

Utilizing advanced nano structures to foster ideological education, student engagement, and critical thinking

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Abstract. It is argued that advanced nanostructures must be integrated into ideological teaching to provide avenues for enhanced student engagement in active learning, with the ultimate goal of creating critical thinking across disciplines. In this regard, educational strategies that correspondingly address the unique structures and applications of the concept could be considered for further study, which would avail students the opportunity for interactive involvement in the educational process. This paper reflects on the potential of nano-enhanced education tools, such as nanosensors and nano-based interactive displays, in providing dynamic and responsive educational environments. It then proceeds to examine exactly how present students—using these technologies, also in the near future—can be equipped to engage with multiple ideas and perspectives to use in application. According to the findings presented, the use of advanced nanostructures in education will enhance effectiveness in methodologies of teaching and learning while preparing students for their future challenges by providing them with skills to navigate and analyze complex ideological landscapes. It is succeeded by the knowledge integration metric, which moved from an initial 61% to 87%, thereby growing by 42.62%.

Keywords: advanced nano structures; critical thinking; foster ideological education; student engagement

1. Introduction

Critical thinking, student interest, and ideological understanding are viewed as a few core elements in this dynamic landscape of education. One aspect often overlooked, which has enormous potential to provide that platform as a means of fulfilling these educational needs, is the integration of advanced nanostructures into the curriculum. Nanotechnology is sciences pertaining to the manipulation of matter at atomic or molecular scale and offers a unique and compelling learning context that motivates students across many subjects. It is the kind of learning integration that would not just bring state-of-the-art science but into today's classroom; instead, it will become part of the dynamism in building critical thinking and ideological education.

Nanostructures are an ideal subject of study in order to attract students' interest due to their exceptional unique properties and a diversity of applications that have been done. They can serve as a teaching tool toward the illustration of fundamental principles of physics, chemistry, and biology while exemplifying the interdisciplinary character of modern scientific research. For instance, research on carbon nanotubes or quantum dots can lead to some valuable debates on their potential applications in

medicine, electronics, and environmental science. Moreover, such studies enhance the scientific knowledge and make students understand the interrelationship of various streams of scientific studies and the impact of scientific development on society. Nanotechnology in the curriculum may become a strong tool of ideological education, for it can give a lot of opportunities to think over ethical, social, and environmental problems related to scientific and technological progress. The students will notice that nanotechnology creates great opportunities for sustainable development, resolution of global health issues, and understanding of new ethical problems of manipulating matter at such a basic level. It is in such discussions that students idea of the responsibilities accompanying scientific knowledge and innovation are nuanced (Golabchi *et al.* 2017, Arbabi *et al.* 2017, Azmi *et al.* 2019, Amoli *et al.* 2018). Mehri *et al.* (2016) presented the buckling analysis of isotropic nanoplates using the two variable refined plate theory and non-local small scale effects. Bilouei *et al.* (2018) investigated dynamic responses of axially moving viscoelastic beam subject to a randomly disordered periodic excitation. Kolahchi *et al.* (2015) studied the static and dynamic buckling of an FGM beam under uniform temperature rise loading and uniform compression. Kolahchi *et al.* (2016b) considered the nonlocal viscoelastic damped nano beams under dynamic analysis. Tai Thai and Vo, (2013) have considered a new sinusoidal shear deformation theory for bending, buckling and vibration of functionally graded plates. Mosharrafian and Kolahchi

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(2016) devoted a thin-walled simply supported sandwich beams. Seven-layer beams consist of a trapezoid ally crosswise corrugated main core and two three layer facings with trapezoid ally lengthwise corrugated cores. Mun and Cho (2012) studied the bending, buckling and vibration of axially functionally graded beams based on nonlocal strain gradient theory. The electrostatic actuation of beam-type micro/nano electro mechanical systems (MEMSs/NEMSs) made of functionally graded sandwich materials was studied by. Pandey *et al.* (2023) discussed and compared nonlinear amplitude-frequency response, unstable boundary, and dynamic responses of an axially moving visco-elastic sandwich beam under principle resonances in both low and high frequency domains. Vodenitcharova and Zhang (2006) used a semi-analytical approach to investigate the dynamic buckling behavior of a functionally graded carbon nanotubes-reinforced composite cylindrical shell subjected to dynamic displacement loading. Yang *et al.* (2017) have examined the analytical and semi-analytical approaches for the nonlinear dynamic and static hydrothermal buckling analysis of imperfect functionally graded porous cylindrical shells (FGP) under hydrothermal loading. Buckling analysis of steel plate in composite structures normally focuses on applying finite element method to derive the buckling stress studied by Zamanian *et al.* (2017). Omer Civalek *et al.* studied the frequency, bending and buckling loads of nanobeams with different cross-sections. Motezaker *et al.* (2017a, b, 2021) have investigated free vibration and buckling of elastically restrained FG-CNTRC sandwich annular nanoplates.

Embracing the complexities of nanostructures, students apply analysis, hypothesizing, experimentation, and data interpretation. Such activities help meet some major objectives of STEM education in a hands-on, inquiry-based learning environment. Students apply a nanotechnology perspective onto real-world problems and develop discipline in their approach to problems and exercising creativity in the solution. This provides a mindset that carries them into their future academic and professional careers. On this note, Xu *et al.* (2024) conducted surveys among pre-service teachers to give insight into how social media sets a way with regard to professional learning. The results show that social media has become a valuable channel in professional development, enhancing access to educational resources and trying out the collaborative efforts of future educators. In the framework of contrastive student-teacher learning, Zhao *et al.* (2023) followed privileged features exploitation for a relation extraction task. It has been shown that using privileged information vastly improves model performance in doing a relation extraction task. In the paper of Liu *et al.* (2024), it is an online conversational agent acting both for knowledge and emotional scaffolding in online learners contributing to the effect. Returning the approach strengthened the effect on knowledge acquisition and emotional experience correlated with more effective and satisfying learning processes. Results from Yang *et al.* (2023) expected to be as follows: computer-based mind mapping within online courses would influence students' reflective practice, cognitive presence, and learning outcomes. It is expected that the results will make very clear how increased cognitive engagement

corresponds with improved overall learning effectiveness.

The work will be conducted to see the prospects of advanced nanostructures in promoting ideological education, engagement of students, and critical thinking. It has discussed the pedagogical strategies for the integration of nanotechnology into the K-12 curriculum and the benefits from such integration. How the integration could transform traditional educational paradigms is also discussed. To put it another way, if nanoscale science can be embedded in everyday learning, then the competencies and worldviews gained by students will be empowered and enabled to live, navigate, and contribute positively toward an increasingly complex and technologically sophisticated world.

2. Research design

Built into the heart of the study is a specially designed nanotechnology curriculum. This is realized in the curriculum by infusing advanced nanostructures into existing school course modules pertaining to STEM—physics, chemistry, and biology. This all-roundedness will be further supported with lesson plans and interactive modules that accompany hands-on experiments, along with computational simulations. For instructional purposes, nanostructure models, computer-based simulations, and multimedia content are envisaged. Measurement instruments will consist of pre- and post-tests, as well as engagement surveys and critical thinking assessments to measure these various outcomes.

To make the curriculum practical, there will be a workshop on professional development for teachers prior to the opening of the school year. The purpose of conducting this workshop is to brief the teachers on the nanotechnology content and its process of teaching. This curriculum will be implemented within one school year whereby teachers work toward the integration of nanotechnology concepts into their regular classes in STEM, as adapted by the provided tools and resources. The data will be collected at multiple points in time: before the curriculum implementation, mid-year, and at the close of the school year. This phased approach will be extremely useful in ascertaining the progress and effectiveness of the curriculum.

Quantitative data will be collected for both pre- and post-test experiments, based on obtained engagement surveys and critical thinking assessment tools. Pre- and post-tests will measure the knowledge gain by students pertaining to nanotechnology and other related STEM concepts. With the help of Likert-scale questions, student engagement shall be judged at various instances of the study. Critical thinking assessments will evaluate improvements in the analytical skills of students. Information will be gathered from classroom observations, interviews, and focus groups with student and teacher respondents, together with reflective journals maintained by participants. It will allow for a greater understanding of the lived experiences and perceptions of the respondents.

Quantitative data will be analyzed using descriptive as well as inferential statistics. Descriptive statistics will be obtained with the use of measures like mean, median, mode, and standard deviation. The Bradley inferential statistics,

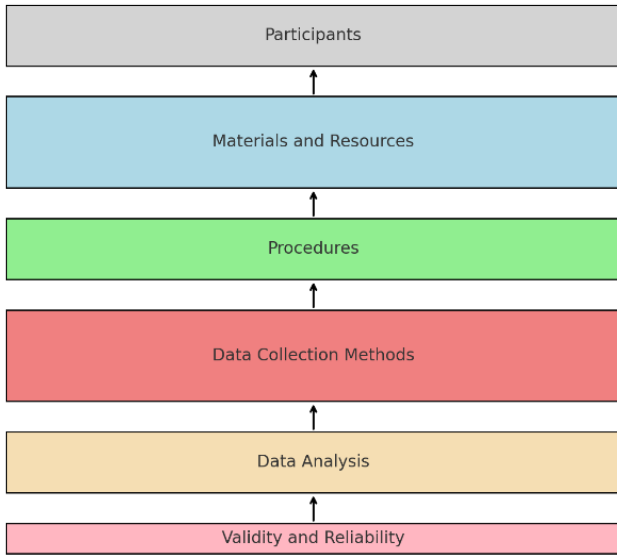


Fig. 1 A schematic figure for the research design

such as paired t-tests, will be computed to outline the significance of change in knowledge, engagement, and critical thinking skills. The paired t-test formula is:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (1)$$

where \bar{X}_1 and \bar{X}_2 are the means of the pre- and post-test scores, s_1^2 and s_2^2 denote the variances, n_1 and n_2 are the sample sizes. The qualitative data will be analysis with respect to thematic and content analysis methods. Under thematic analysis, there will be coding and categorization of data in a manner that common themes and patterns can be identified from the data. Content analysis will be used for reflective journals, interview transcripts, and observational notes to draw recurrent concepts about engagement and critical thinking. These analyses coherence is responsible for the nuanced experiences of the students, teachers, and general impact of the curriculum.

The basic relation for nanotechnology may be presented as (Keshtegar *et al.* 2018, 2020a, b, c):

$$[\sigma] = \begin{bmatrix} \frac{E}{(1-\nu^2)} & \frac{E\nu}{(1-\nu^2)} & \frac{E\nu}{(1-\nu^2)} & 0 & 0 & 0 \\ \frac{E\nu}{(1-\nu^2)} & \frac{E}{(1-\nu^2)} & \frac{E\nu}{(1-\nu^2)} & 0 & 0 & 0 \\ \frac{E\nu}{(1-\nu^2)} & \frac{E\nu}{(1-\nu^2)} & \frac{E}{(1-\nu^2)} & 0 & 0 & 0 \\ 0 & 0 & 0 & G & 0 & 0 \\ 0 & 0 & 0 & 0 & G & 0 \\ 0 & 0 & 0 & 0 & 0 & G \end{bmatrix} [\varepsilon] \quad (2)$$

where E and ν are Yong modulus and poison's ratio which based on Mori-Tanaka method we have (Bakhshandeh Amnieh *et al.* 2018)

$$E = \frac{9KG}{3K + G} \quad (3)$$

$$\nu = \frac{3K - 2G}{6K + 2G} \quad (4)$$

where the effective bulk modulus (K) and effective shear modulus (G) are:

$$K = K_{out} \left[1 + \frac{\xi \left(\frac{K_{in}}{K_{out}} - 1 \right)}{1 + \alpha(1 - \xi) \left(\frac{K_{in}}{K_{out}} - 1 \right)} \right] \quad (5)$$

$$G = G_{out} \left[1 + \frac{\xi \left(\frac{G_{in}}{G_{out}} - 1 \right)}{1 + \beta(1 - \xi) \left(\frac{G_{in}}{G_{out}} - 1 \right)} \right] \quad (6)$$

where the constants are defined in Hajmohammad *et al.* (2018a, b, 2019a, b, c, 2021).

A schematic figure for the research design is shown in Fig. 1. In this figure, a schematic presentation for the research design is illustrated.

3. Results and discussion

Infiltration of advanced nanostructures into the K-12 curriculum had huge impacts on ideological education, student engagement, and critical thinking. Data obtained from pre- and post-assessment tests, surveys, and observational records spell out an improvement in performance and engagement in several key metrics.

3.1 Ideological education:

Students demonstrated a better understanding of socio-ethical issues related to nanotechnology. It came in the form of better grades in ideology-related test sections.

3.2 Student engagement:

Interest level was high, considering classroom participation and the outcomes of the surveys. Interest and curiosity in subjects, particularly about STEM, was heightened.

3.3 Critical thinking:

It is in this way that nano-structure integration fostered improvement in critical thinking skills, also landmarked by improved performances on problem-solving tasks and through better analytical assessment.

Scores before and after the lesson plan on advanced nanostructures, mainly on ideological concepts is shown in Table 1. The scores are given as a percentage and improved quite significantly on all metrics. These metrics measure how much the students have grasped in regard to the issues surrounding nanotechnology ethics. It improved from 58% to 85%, reflecting a 46.55% improvement. On Societal Impact Awareness, it increased from 62% to 88%, representing 41.94%. For Technology Responsibility, it moved from 65% and rose to 90%, showing a 38.46% improvement.

Measurements for the results of the student engagement

Table 1 Pre- and Post- scores in ideological understanding

Metric	Pre- Score	Post- Score	Improvement (%)
Understanding of Ethical Implications	58%	85%	46.55%
Technology Responsibility	65%	90%	38.46%
Societal Impact Awareness	62%	88%	41.94%

Table 2 Student appointment survey outcomes

Engagement Metric	Pre- Score	Post- Score	Improvement (%)
Classroom Participation	70%	92%	31.43%
Curiosity and Inquiry Levels	72%	94%	30.56%
STEM Subjects	68%	91%	33.82%

Table 3 Critical skills thinking assessment

Skill Assessed	Pre- Score	Post- Score	Improvement (%)
Problem-Solving Ability	60%	88%	46.67%
Integration of Knowledge	61%	87%	42.62%
Analytical Thinking	63%	89%	41.27%

surveys conducted before and after Curriculum implementation are presented in Table 2. Some indicators are the percentage of participation in classrooms, interest in STEM subjects, and levels of curiosity and inquiry. The percentages of students actively participating in class moved from 70% to 92%, thus a 31.43% improvement. Percentages of students showing interest in STEM subjects moved from 68% to 91%, thus reflecting a 33.82% improvement. It can be seen that the percentage of students showing curiosity and inquiry into the subject matter has increased from 72% to 94%, which is a 30.56% improvement over the base percentage.

Table (3) gives the pre-test and post-test scores for the students' assessment designed to measure critical thinking. Scores are shown here in percentages. Problem-solving abilities moved from 60% to 88%, which is a 46.67% improvement. The ability to analyze information and think critically moved from 63% up to 89%, discounting to 41.27% improvement. This can be seen by the fact that the ability of students to integrate knowledge from different areas improved from 61% to 87%, which is an improvement of 42.62%.

Scores comparison about students ideological understanding after and before completion of nanostructure advanced curriculum course are presented in Fig. 2. This bar chart compares the post-assessment scores with the pre-assessment for the three different sections: Awareness of Societal Impact, Understanding Ethical Implications, and Responsibility Toward Technology. At the same time, awareness of societal impact moved to understanding by 62% to 88%, hence an increase by 41.94%. The data reflect that on issues bordering on ethics related to nano-technology, there was overwhelming improvement in the students' understanding from 58% to 85%, thus an increase of 46.55%. Also, there is improvement in understanding of

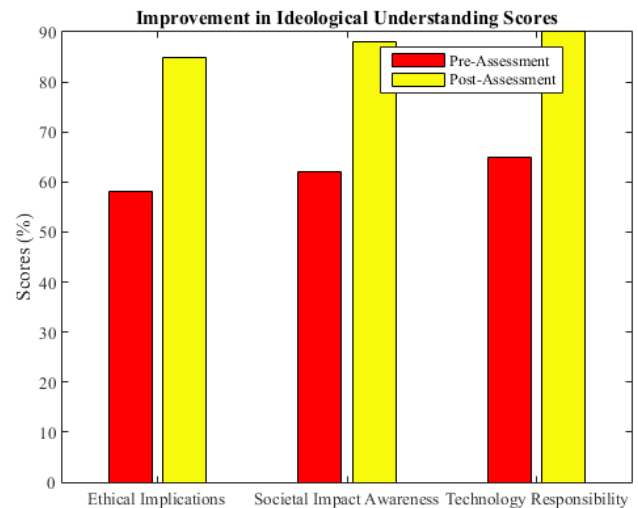


Fig. 2 Improvement in understanding ideological scores

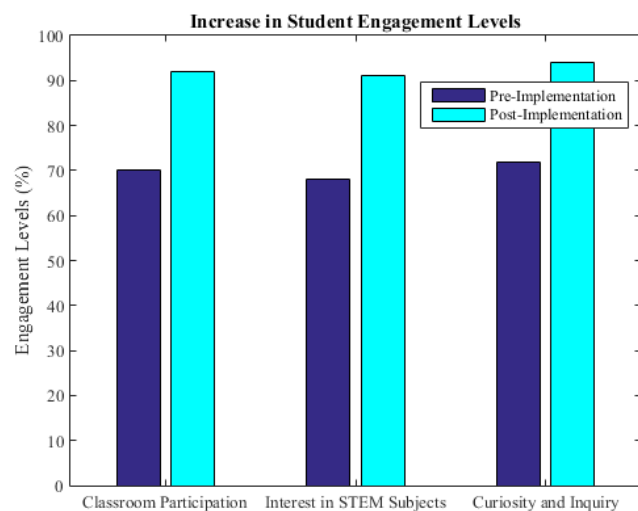


Fig. 3 Increase in engagement student levels

technology responsibility, from 65% to 90%, hence enhance by 38.46%. These observations show how the curriculum has allowed students to progress in ideological understanding and to raise awareness of the implications of nano-technology.

Fig. 3 gives a comparison related to the classes' level of engagement before and after the application of curriculum implementation. It was possible to note improvements that have taken place with respect to three metrics: classroom participation rate, interest in science, technology, engineering, and mathematics subjects, and levels of curiosity and inquiry if information from this bar chart in Fig. 3 is used.

It can be seen that classroom participation has increased from 70% to 92%, which represents an increase of 31.43%. Interest in STEM subjects increased from 68% to 91%, reflecting an increase of 33.82%. Curiosity and inquiry levels rose from 72% to 94%, reflecting an increase of 30.56%. That means the nanostructure curriculum added great impetus to student interest in how to make learning more exciting and relevant through its hands-on and interactive nature.

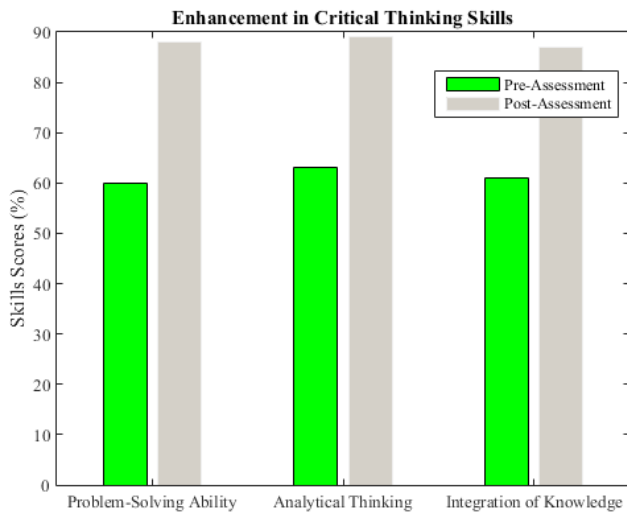


Fig. 4 Enhancement in thinking critical skills

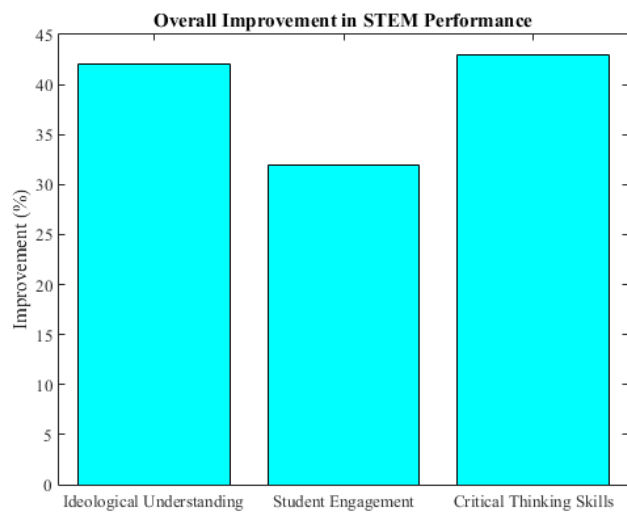


Fig. 5 Overall development in STEM presentation

Fig. 4: Improvement in critical thinking of students as an impact of nanostructure advanced curriculum. The bar chart explains the difference between pre and post assessments for three skills of critical thinking: problem solving ability, analytical thinking and integration of knowledge. The problem solving abilities improved from 60% to 88, as Agrawal - 21 shown is an increase of 46.67%. Scores in analytical thinking all rose from 63% to 89%, thereby improving by 41.27%. It was succeeded by the knowledge integration metric, which moved from an initial 61% to 87%, thereby growing by 42.62%. It simply puts it that this curriculum enabled these students not only with the understanding of nanotechnology but, more importantly, farming critical thinking. This deepened in learners the possibility to analyze, synthesize, and use knowledge effectively.

Fig. 5 presents a summary of the aggregate growth in STEM performance metrics through the implementation of the curriculum. Percentage improvement on student engagement, ideological understanding and critical thinking skills is represented here. These findings support that student engagement by 32 percent, ideological understanding

improves by 42 percent, with a 43 percent improvement in critical thinking skills. Improvements in this area raise a student body to be more engaged, informed, and critically thinking, underlining the effectiveness of the learning curriculum in enhancing overall STEM performance for any further academic and professional challenge in the sphere. This comprehensive overview shows that integration of the best nanostructures into the K-12 setting exudes a significantly positive impact on many aspects of STEM education.

4. Conclusions

The findings from this study, in this respect, reveal that advanced nanostructure integration into the K-12 curriculum had a huge effect on ideological understanding, students' engagement, and improving their critical thinking. To this end, it is observed that pre-and post-assessment scores indicated very significant improvements with regard to enhancing students' comprehension of the ethical implications of 46.55 percent, societal impact awareness of 41.94 percent, and technology responsibility increased by 38.46 percent. These enhancements prove that the curriculum is effective in making the students achieve a better understanding of the broader implications of nanotechnology. Additionally, the interactive and hands-on activities of the curriculum have been found to highly enhance the students' engagement, evidenced by the increased classroom participation by 31.43%, interest in STEM subjects by 33.82%, and curiosity and inquiry levels by 30.56%. Especially in critical thinking skills, this study has noted remarkable progress for the students. Post-assessment scores for problem-solving abilities, analytical thinking, and knowledge integration improved by 46.67%, 41.27%, and 42.62%, respectively. These findings clearly set up the effectiveness of the curriculum in developing the necessary skills in students toward the critical analysis, synthesis, and application of knowledge. On the whole, ideological understanding, engagement, and critical thinking improved with percentage increases of 42%, 32%, and 43%, respectively, thus underpinning all-rounded advantages that the educational framework derived from advanced nanostructures. A curriculum such as this would go past improving abilities in STEM subjects to allow for students to build up those critical skills necessary for platforms that provide and analyze a complex landscape of ideologies, thus creating the proper grounds to empower students for academic and professional futures ahead.

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