing country should not be left behind in the field of Nanoscience and Nanotechnology Education at the undergraduate level. The undergraduate physics students' awareness of, exposure to and motivation for Nanotechnology and its disciplinary perspective becomes highly necessary. This study aims to investigate the disparities in nanotechnology awareness, exposure and motivation between male and female undergraduate Physics student in Oyo state, there by contributing to the development of more effective strategies for promoting nanotechnology education.

## Objective of the Study

The objectives of this research are to determine the:

1. influence of gender on physics undergraduates' awareness of nanotechnology;
2. influence of gender on physics undergraduates' exposure to nanotechnology;
3. influence of gender on physics undergraduates' motivation for nanotechnology;

## Research Hypotheses

These hypotheses are formulated for the study.

$H_{01}$: Awareness level of Nanotechnology is independent of gender of respondents

$H_{02}$: Exposure level to Nanotechnology is independent of gender of respondents

$H_{03}$: Motivation level for Nanotechnology is independent of gender of respondents

## Research Methodology

This study is a descriptive survey that assessed gender differences in nanotechnology awareness, exposure and motivation among physics undergraduates.

The population of the study consisted of all physics undergraduates of Ekiti State University affiliated with Emmanuel Alayande College Education, Oyo, Oyo State during the 2022/2023 academic session. The study made use of all the twenty-one (21) 100-level students comprising twelve males and nine females, all thirteen (13) 200-level students comprising six males and seven females, all twenty-three (23) 300-level students comprising fifteen males and eight females, all twenty-seven (27) 400-level students comprising fourteen males and thirteen females, making a total of eighty-four (84) respondents comprising forty-seven males and thirty-seven females.

A designed questionnaire titled Nano-Awareness, Exposure, and Motivation Questionnaire (NAEMQ) was used as instrument to collect information from the respondents. The questionnaire consisted of two parts. The first part consisted of personal and demographic information which include gender and academic level in the institution while the second part investigated physics undergraduates' awareness of, exposure to and motivation for Nanotechnology. The responses were rated on a five-point Likert- type scale. A five-point Likert scale type of strongly agree, agree, neutral, disagree, and strongly disagree was employed to obtain responses of respondent. The option assigned in numerical weight are 5,4,3,2 and 1 for strongly agree, agree, neutral, disagree, and strongly disagree respectively. The mean of the rating scale was computed and yielded (3) which was used for taking decision. Any mean below the mean of (3) was rejected while items with mean of (3) and above were accepted. Also, research hypothesis was approached using chi-Square test of Association and independence

The Questionnaire was subjected to peer-review by professionals to ascertain its validity while Cronbach Alpha reliability method was used to ascertain the reliability of the instrument and this yielded a reliability coefficient of 0.82. The reliability of items of questionnaire examined for second part was 0.82 affirming the instrument is reliable.

Permission and approval were sought from the head of Physics department of the College of the above aforementioned institution for the personal administration of the questionnaire. The instrument was administered to the respondents personally by the researcher and he waited for immediate collection.

The data collected were analyzed using frequency counts, and simple percentages for the demographic variables while the data collected for each item in section B of the questionnaire were coded and analyzed using descriptive statistic mean.

## Result and Discussion of Findings

**Table 1: Physics undergraduates' awareness level of nanotechnology.**

| S/N | ITEMS<br>I can: | SA | A | N | D | SD | Mean | Decision |
|---|---|---|---|---|---|---|---|---|
| 1 | Name a Nano scale-sized object. | 59 (70.2%) | 13 (15.5%) | 9 (10.72%) | 2 (2.38%) | 1 (1.2%) | 4.51 | Accepted |
| 2 | Describe one way nanotechnology directly impacts my life. | 15 (17.9%) | 27 (32.14%) | 27 (32.14%) | 9 (10.71%) | 6 (7.14%) | 3.43 | Accepted |
| 3 | Name a field of study that currently conducts Nanotechnology research. | 38 (45.23%) | 13 (15.5%) | 17 (20.23%) | 11 (13.1%) | 5 (5.95%) | 3.81 | Accepted |
| 4 | Describe one-way nanotechnology may benefit Society/ humankind. | 13 (15.5%) | 22 (26.2%) | 13 (15.5%) | 24 (28.6%) | 12 (14.28%) | 3.00 | Accepted |
| 5 | Name an application of nanotechnology. | 36 (42.9%) | 13 (15.5%) | 14 (16.6%) | 12 (14.3%) | 9 (10.7%) | 3.65 | Accepted |
| 6 | Describe a process to manufacture objects at the Nano-scale. | 16 (19.05%) | 14 (16.6%) | 27 (32.14%) | 17 (20.23%) | 10 (12%) | 3.11 | Accepted |

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|---|---|---|---|---|---|---|---|---|
| 7 | Name an instrument used to make measurements at the Nano-scale. | 39 (46.43%) | 8 (9.5%) | 12 (14.3%) | 14 (16.6%) | 11 (13.1%) | 3.60 | Accepted |
| 8 | Describe one-way nanotechnology may directly impact my life in the future | 23 (27.38%) | 11 (13.1%) | 14 (16.6%) | 18 (21.42%) | 18 (21.42%) | 3.04 | Accepted |

The results in Table 1 show that physics undergraduates possess a generally positive awareness of nanotechnology, as all the mean scores were above the acceptance benchmark of 3.00. The highest awareness was recorded in the ability to name nanoscale objects (Mean = 4.51) and applications of nanotechnology (Mean = 3.65), indicating that students are familiar with basic concepts and examples. They also demonstrated reasonable awareness of fields of research (Mean = 3.81) and instruments used for nanoscale measurements (Mean = 3.60). However, weaker awareness was observed in describing societal benefits (Mean = 3.00), nanomanufacturing processes (Mean = 3.11), and future impacts of nanotechnology on their lives (Mean = 3.04). This suggests that while the undergraduates have a fair conceptual understanding, their knowledge is largely superficial, with limited ability to connect nanotechnology to real-life applications, societal development, and future implications.

**Table 2: Physics undergraduates' exposure level to nanotechnology.**

| S/N | ITEMS<br>I have: | SA | A | N | D | SD | Mean | Decision |
|---|---|---|---|---|---|---|---|---|
| 1. | Heard the term nanotechnology | 39 (46.4%) | 10 (11.9%) | 20 (23.8%) | 7 (8.3%) | 8 (9.5%) | 3.77 | Accepted |
| 2. | Read something a bout Nanotechnology | 18 (21.4%) | 17 (20.2%) | 27 (32.1%) | 12 (14.3%) | 10 (11.9%) | 3.25 | Accepted |
| 3. | Watched a program about nanotechnology | 27 (32.1%) | 14 (16.7%) | 15 (17.9%) | 16 (19.0%) | 12 (14.3%) | 3.33 | Accepted |
| 4. | Had one or more instructors/ teachers talk about nanotechnology in class | 21 (25.0%) | 16 (19.0%) | 23 (27.4%) | 15 (17.9%) | 9 (10.7%) | 3.29 | Accepted |

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|---|---|---|---|---|---|---|---|---|
| 5. | Participated in an activity involving nanotechnology (lab, project) | 22 (26.2%) | 20 (23.8%) | 18 (21.4%) | 18 (21.4%) | 6 (7.1%) | 3.40 | Accepted |
| 6. | Taken a class about nanotechnology | 28 (33.3%) | 15 (17.9%) | 15 (17.9%) | 16 (19.0%) | 10 (11.9%) | 3.42 | Accepted |

The results in Table 2 reveal that physics undergraduates have a generally moderate level of exposure to nanotechnology, with all items scoring above the acceptance benchmark of 3.00. The highest exposure was reported in simply hearing the term nanotechnology (Mean = 3.77), showing that students are broadly familiar with the concept at a surface level. However, fewer students had read about nanotechnology (Mean = 3.25) or heard instructors discuss it in class (Mean = 3.29), indicating limited integration of the subject into formal coursework. Exposure through media such as programs or documentaries was also modest (Mean = 3.33). More encouragingly, some undergraduates reported hands-on experiences, such as participating in nanotechnology-related laboratory or project activities (Mean = 3.40), and a number had taken dedicated classes in nanotechnology (Mean = 3.42). Overall, the findings suggest that while students are aware of nanotechnology, their exposure remains uneven and largely introductory, with stronger emphasis on general familiarity than on structured academic or practical engagement.

Table 3: Physics undergraduates' motivation level for nanotechnology.

| S/N | ITEMS I plan to: | SA | A | N | D | SD | Mean | Decision |
|---|---|---|---|---|---|---|---|---|
| 1. | Read a fiction story about nanotechnology. | 43 (51.2%) | 15 (17.9%) | 9 (10.7%) | 11 (13.1%) | 6 (7.1%) | 3.93 | Accepted |
| 2. | Formally teach nanotechnology concepts (e.g., as a teaching assistant). | 14 (16.7%) | 17 (20.2%) | 31 (36.9%) | 17 (20.2%) | 5 (6.0%) | 3.21 | Accepted |
| 3. | Investigate the implications of nanotechnology. | 27 (32.1%) | 20 (23.8%) | 18 (21.4%) | 10 (11.9%) | 9 (10.7%) | 3.55 | Accepted |
| 4. | Informally/casually teach someone something about nanotechnology. | 20 (23.8%) | 17 (20.2%) | 20 (23.8%) | 19 (22.6%) | 8 (9.5%) | 3.26 | Accepted |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5. | Seek information about internships or Co-op experiences with companies engaged in nanotechnology. | 13 (15.5%) | 18 (21.4%) | 13 (15.5%) | 14 (16.7%) | 26 (31.0%) | 2.74 | Rejected |
| 6. | Read a news story or popular magazine article about nanotechnology. | 44 (52.4%) | 9 (10.7%) | 13 (15.5%) | 11 (13.1%) | 7 (8.3%) | 3.85 | Accepted |
| 7. | Give a presentation related to nanotechnology to an audience I perceive as having more experience with nanotechnology than I. | 20 (23.8%) | 17 (20.2%) | 29 (34.5%) | 12 (14.3%) | 6 (7.1%) | 3.39 | Accepted |
| 8. | Read a research journal article about nanotechnology. | 33 (39.3%) | 14 (16.7%) | 15 (17.9%) | 14 (16.7%) | 8 (9.5%) | 3.56 | Accepted |
| 9. | Enroll in a course about nanotechnology. | 17 (20.2%) | 16 (19.0%) | 14 (16.7%) | 24 (28.6%) | 13 (15.5%) | 3.00 | Accepted |
| 10. | Attend a non-course related seminar about nanotechnology. | 18 (21.4%) | 25 (29.8%) | 17 (20.2%) | 14 (16.7%) | 10 (11.9%) | 3.32 | Accepted |
| 11. | Visit an industry or business that specializes in nanotechnology. | 17 (20.2%) | 11 (13.1%) | 23 (27.4%) | 23 (27.4%) | 10 (11.9%) | 3.02 | Accepted |
| 12. | Give a presentation related to nanotechnology to an audience I perceive as having less experience with nanotechnology than I. | 31 (36.9%) | 11 (13.1%) | 16 (19.0%) | 19 (22.6%) | 7 (8.3%) | 3.47 | Accepted |

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|---|---|---|---|---|---|---|---|---|
| 13. | Watch a program about nanotechnology. | 21 (25.0%) | 12 (14.3%) | 19 (22.6%) | 23 (27.4%) | 9 (10.7%) | 3.15 | Accepted |
| 14. | Apply or interview for a nanotechnology related work or research experience. | 26 (31.0%) | 16 (19.0%) | 17 (20.2%) | 16 (19.0%) | 9 (10.7%) | 3.40 | Accepted |
| 15. | Investigate fields of study in which I can learn more about nanotechnology. | 26 (31.0%) | 17 (20.2%) | 13 (15.5%) | 17 (20.2%) | 11 (13.1%) | 3.35 | Accepted |
| 16. | Obtain a work experience or undergraduate research opportunity related to nanotechnology. | 27 (32.1%) | 13 (15.5%) | 12 (14.3%) | 22 (26.2%) | 10 (11.9%) | 3.29 | Accepted |

The findings in Table 3 show that physics undergraduates display an overall positive motivation toward nanotechnology, though the intensity of motivation varies. The highest motivation was seen in activities such as reading fiction stories (Mean = 3.93) and news or popular magazine articles (Mean = 3.85), suggesting that students prefer accessible, informal sources of knowledge. Similarly, a fair number expressed motivation to read research journals (Mean = 3.56) and investigate the broader implications of nanotechnology (Mean = 3.55). In contrast, motivation was weakest for career-oriented engagements such as seeking internships (Mean = 2.74), visiting industries (Mean = 3.02), or enrolling in formal courses (Mean = 3.00). These results indicate that while undergraduates are eager to explore nanotechnology at an introductory and conceptual level, their motivation for structured academic or professional involvement is comparatively low, likely due to limited opportunities, lack of confidence, or perceived difficulty.

## Testing of Hypothesis

### Hypothesis One

$H_{01}$: Awareness level of Nanotechnology is independent of Gender of respondents

Table 4: Impact of gender of respondent on awareness level of Nanotechnology

Chi-Square Tests

| | Value | Df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 3.580a | 4 | .466 |
| Likelihood Ratio | 4.324 | 4 | .364 |
| Linear-by-Linear Association | .437 | 1 | .509 |
| N of Valid Cases | 84 | | |

a. 6 cells (60.0%) have expected count less than 5. The minimum expected countis .88.

Decision 1

The Pearson Chi Square value of 3.580 which is less than the tabulated Chi-square at 4 degrees of freedom, and the Asymptotic significant 2-sided value of 0.466 which is greater than the alpha value (0.05), both suggested the rejection of the null hypothesis and it was concluded that Awareness level of Nanotechnology is dependent of gender

**Hypothesis Two**

$H_{02}$: Exposure level to Nanotechnology is independent of Gender of respondents

Table 5: Impact of gender of respondent on exposure level to Nanotechnology

Chi-Square Tests

| | Value | Df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 4.724a | 4 | .317 |
| Likelihood Ratio | 5.480 | 4 | .241 |
| Linear-by-Linear Association | .194 | 1 | .660 |
| N of Valid Cases | 84 | | |

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .88.

Decision 2

The Pearson Chi Square value of 4.724 which is less than the tabulated Chi-square at 4 degrees of freedom, and the Asymptotic significant 2-sided value of 0.317 which is greater than the alpha value (0.05), both suggested the rejection of the null hypothesis and it was concluded that Exposure level to Nanotechnology is dependent of gender of respondents.

**Hypothesis Three**

$H_{06}$: Motivation level for Nanotechnology is independent of Gender of respondents

Table 6: Impact of gender of respondent on motivation level for Nanotechnology
Chi-Square Tests

| | Value | Df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 3.846a | 3 | .279 |
| Likelihood Ratio | 4.230 | 3 | .238 |
| Linear-by-Linear Association | .010 | 1 | .922 |
| N of Valid Cases | 84 | | |

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is .44.

Decision 3

The Pearson Chi Square value of 3.846 which is less than the tabulated Chi-square at 3 degrees of freedom, and the Asymptotic significant 2-sided value of 0.279 which is greater than the alpha value (0.05), both suggested the rejection of the null hypothesis and it was concluded that Motivation level for Nanotechnology is dependent of gender of respondents.

Discussion of findings

This finding revealed that the participants have good awareness level of Nanotechnology and the level of awareness is dependent on their gender. This result is consonant with the submission of Adegboyega et al (2023) who studied determinants of awareness levels of physics teachers about nanoscience and nanotechnology (NSNT) in senior secondary schools and concluded that majority of the participants have awareness about Nanoscience and Nanotechnology. Also, the result is not in agreement with Adegboyega et al (2023) who stated that the level of awareness of the physics teachers was independent of their gender. This is also contradicted the submission of Gana et al., (2020) that science educators in science and technical schools are not aware of Nanoscience and Nanotechnology (NSNT). The finding of the study is concurrence with that of Ahmed et al., (2015) who examined the level of awareness and the attitude towards Nanotechnology (NT) among students and teachers of some higher Educational institutions of Islamabad, Pakistan and revealed a high level of awareness about Nanoscience and Nanotechnology both among teachers and students.

The finding of this showed that the participants have good exposure level to Nanotechnology and the level of exposure is dependent on their gender. Public surveys of exposure to nanotechnology do reveal that men and women have very different exposure towards the risks and benefits associated with nanotechnology. Harthorn (2010) has noted that women are less familiar with nanotech, less enthusiastic about it, and less willing to tolerate nano-related risk.

Another finding of this study revealed that the participants have good motivation level for Nanotechnology and the level of motivation is dependent on their gender. This result aligns with the submission of Khosrava & Khusro (2021) that students and researchers are highly motivated to pursue studies in nanotechnology due to its interdisciplinary nature and the promising career opportunities it offer.

## Conclusion

From the findings of this study, it could be concluded that physics undergraduates have good awareness of, exposure to, and motivation for nanotechnology, and that level of awareness of, exposure to, and motivation for nanotechnology was dependent on the gender of the respondents.

## Recommendations

Based on findings, it is recommended that:

i. Physics education programs should capitalize on the existing awareness, exposure, and motivation of undergraduate students towards nanotechnology, and enhance their curriculum to include more nanotechnology-related content, particularly in areas where gender disparities were identified.
ii. Educators and policymakers should develop targeted strategies to address the gender-dependent disparities in awareness, exposure and motivation for nanotechnology, ensuring equal opportunities for all students to engage with this field
iii. Further studies should be conducted to explore the underlying reasons for the gender-dependent disparities and to identify effective interventions to promote gender inclusivity in nanotechnology education.
iv. Universities and institutions should provide resources and support to encourage students, especially those from underrepresented groups, to pursue nanotechnology-related research and career paths.

## References

Adegboyega, O., Oladejo, O. P., & Amusat, T. A. (2023). Determinants of Awareness Levels of Physics Teachers about Nanoscience and Nanotechnology (NSNT) in Senior Secondary Schools: Oyo Educational Zone Experience. African Scholars Journal of Education Research and Library Practice. 28(8). 1-12 africascholarpublications@gmail.com

Ahmed, T., Imdad, S., Yaldram, K. & Raza, S.M. (2015). Awareness and Attitude about Nanotechnology in Pakistan. Journal of Nano Education. 7(1), 44-51.

Alpat, S. K., Uyulgan, M. A., Şeker, S., Altaş, H. Ş. & Gezer, E. (2017). Effect of cooperative learning on academic achievement and opinions of the 10th grade students in the topic of nanotechnology at secondary level]. İnцnь University Journal of the Faculty of Education, 18(1), 27-57. https://dergipark.org.tr/en/download/article-file/268770

Alqahtani, A. S. (2020). A proposed conception to include the concepts of nanotechnology in the developed mathematics curricular in general education stages. Journal of Nanotechnology Research, 2(1), 1-12.

Andina, R. E., Rahmawati, Y. & Budi, S. (2019). Improved learning designs for shaping Indonesia's future science teachers applied in a nanoscience project. Issues in Educational Research, 29(4), 997-1015. http://www.iier.org.au/iier29/andina.pdf

Ayad, F. I. (2017). Degree awareness of nanotechnology among technology teachers and the impact of a proposed unit on developing cognitive achievement and learning satisfaction among Al-Aqsa University students in Gaza. Al-Aqsa University Magazine, 21(1), 175-217.

Ban, T. & Kocijancic, S. (2011). Nanotechnology and its integration into the educational system. Journal of Technology Education, 22(2), 48-63.

Boras, M. A., Fayza, M. M. & Haroun A. A. (2018): The importance of applying nanotechnology in renewable energies to achieve sustainable development, Journal of Human Sciences of Oum El Bouaghi University, 5(2), 555-567.

Darwish, A. H. & Abu, U. H. H. (2018): The level of knowledge of nanotechnology applications among students of faculties of education majoring in science in Gaza universities and their attitudes towards it. Journal of the Islamic University of Educational and Psychological Studies, 26(1), 200-229.

Ekli, E & Sahin, N. (2010). Science teacher and teacher candidates' basic knowledge, opinions and risk perceptions about nanotechnology. Procedia-Social and Behavioral Sciences, 2(2), 2667-2670. https://doi.org/10.1016/j.sbspro.2010.03.392

Gana, S. C., Aji, E. O., & Gimba, R. W. (2020). Awareness of nanoscience and nanotechnology among science teachers in science and technical schools in Federal Capital Territory Abuja, Nigeria. Assumption University-e Journal of Interdisciplinary Research (AU-eJIR), 5 (1), 77 – 84.

Harthorn, B. (2010). Encyclopedia of Nanoscience and Society (ed. Huston, D.) 269-271

Khan, S. (2016). Nanotechnology education: A review of current status. Journal of Nanotechnology Research, 18(2), 1-15.

Khosravi, M., & Khusro, M. (2021). Students' Motivation and Career Choices in Nanotechnology. Journal of Nanoscience and Nanotechnology, 21(5), 2423-2432.

Mammino, L. (2012). Nanotechnology education and training for the workforce. Journal of Nanotechnology Research, 14(1), 1-11.

Paš, M., Vogrinc, J., Raspor, P., Knežević, N. U. & Zajc, J. Č. (2019). Biotechnology learning in Slovenian upper-secondary education: Gaining knowledge and forming attitudes. Research in Science & Technological Education, 37(1), 110-125 https://doi.org/10.1080/02635143.2018.1491473

Roco, M. C. & Bainbridge, W. S. (2005). Societal implications of nanoscience and nanotechnology: Maximizing human benefit. Journal of Nanoparticle Research, 7(1), 1 13. https://doi.org/10.1007/s11051-004-2336-5

Roco, M. C., Mirkin, C. A. & Hersam, M. C. (2011). Nanotechnology research directions for societal needs in 2020: Summary of international study. Journal of Nanoparticle Research, 13(3), 897-919. https://doi.org/10.1007/s11051-011-0275-5

Sagun-Gɯkɯz, B. & Akaygɒn, S. (2013). A bridge connecting high school to university: A nanoscience workshop. Boğaziɜi University Journal of Education, 31(2), 49-72.

Saidi, T. & Sigauke, E. (2017). The use of museum-based science centres to expose primary school students in developing countries to abstract and complex concepts of nanoscience and nanotechnology. Journal of Science Education and

Technology, 26(5), 470- 480. https://doi.org/10.1007/s10956-017-9692-2

Winkelmann, K. & Bhushan, B. (Eds.) (2016). Global perspectives of nanoscience and engineering education. Science Policy Reports: Basel: Springer. https://www.springer.com/gp/book/9783319318325

Yawson, R. (2012): An epistemological framework work for nanoscience and nanotechnology literacy, International Journal of technology and design education, 22(3), 297-310.