Developing SIPCaR projects utilizing modern technologies: Its impact to students' engagement, R&D skills, and learning outcomes

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Due to the onset of the COVID-19 pandemic, the education sector responded quickly to change the mode of delivering instructions to students in hybrid learning. Since in-school learning is no longer feasible, schools are devising teaching-learning pedagogies that are practical to achieving positive students' learning and quality instruction. This study aims to find out the impact of science investigatory projects, capstone projects, and robotics (SIPCaR) to students' engagement, and research and development (R&D) skills, and learning outcomes. Using purposive sampling and mixed-method research design, results revealed that students were very engaged, their R&D skills and learning outcomes proficiency are highly evident. Students were very cognitively engaged, behaviorally engaged, socially engaged, and moderately emotionally engaged, with means 4.27, 4.16, 4.41, and 3.44, respectively. Their R&D skills consist of analytical skills, information seeking skills, problem-solving skills, communication skills, and methodology skills are proficient with means 4.10, 4.06, 3.80, 4.30, and 3.78, sequentially. The findings of the study prove that, if appropriately implemented, SIPCaR projects open countless opportunities for students to achieve high-level learning outcomes, collaborate and innovate modern technologies that could potentially help emerging societal problems. Despite the challenges posed by the health crisis, STEM educators may formulate activities that result in students' holistic development in a remote classroom setting.

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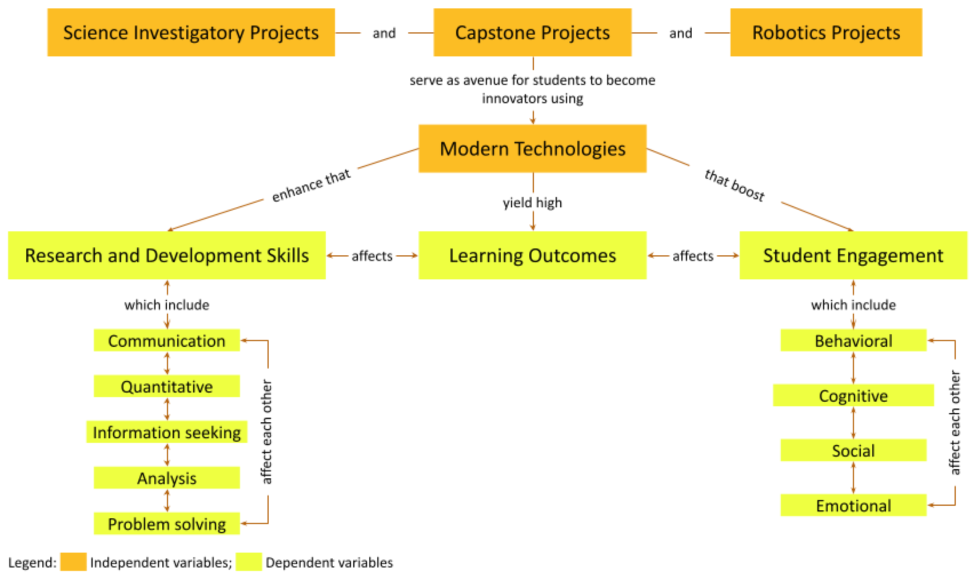


1 Introduction

The Programme for International Student Assessment (PISA) published that Filipino students obtained an average score of 340 points in Overall Reading Literacy, 353 points in Mathematical Literacy, and 357 points in Scientific Literacy. These scores were significantly lower than the OECD average of 487, 489, and 489 points, respectively. Meanwhile, the Philippines ranked last in an assessment for Grade 4 mathematics and sciences in the recent 2019 trends in International Mathematics and Science Study (TIMMS) among the 58 participating countries. The PISA 2018 and TIMMS 2019 results reflect the urgency of improving and furthering the department's effort to uplift the quality of basic education in the Philippines (DepEd, 2019).

The Department of Education (DepEd, 2019) further reiterated its lifelong commitment to ensure and push for education quality by leading this national effort through "Sulong EduKalidad" or advancing the quality of education, whereby implement aggressive reforms in (1) upskilling educators and school leaders through a transformed professional development; (2) review and updating the curriculum; (3) on-going improvement of the learning environment; and (4) multi-stakeholder collaboration.

The enactment of the Enhanced Basic Education Act of 2013 paved the way for allowing every student to receive a globally competitive education based on a pedagogically sound curriculum that is at par with national standards. Through this, DepEd joined PISA for the first time in its 2018 round and welcomed TIMMS 2019 report as a step towards globalizing the quality of Philippine basic education.

With the continuous efforts towards educational quality, yet another challenge arises and pushes the education sector to deliver instructions in the new normal since in-school learning is no longer feasible. With the onset of the COVID-19 pandemic, barriers for effective learning abound - inadequate learning resources, limited teacher scaffolding, vague learning contents, unstable internet connectivity, poor learning environment, related financial problems, and others (Rotas & Cahapay, 2020).

In a paper presented by Buntting (2021), the researcher emphasized that in supporting curricular reforms, the synergistic play between policy, research, learning, and practice development is the critical factor towards successful implementation. Through flexible learning, educational practitioners utilize teaching-learning resources that can be used in any classroom environment, whether face-to-face or remote learning, to continue delivering quality education amidst the health crisis following the policies and guidelines provided by DepEd and with the help of educational stakeholders.

Modern technologies are widely used in the academe nowadays and are often assumed to engage learning in science (Bull & Bell, 2008). However, only a few researches have been conducted to study and investigate students' doing innovative projects using modern technologies on a prototype scale (Petrakis et al., 2021) and its impact on students' engagement in learning, research and development (R&D) skills, learning outcomes, as well as its implications to educational transformation.

1.1 Research questions

Science Investigatory Projects, Capstone, and Robotics (SIPCaR) are avenues where higher-order thinking skills are honed (Alarde et al., 2021a; Sullano et al., 2021), basic research skills are instilled, and science characters are developed (Sanchez & Rosaroso, 2019) in the basic education level. This paper seeks to find out whether doing innovative projects remotely engages students and develops R&D skills. Specifically, this research aimed to answer the following questions:

1. What modern technology projects were developed by the students?
2. What are the levels of students' engagement in doing SIPCaR projects?
3. What are the levels of students' R&D skills in doing SIPCaR projects?
4. What are the levels of students' learning outcomes in doing SIPCaR projects?
5. What challenges did the students encounter in doing SIPCaR projects?

1.2 Significance of the study

A significant goal of this study is to add up to research literature providing relevant and timely findings on how students were engaged cognitively, behaviorally, emotionally, socially, and in general and how research participants self-assessed their R&D skills while doing the science projects.

The results would help educational practitioners to highlight 21st-century learning competencies in the curriculum, provide technical and emotional scaffolding to students, and resolve the challenges encountered in the teaching-learning process in the remote learning environment. If educational gaps are filled in and addressed constructively, these would pave the way for globalizing the quality standards in basic education.

2 Theoretical-Conceptual framework

2.1 Educational Pedagogies used in doing SIPCaR projects

The SIPCaR curriculum is rooted in the conceptual framework of science education in the Philippines' K to 12 Curriculum. The approaches are based on sound educational pedagogies, namely - multi/interdisciplinary approach, science-technology-society (STS) approach or contextual learning, problem/issue-based learning, inquiry-based approach, constructivism, social cognition learning model, learning style theory, and brain-based learning.

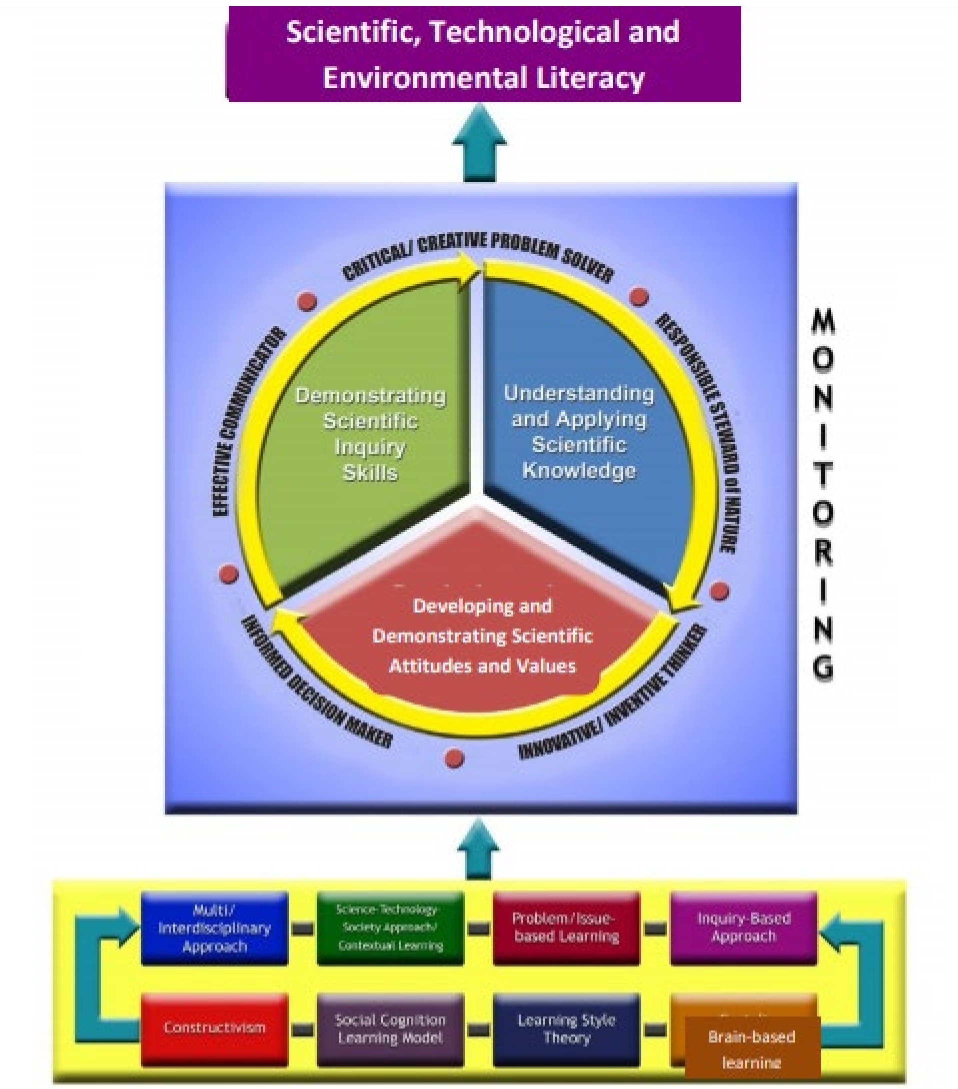


Figure 1. Philippine Science Education Framework, DepEd (2016)

Interdisciplinary teaching is attributed in which teachers of different subject areas are assigned to a specific group of learners who are encouraged to correlate some of their teaching (Vars, 1991), in which a common theme is studied in more than one content area forming thematic units (Barton & Smith, 2000), lessons or units developed across many disciplines with a familiar topic (Jackson & Davis, 2000), and in which the curriculum is collaboratively designed around essential issues that begin with a central theme that arises from questions or societal concerns learners have, without regard to the delineations of the subject (Beane, 1997). As per previous proponents' point of view, this article applies an interdisciplinary approach when students identify the different disciplines involved in problem-solving (i.e., science, technology, engineering, and mathematics) with their proposed innovative science projects.

The constructivist approach is best attributed to how humans make meaning about the interaction between experiences and ideas (Piaget, 1971), how students internalize interaction with adults, more capable peers, and cognitive tools to form mental constructs (Vygotsky, 1987 as cited in Liu & Matthews, 2005; Acut et al., 2016), and to which social or informational environment scaffolds for learning (Bruner, 1961). STS learning approach, brain-based and inquiry-based learning are derived from constructivism theory that highlights the development of the concept in cognitive structure (Primastuti & Atun, 2018), and attaining knowledge becomes more meaningful because STS directly affects their lives (Yuenyong, 2006). Participants in this research constructed their innovative SIPCaR projects guided by the following stages - identification of social issues, identification of a social solution, need for knowledge, decision making, and socialization and completion (Pimvichai, 2019).

Dewey's "learning by doing" principle (1897) was recognized as one of the early proponents of project-based education. Markham (2011) describes PBL where students learn knowledge and elements of the core curriculum and apply what they know to solve authentic problems...which cannot be taught using textbooks but must be activated through experience. In doing SIPCaR projects, students took advantage of digital tools to produce high quality, collaborative outputs. Participants engaged themselves in an investigation and pursued solutions to emerging societal problems.

Among 71 different models of learning styles theory, Kolb's model (1981) is widely credited. As cited in the study of Coffield et al. (2004), knowledge results from the combination of grasping experience and transforming it. Thus, learning is the process where knowledge is created through the transformation of experience. The Science curriculum in the Philippines recognizes the place of science and technology in everyday human affairs (DepEd, 2016). SIPCaR implementation, thus, revolves around these teaching-learning pedagogies to develop students into critical thinkers, independent learners, credible collaborators, and responsible and moral citizens from the safety of their homes. It envisions scientifically, environmentally, and technologically literate students capable of making judgments and decisions about scientific knowledge applications that may have social, environmental, and health repercussions. At the heart of doing SIPCaR is to challenge and engage learners to arouse their curiosity, motivating them to learn and appreciate science and technology as relevant and valuable. Rather than relying solely on textbooks, active learning is emphasized where students are engaged through varied hands-on, minds-on, and hearts-on tasks.

2.2 Students' Engagement in STEAM

In the Philippines, basic education (elementary and high school) students' engagement in class during modular or online learning has not been reported recently. Since the mode of learning delivery abruptly changed, most research focuses on the challenges encountered by both teachers and students. Given the proponent's inclination and research interest in understanding the correlation between students' engagement and Science, Technology, Engineering, Arts, and Mathematics (STEAM) outcomes, this study is focused on engagement in STEAM-oriented classroom settings.

According to Deci & Ryan (2002), engagement refers to the observable and unobservable qualities of students' interactions with learning activities. Engagement includes four (4) dimensions: behavioral, emotional, cognitive, and social engagement (Wang et al., 2016). *Behavioral engagement* involves students' involvement in academic and class-based activities, with the presence of positive conduct and the absence of disruptive behavior. This engagement is measured with items about students' participation, attention, concentration, assignments completion, and adherence to classroom rules. On the other hand, *emotional engagement* is defined as positive emotional reactions to teachers, classmates, classroom activities, and interest in the learning content. This engagement is measured with items about students' interest, enjoyment, and the regarded value of learning (Fredricks et al., 2004; Fredricks & McColskey, 2012). Zimmerman (2010) and Greene (2015) conceptualized *cognitive engagement* as self-regulated learning, using deep learning strategies and exerting the necessary mental strategies for comprehending complex ideas. This engagement has been measured with items about self-regulation, persistence, and the use of metacognition and connectivism to learn and understand concepts. Finally, *social engagement* includes the quality of social interactions with peers and adults and the enthusiasm to invest in forming and sustaining relationships while learning (Fredricks et al., 2004). This engagement is measured with items about understanding peers, building on others' ideas, and paying attention to everyone's contribution.

Previous research has shown that students' engagement was enhanced through project-based learning units (Juuti et al., 2021), robotics courses (Verner et al., 2021), science investigatory projects (Sanchez & Rosaroso, 2019), and team-based capstone courses (McCubbins et al., 2018). Although these studies provide satisfactory results and findings on how students were engaged in STEAM-oriented courses, this article offers the specific dimensions of students' engagement rather than focusing on a general form that failed to consider the unique contributions of each aspect of the engagement.

2.3 Delineating research and development skills

There have been numerous studies on students' research and development skills as requisites of their research-oriented subjects. A review of related research literature revealed that there were many components of research skills involved. Palines & Ortega-Dela Cruz (2021) measured R&D skills which the authors termed scientific literacy in terms of writing and presenting scientific research. In the study of Gilmore et al. (2010), R&D skills were assessed through writing research components and research experiences, including autonomy, collaboration, and motivation. Gomez (2013), on the other hand, used a project-based approach as a pedagogical tool in enhancing students' R&D skills in conducting science investigatory projects.

There are ranges of skills necessary for research, and how previous researchers measured it varies also. However, in this article, R&D skills are defined as a set of skills deemed essential to conduct research. There are five (5) dimensions of R&D skills as per Meerah et al. (2012b) - analytical skills, information seeking skills, problem-solving skills, communication skills, and methodology skills. *Analytical skills* refer to the ability to carry out data collection procedures and interpret appropriate conclusions from analysis results. These skills are measured with items about communicating important data, thinking outside the box, understanding logical relations between data, and analyzing patterns and trends. *Information-seeking skills* are defined as the awareness of various sources of information and the ability to search, use, and evaluate information. Sorting types of information, relying on peer-reviewed journals, using main ideas obtained from sources are the items used to measure these skills. Further, *problem-solving skills* are conceptualized as identifying, defining, and analyzing problems to formulate and evaluate solutions. These skills are measured with items about identifying the problems before formulating solutions, doing a pilot test before implementing the solution to a bigger scale and seeking alternatives if the solutions formulated are not working. Writing and presenting the research and its findings and collaborating with peers effectively are defined as *communication skills*. These skills are measured with items about making messages as precise and to the point as possible, expanding listening skills, and considering the delivery methods for their messages. Subsequently, *research methodology skills* are established to distinguish appropriate research procedures and understand the limitations and scope of research. These skills are then measured with items about evaluating and interpreting evidence, both qualitative and quantitative data, analyzing contemporary social problems using conceptual and theoretical perspectives, and explaining the interaction between questions, theories, evidence, and explanations related to their projects.

2.4 Science Investigatory Projects, Capstone and Robotics (SIPCaR) synergy: Practices, challenges, and ways forward

Science investigatory project (SIP) has been used as an inquiry-based assessment to promote students' understanding of the nature of science. SIP allows students to conduct investigations using the scientific processes to systematically and scientifically solve problems to their questions (Jugar, 2013). Cuartero (2016) reported that students' interest in science and science process skills are developed by doing SIP. However, the conduct of SIP is not a requirement of the science education curriculum of DepEd, Philippines. Nevertheless, the department conducts a yearly event in the form of Science and Technology Fair to showcase the best SIPs of all elementary and secondary schools in the country from the district, division, regional, and national levels.

DepEd requires a capstone project as a specialized subject in the Grade 12 Senior High School STEM track. In this course, students, under the direction of a research mentor, recognize a scientific, technological, or mathematical problem, design and apply a suitable methodology, formulate a hypothesis, and draw conclusions based on their inquiry. At the end of the term, students prepare a scientific report to be presented and defended in a forum (DepEd, 2018). In the Philippines, capstone projects have been practiced widely in higher education, specifically those college students majoring in information technology and computer-related courses. With the enactment of the K to 12 curriculum, this subject is embedded to hone students' scientific and technological skills. However, there are limited reports on the conduct of this course; thus, the overall understanding of the impacts of capstone projects on pre-college students is still unclear and indefinite.

Robotics has become an elective course in other elementary and high schools in the country (Montemayor, 2018). Other schools started robotics as a club (an organization dedicated to a particular interest) inside the school campus. Several reports have shown that robotics creates awareness of science and technology. Students are engaged in working with their peers to create everything from raw materials. They also performed electronics and 3D printing with the guidance of their mentors. Although the concept of robotics is new to DepEd, officials are looking into strengthening the current program and incorporating it into the curriculum. Fortunately, the Science Education Institute of the Department of Science and Technology (DOST) and its partners host the Philippine Robotics Olympiad annually to challenge elementary and high school students' intellectual skills and critical thinking.

How to move forward? With the fragmented implementation of the SIPCaR projects, a particular school could adhere to its best practices to gauge students' inclination towards science. Effective mentoring and instruction (Sanchez & Rosaroso, 2019), providing appropriate materials and tools, promoting a child-friendly learning space, conducting frequent feedback systems, utilizing practical assessment tools, and implementing a reward system are keys to successful inquiry and solutions-generation. Until DepEd should come to a policy in institutionalizing SIPCaR projects in basic education curriculum, implementing schools are motivated to integrate these projects because of their potential and impact on students' technological and scientific skills and could help shape the nation's Science and Technology (S&T) advancements. Attending competitions should be a secondary motive to improve the practice further and should not be the main reason a distinct entity does a project.

3 Research methodology

3.1 Research design

This study utilized a qualitative and quantitative research design to describe and quantify the impact of doing SIPCaR through modern technologies on students' engagement and R&D skills in a cross-sectional study.

3.2 Participants and Ethical consideration

This study utilized non-probability sampling methods - purposive and convenience sampling. After a thorough evaluation, only twenty-five (25) high school (upper-secondary) participants are included in this particular research. The researcher only included those students whose SIPCaR projects are developed through modern technologies since there are projects made using traditional technologies.

Consents were sought for the participation of the respondents. Researchers gave details of the nature and purpose of research, who will have access to the gathered data, and the proposed outcome of the research. Before data gathering, participants were given a consent form to confirm their cooperation; thus, the participants have the freedom to choose whether or not they will be involved in the research. In the entire study, it was emphasized that all the gathered data would be treated with utmost confidentiality and be exclusively used for this research. The school's guidelines on data privacy are strictly followed, and ethical approval was sought and granted.

3.3 Research instruments

This study made use of self-assessment questionnaires derived from related literature and studies. The Students' Engagement Self-Assessment questionnaire was obtained and modified from the study of Wang et al. (2016). This instrument consists of four (4) dimensions: cognitive engagement, behavioral engagement, emotional engagement, and social engagement. To examine the proficiency of R&D skills, the instrument from Meerah et al. (2012) was modified. There are five (5) dimensions in this self-assessment questionnaire: analytical skills, information-seeking skills, problem-solving skills, communication skills, and methodology skills. The instruments consist of five (5) statements per dimension, and students rated it using the scales 5 (Strongly Agree), 4 (Agree), 3 (Neutral), 2 (Disagree), and 1 (Strongly

Disagree). The proponent revised all the statements per dimension to fit the intentions of this study. The instruments were face validated and underwent a pilot test, through Cronbach alpha, to ensure its readability, reliability, and validity (Madaiton et al., 2022).

3.4 Research procedure

SIPCaR projects are integrated into the school's curriculum (research locale of this study). Science Investigatory Projects (SIP) are project components (performance task) of the junior high school science curriculum where students submit their project proposal in the 1st trimester of the school year for approval. Once approved, students experiment and implement their projects with the entire duration of the 2nd trimester and present/defend their results on the 3rd and final trimester of the school year. The Capstone Project, on the other hand, is a subject for the Grade 12 STEM strand where students will identify a scientific, technological, or mathematical problem, design and apply an appropriate methodology, formulate a hypothesis, and draw conclusions based on their investigation. Students will prepare a scientific report at the end of the semester to be presented/defended in a forum. Additionally, robotics projects are performance tasks of the Empowerment Technologies subject for the Grade 12 STEM strand. Students do the planning, conceptualizing, developing, and sustaining of an ICT Project for Social Change. Then the participants were asked to answer the self-assessment questionnaires on engagement and R&D skills via Google Forms. Lastly, the researcher gathered the data, performed statistical tests to answer the research questions, and prepared the manuscript for proofreading and results dissemination.

3.5 Data analysis

Descriptive statistics, specifically the weighted means, were computed to examine the ratings and determine the level of engagement, R&D skills, and students' academic achievement. Means and standard deviations were calculated to analyze the distribution of the values and to interpret whether the items (statements) contribute equally to the total scale score. Adding-up, the item mean and standard deviation were used to determine whether the items in each hypothesized grouping contain roughly the same proportion of information about the construct being measured (Othman et al., 2011).

Moreover, to interpret the mean ratings, the scales 1.00 to 1.50, 1.51 to 2.50, 2.51 to 3.50, 3.51 to 4.50, and 4.51 to 5.00 were employed with the following interpretations - extremely not engaged, not engaged, moderately engaged, very engaged, and extremely engages, respectively for the engagement components. For the R&D skills, the same scales were used, but the interpretations include -beginning, developing, approaching proficiency, proficient, and advance, sequentially. The grading scales - below 79, 80 to 84, 85 to 89, 90 to 94, 95 to 99 were used regarding the students' learning outcomes in their respective projects. The corresponding descriptors of the grading scales are as follows, did not meet expectations, fairly satisfactory, satisfactory, very satisfactory, and outstanding, respectively.

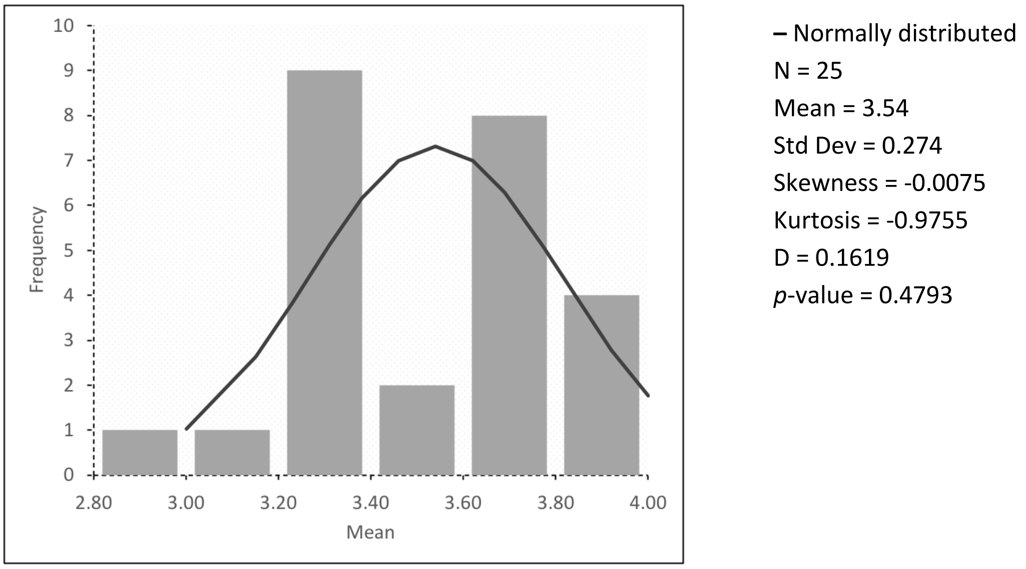


Figure 2. Histogram with Normal Curve Overlay

Figure 2 presented the histogram with normal curve overlay of the respondents' responses during the gathering of data (M = 3.54, SD = 0.274), with the skewness of -0.0075 and kurtosis of -0.9755. Using the Kolmogorov-Smirnov Test of Normality, it showed the divergence of the data distribution. Results indicated that the value of the K-S test statistic *(D)* is 0.1619 and the *p*-value is 0.4739. The data does not differ significantly from that which is normally distributed.

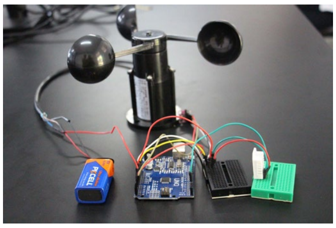
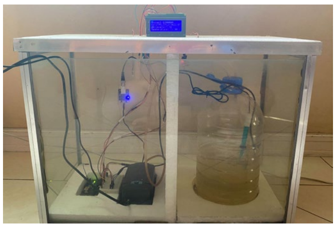
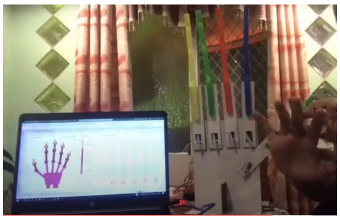
Inferential statistics was also used to investigate the relationship and correlation of the variables in this study. The Pearson Correlation Coefficient (R) and p-values were calculated and interpreted (Yadav, 2018). Thematic analysis was used to organize the participant's comments regarding the challenges they encountered in developing SIPCaR projects. All the numerical data gathered were tallied using the Google Sheet application for Windows and calculated using IBM SPSS Data Collection Author 7.

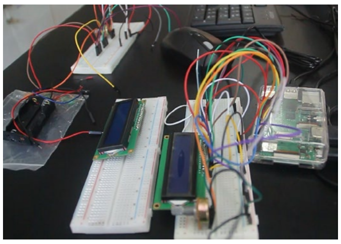
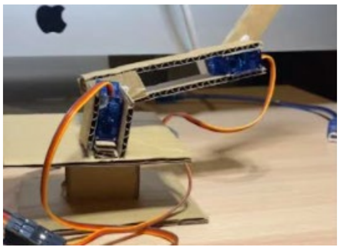
4 Results and findings

4.1 SIPCaR projects

The usage of modern technologies is becoming more prevalent in societies worldwide. More schools are integrating SIPCaR projects in their lessons and curricula. Such initiatives produced promising results, projects that can monitor and solve environmental issues and problems.

Table 1. Sample SIPCaR Projects developed by the students

Project Description	Subject	Modern Technologies Used	Actual Image
Weather Monitoring System Can monitor temperature (°C), pressure (hpa), humidity (%), wind speed (kph), altitude (agl), and weather	SIP	Arduino and Raspberry Pi Microcontrollers; Arduino, Python and C# Programming Languages; Sensors on Temperature, Pressure, Humidity; Arduino-fit anemometer	
Photobioreactor Use to examine algae growth rate and carbon dioxide absorption *Capstone Project, Alarde et al. (2021b)*	Capstone	Arduino IDE and Microcontroller; LCD Module; CO_2 Gas sensor; analog pH meter/sensor; submersible temperature sensor; air pump; breadboard; computer fans	
Water Indicator Robot Can measure water's pH level, dissolved oxygen (mg/L), turbidity (NTU), and temperature (°C)	Capstone	Arduino IDE and microcontroller; temperature sensor; turbidity sensor; pH sensor; dissolved oxygen sensor; 3D printer	
Robotic Hand Emulates human hand anatomy and biomechanics *Adapted from Microsoft Hacking STEM: Activity Library*	Capstone	Arduino IDE and microcontroller; Data Streamer; Spreadsheet; Micro:bit; Resistors, Breadboard, USB cables	

Seismograph Use to visualize earthquake data and explore modern engineering techniques used to mitigate earthquake damage *Adapted from Microsoft Hacking STEM: Activity Library*	Capstone	Arduino IDE and microcontroller; Data Streamer; Spreadsheet	
Attendance System Saves real-time attendance data *Adapted from Arduino Project Hub (Embedotronics Technologies, 2019)*	Robotics	Raspberry Pi Microcontroller; Python IDLE; RFID Reader; Distance Sensor; LED; DFRobot LCD Display Module	
Robotic Arm Can record and play five positions using potentiometers and buttons *Adapted from Arduino Project Hub (Chan, 2016)*	Robotics	Arduino IDE and Microcontroller; Potentiometers, Micro Servos; Capacitors; Resistors; LEDs	

In developing the SIPCaR projects, students used modern technologies such as microcontrollers, programming languages, sensors, and electronics equipment. These components made the prototypes and projects in good working condition and harnessed data that were used to answer various research questions. The courses made the students hone their high-order thinking and collaboration skills as they engaged with peers to finish the tasks.

All the projects underwent testing to evaluate their accuracy and precision of harnessing data, the efficiency of performing the programmed tasks, and sustainability for further usage.

4.2 Levels of students' engagement while doing the SIPCaR projects

During the conduct of the projects, students were actively engaged. They enjoyed making prototypes, constructing tangible and working devices, and evaluating the devices' performance. After the duration of the courses, participants were asked to assess their engagement in doing SIPCaR projects. The majority of them showed high levels of engagement in cognitive, behavioral, emotional, social aspects, and in general. Students formed positive relationships with their group mates and valued the essence of social interactions as support of each other for academic-related tasks. These indicators show that SIPCaR projects, as educational activities, cumulate to influence participants' engagement.

Table 2. Self-reported engagement in doing the projects

Dimension	Mean	SD	Interpretation
Cognitive Engagement	4.27	0.154	Very engaged
Behavioral Engagement	4.16	0.392	Very engaged
Emotional Engagement	3.44	0.341	Moderately engaged
Social Engagement	4.41	0.278	Very engaged
Overall Engagement	**4.07**	**0.434**	**Very engaged**

Results showed that the participants are very cognitively engaged ($\bar{x}$=4.27). They go through the work and make sure they did it right, think about different ways to solve a problem, try to connect what they are learning to things that they have learned before, try to understand their mistakes when they get something wrong, and think hard when they are doing work for the projects. Likewise, students stay focused and put effort into learning and doing the projects, and they keep trying even if something is hard. They also completed the tasks assigned to them on time and talked about their projects to their friends, family, and relatives, which means that they are behaviorally engaged ($\bar{x}$=4.16) in doing the projects. Meanwhile, participants are moderately engaged ($\bar{x}$=3.44) in the emotional aspect. About 70% of them always look forward to the SIPCaR class, enjoy learning new things, and think the course is enjoyable.

While doing the projects, students were very socially engaged ($\bar{x}$-4.41). They build on others' ideas and help their group mates who are struggling. They also liked working with peers and cared to pay attention to the contributions made by them. Participants also tried to understand the ideas of their group mates relative to theirs.

4.3 Level of R&D skills after doing SIPCaR projects

After developing the SIPCaR Projects, participants were asked to complete a self-assessment questionnaire to identify the level of competencies in their R&D knowledge and skills.

Table 3. Self-assessed research and development skills acquired in doing the projects

Dimension	Mean	SD	Interpretation
Analytical Skills	4.10	0.382	Proficient
Information-seeking Skills	4.06	0.376	Proficient
Problem-solving Skills	3.80	0.327	Proficient
Communication Skills	4.30	0.129	Proficient
Methodology Skills	3.78	0.141	Proficient
Overall R&D Skills	**4.01**	**0.221**	**Proficient**

Based on the results, students are proficient in R&D skills. They are analytical, information seeker, problem-solver, communicator, and methodological with means ($\bar{x}$) - 4.10, 4.06, 3.80, 4.30, and 3.78, respectively. Students think "out of the box" when working, communicate essential details, analyze data, identify patterns and trends, and understand the logical relationship between their gathered information and scientific concepts.

Moreover, in doing the projects, participants know that information found in research journals is more reliable than information found on blogs and magazines. They also identify and analyze the problem needed to address and seek alternative solutions. Students often use diagrams to plot the complexity of their problems. Likewise, they can identify and design appropriate research procedures, develop instruments to gather data, and write and present research findings.

4.4 Learning outcomes and its relation to engagement and R&D skills

The panel members and subject teachers evaluated the SIPCaR projects developed by the students following a scoring rubric. Results showed that eighteen (72%) participants got outstanding grades, and seven (28%) got very satisfactory grades. These evaluations are of high-level ranking, meaning to say, students achieved the evaluation criteria, which includes the significance of the study, problem statement, system or population impact, project synthesis and framework, design, data collection tools, data analysis, and budget justification (cost-cutting measures principle).

Table 4. Level of students' final grades in doing SIPCaR projects

Grade range	Frequency	Percentage	Interpretation
95-99	18	72.00	Outstanding
90-94	7	28.00	Very Satisfactory
89 and below	0	00.00	Not Applicable

Moreover, students' oral presentation, contribution, subject knowledge, composition, and creativity were also part of the academic achievement evaluation tool. Results were taken from the panelists and subjects teachers and served as their final grades in SIPCaR projects.

To examine the relationship of students' level of engagement, R&D skills, and academic achievement, Pearson Correlation Coefficient (R) and the p-values were computed. Statistical tests manifested a very strong positive relationship ($\rho=0.810$) and a significant correlation ($p<0.01$) linking students' general engagement and R&D skills. A strong positive relationship ($\rho=0.613$) and s significant correlation ($p<0.01$) between students' general engagement and academic achievement. Likewise, students' R&D skills and academic achievement exhibited a strong positive relationship ($\rho=0.553$) and a significant correlation ($p<0.01$).

Table 5. Correlation summary between engagement, R&D skills, and Learning outcomes

Dimension	Pearson's correlation (ρ)	p-value	Interpretation
General Engagement vs R&D Skills	0.810	0.00001*	Significant
General Engagement vs Learning Outcomes	0.613	0.00068*	Significant
R&D Skills vs Learning Outcomes	0.553	0.00278*	Significant

*Significant at $p < 0.01$

4.5 Challenges encountered in doing SIPCar projects

In spite of the successful development of SIPCaR projects, participants also accounted for the challenges they encountered along the way. They also provide mechanisms of best practices in overcoming the said challenges.

> "In some cases, it was challenging to execute the plan since we are distant from each other. We met through online meeting applications and just maximized the time and resources to complete the project. Despite the distance, we were able to overcome the barriers since we set a common goal to manage the time and collaborate to finish the tasks." P2, P3, P6, P10, P13, P20, P25
>
> "At first, I was worried about how to acquire the materials for our robotics projects. Purchasing electronic materials is not parents' forte, so I am afraid they will buy the wrong ones. Good thing the school provided the materials, and all we need to do is to get it from the school's campus following minimum health standards." P4, P11, P21, P22
>
> "I do not like online classes, to the point that it discourages me from performing the tasks assigned. I kept on procrastinating and tried to miss deadlines. I am just so thankful to my teacher for constantly reminding me. He constantly gave feedback so that we are still on track with the tasks." P1, P14, P17
>
> "Doing SIP is kind of costly. But my parents are very supportive of my studies. They provided me with the resources I needed." P15, P18
>
> "Remote learning is very challenging. You cannot ask for direct physical guidance from your research mentor. Although my mentor provided me with all the resources to complete our project, distant learning somehow helped me become an independent and self-directed learner." P8, P23, P25
>
> "Although challenging, I find it interesting because it gives me a glimpse of what I will be doing in the future. Having sleepless nights sometimes paid off when we achieved our desired results." P1, P5, P9, P12, P19

To summarize, participants found it challenging to develop the proposed project plans, acquire materials, online learning set-up and environment. All of these were resolved since they noted that through teamwork, school's aid, effective teacher's feedback mechanisms, family support, and self-directed learning, they accomplished their tasks and achieved very good to excellent grades/project ratings.

5 Discussion and implications

Notwithstanding the learning setup implemented recently, participants were able to develop promising SIPCaR projects. The majority of the outputs are geared towards environmental monitoring and protection. This indicator implies that students are environmentally aware. They are updated concerning the carbon dioxide concentration in the earth's atmosphere, water pollution, weather conditions, and natural calamities. Thus, paving the way to develop photobioreactor devices to investigate the algae growth rate and CO_2 removal efficiency, a water robot to monitor water status and parameters (acidity, turbidity, temperature, and dissolved oxygen), and a weather monitoring system to keep track of the meteorological conditions. The seismograph to simulate ground shaking led to students' understanding of plate tectonics and paved the way for disaster preparedness and mitigation. Similarly, these results recall the Uitto et al. (2011) study, which investigated the secondary school student's interests, attitudes, and values concerning school's activities related to environmental issues. The study revealed that environment-related activities were suggested to enhance students' interest in environmental issues. Furthermore, interests, attitudes and values in teaching environmental issues are essential factors for future research in science, environment, and sustainable development education.

In doing projects, participants were actively engaged when assigned to solve a problem and when one has a role to perform (Guarin et al., 2019; Gamale et al., 2021). The same goes through this study, each student has a position to play. These roles entail higher-order thinking skills (HOTS), lasting scientific attitudes, established passion and intrapersonal skills, and deep-rooted collaboration skills. Throughout doing the project, students portrayed as programmers to write, test, debug, and maintain the project's computer applications; prototypes to research, design, and evaluate the project's model; data analysts to investigate the gathered information and make interpretations; science communicators to write and prepare the manuscript for practical info dissemination. Hence, the participants in this study were engaged in the cognitive, behavioral, emotional, and social aspects. Implications of these findings suggest that students are highly engaged in a manner that, while performing their respective roles, they brainstormed and planned the best ideas, stayed focused and determined, enjoyed learning new things, and paid attention and care to their group mates. Students' engagement in project-based approach significantly increased their self-efficacy in conducting SIPs and developed skills in collaborating, problem solving, and critical thinking (Gomez, 2013). The same findings were reported by McCubbins et al. (2018); students who completed team-based projects were physically and psychologically engaged. Due to the pandemic, the mode of delivery of teaching instructions is transitioned to online learning, and students found that synchronous activities (the way SIPCaR projects are implemented) are more engaging (Walker, 2021). However, students experienced positive and negative outcomes. Consequently, monitoring students' engagement is of particular importance for experiential learning in SIPCaR projects, as it allows the teacher to gain a holistic understanding of the students as individuals and as group contributors (Verner, 2021).

Student engagement has been described as active involvement in a learning task that significantly affects learner's achievement (Verner et al., 2021). The aforementioned confirms the findings of this study - when students are engaged cognitively, behaviorally, emotionally, and socially, it benefits them to be proficient data analysts, credible information-seekers, problem-solvers, science communicators, and research methodologists. It was also revealed that, students being highly engaged in doing SIPCaR projects, generated outstanding grades. These findings support the previous research that students under robotics intervention had a notable increase in mean scores from the pretest to the posttest when they examined robotics as a means to improve achievement scores in an informal learning environment (Barker & Ansorge, 2007). Similarly, students' academic performance, literacy and interest in science and science process skills are developed by doing SIPs (Meerah et al., 2012a; Gomez, 2013; Cuartero, 2016; Aparecio, 2018), modern technologies (Acut et al., 2021), and research projects (Palines & Ortega-Dela Cruz, 2021). Implications can be drawn that engagement significantly affects students R&D skills and academic achievements. On a note that they passionately and collaboratively worked on their respective SIPCaR projects, students enhanced their skills, thus becoming knowledgeable and skillful researchers and innovators.

6 Conclusion

As the COVID-19 pandemic continues to obstruct meaningful in-school learning, educational practitioners should consider devising learning modalities that engage and cater to students' needs at all costs. Indeed, developing SIPCaR Projects yields a high level of engagement, R&D skills and contributes to a holistic understanding that:

- Integrating project-based learning fused with environmental issues and concerns, such as SIPCaR projects, foster students' high level of cognitive, behavioral, emotional, and social engagement;
- When students are multi-dimensionally engaged, these results in a proficient level of R&D skills that support students have outstanding academic achievements;
- Amidst health crisis, students were challenged in completing their projects but resolved with effective peer collaboration, continuing school's support, active teachers' mentorship and feedback, enduring family's assistance, and love of life-long learning (self-directed and independent learning).

In one way or another, this research intervention trained students' higher-order-thinking skills (HOTS) and essential competencies at par with international standards. It has been established in the findings of this study and previous research outcomes that student engagement is a potent predictor of R&D skills, academic achievement and choice. Students with higher behavioral, emotional, social, and cognitive engagement favor accomplishing and aspiring for higher education. Students engaged in science processes believe in the importance of science and math in solving the world's emerging problems, thus leading them to enroll in STEM-related courses and career aspirations. The significant goal of integrating SIPCaR projects in the curriculum is to strengthen Science, technology, engineering, and mathematics (STEM) education at the high school level to encourage and inspire students to pursue STEM-related courses in college all the way to joining the STEM workforce. With proper and effective implementation, developing SIPCaR projects is a viable key towards reaching future occupational needs, fostering modern technological innovations, and revolutionizing the country's competitiveness.

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