Journal of Education and Learning (EduLearn)
Vol. 20, No. 1, February 2026, pp. 456~464
ISSN: 2089-9823 DOI: 10.11591/edulearn.v20i1.22734

Creating educational vodcast incorporating PhET simulations to enhance vector teaching

Jas Felicisimo A. Cane[1], Kim Burns[2], Erniel Ghrizcer G. Ecle[3], Rachel M. Tacubao[2]
[1]Integrated Developmental School, College of Education and Social Sciences, Mindanao State University at Naawan, Naawan, Philippines
[2]Department of Senior High School, Liceo de Cagayan University, Cagayan de Oro City, Philippines
[3]Department of Secondary and Elementary Education, College of Education and Social Sciences, Mindanao State University at Naawan, Naawan, Philippines

Article Info

Article history:

Received Jul 10, 2024
Revised May 1, 2025
Accepted Jul 17, 2025

Keywords:

Creating
PhET simulations
STEM
Vectors
Vodcast

ABSTRACT

Accelerating science education in the Philippines remains a challenge for many educators. Consistent low performance scores of the Filipino learners based on the Programme for International Student Assessment (PISA) 2022 results call for a need to innovate learning materials and approaches in the field of science education. Hence, this research focuses on the creation of vodcasts enriched with PhET simulations to teach vector concepts in physics and evaluate its effects on the students' understanding and perception. This is to provide supplementary learning resources to grade 12 science, technology, engineering, and mathematics (STEM) students who face challenges in understanding physics caused by insufficient instructional materials that concretize concepts through visuals. The study is grounded on analysis, design, development, implementation, and evaluation (ADDIE) model for developing vodcasts on vectors as supplementary educational materials. The evaluators rated the vodcasts "satisfactory" yielding a mean rating of 4.15. The implementation resulted in a normalized gain of <g>=0.68, signifying an average improvement in the understanding of the learners. The main conclusion drawn from this study emphasizes on the effective use of vodcasts to supplement the learning of vectors. In other words, the implementation of well–designed vodcasts can significantly enhance vector instruction and lay the foundation for further improvements in physics and science education.

Corresponding Author:

Jas Felicisimo A. Cane
Integrated Developmental School, College of Education and Social Sciences
Mindanao State University at Naawan
Pedro Pagalan Street, Barangay Poblacion, Naawan, Misamis Oriental 9023, Philippines
Email: jasfelicisimo.cane@msunaawan.edu.ph

1. INTRODUCTION

In the field of science education, various branches remain a difficult task for students to understand which includes learning physics [1]. One of the topics belonging to this discipline is about vector which is considered critically important in the related fields of mathematics and physics [2], [3]. While many studies support the importance of this in education, there is observed insufficiency in the mastery of vector concepts among high school students [4]. Several studies also reported that there is a decreased understanding of physics concepts, like vectors, among students in the university which may be associated with a lack of concept foundation during their basic education, as previously mentioned [5]–[7].

Despite all the efforts to leverage a concrete understanding of physics in the Philippine context, specifically learning vectors, there is still an observed struggle to attain this. This is evidenced in the Programme for International Student Assessment (PISA) results where Filipino learners consecutively maintained their lowest rank in science among the PISA-participating countries and economies during the PISA 2022 [8], as cited in the study of De La Cruz [9]. This further implicates the need to strengthen science education in the country, particularly in physics education, through the utilization of novel learning strategies.

Learning scientific concepts requires extra effort from the learners and teaching it is a challenge for educators and for this reason, some literature delved into figuring out the reasons why there are consistent difficulties in learning vectors among learners. One of the possible factors considered is the insufficiency of visualization which primarily contributed to the students' poor performance while learners with correct solutions and improved performance in solving vector problems utilized clear diagrams as representations [6]. Similar findings were also observed in other studies where various forms of representations like illustrations, graphical representations, simulations, and multimedia elements are found to be very effective in communicating scientific concepts to the learners [10].

Aside from incorporating representations during lectures, supplementary materials, like resorting to the utilization of technology, facilitate in refining the performance of learners and understanding of scientific concepts [11], [12]. One of these supplementary materials is a vodcast that integrates different instructional and evaluation technologies which include social media, video clips, direct instruction, and gaming components [13]. In this way, the active process of learning can be stimulated among the students through multi-sensory materials, like the use of vodcasts. Furthermore, vodcasts can maximize the ability of the learners to comprehend difficult topics, like vectors, and facilitate them in driving autonomous learning [14], [15]. Other studies focusing on the utilization of vodcasts to teach difficult courses in physics yielded positive outcomes mostly on the performance and perception of the learners where they attain improved performance based on the normalized gain scores and perceived vodcasts as very useful in learning abstract concepts in physics [16]–[20]. Vodcast minimized the gap in communication between teachers and learners by fostering collaborative learning and decreasing in feelings of isolation [21], as well as reinforce the adoption of language skills such as listening and reading comprehension [22]. In the study of Fernandez-Pacheco [23], they explored the use of vodcasts to assess the effect of multimodal ensembles on the students' audio-visual comprehension. They found out that those the students' auditory and visual comprehension enhanced after the use of vodcasts highlighting that the use of greater number of orchestrated modes boosts the students' comprehension and understanding on a specific topic.

In addition to this, incorporating interactive simulations in learning vectors can guarantee the improvement of students' understanding of learning scientific concepts, particularly vectors in physics [24]. While there may be various technology-assisted simulations available over the web, this paper chiefly utilized physics education technology (PhET) simulation in crafting the vodcasts. PhET simulations were pioneered by the University of Colorado [25]. PhET simulations are one of the existing science simulations that drive students to enhance conceptual understanding, explore scientific concepts, make connections to everyday life, and concretize abstract concepts in sciences like vector concepts in physics [26]–[31]. Additionally, a study authored by Susilawati *et al*. [32] suggested that integrating PhET simulations in physics classes can improve the motivational aspect and students problem-solving skills which are necessary characteristics for students in the science education.

With all the statements specified above, this paper was conceptualized and grounded from the ADDIE model in order to evaluate the developed vodcast on the performance of the learners and cater the following targets:

- Design educational vodcasts incorporated with PhET simulations in teaching vectors based on the Department of Education content standards and learning competencies.
- Develop educational vodcasts incorporated with PhET simulations in teaching vectors based on expert evaluation in terms of; i) content; ii) delivery; and iii) technical production
- Implement the developed vodcasts and determine the performance of the grade 12 science, technology, engineering, and mathematics (STEM) students according to their pretest and posttest results.
- Evaluate the developed vodcasts in terms of its usefulness and the students' perception on the teachers through the following factors; i) teacher's voice quality; ii) teacher's language; and iii) teacher's knowledge of the subject

2. METHOD

2.1. Procedure

This study is grounded on descriptive developmental paradigm utilizing the analysis, design, development, implementation, and evaluation (ADDIE) model as the main framework in creating the

educational vodcasts. The model is a comprehensible instructional system-design model [33] utilized particularly by technology-based educational developers [34]. As shown in Figure 1, this study underwent its fives stages including ADDIE. Following the analysis part, the vector topic was selected according to the learning competency indicated in Department of Education Curriculum. The incorporation of PhET simulations in the vodcasts were also done meticulously with the help of hardware and software resources. In the design stage, it included the process of crafting the topic outline, making of the manuscript as well as the creation of the PowerPoint presentation and the development stage mainly applied the experts' suggestions. When the vodcasts were polished, it was then implemented along with the conduct of the pretest as well as posttest. Finally, the developed vodcasts incorporated with PhET simulations in teaching physics were evaluated based on the students' perception.

This study is guided by the one-group pretest-posttest quasi experimental design when the developed vodcast was subjected to implementation and evaluation. After the students took the pretest, the instructional material was then introduced to the respondents which was followed by a posttest. Four instruments were adapted from other studies. The 12-item evaluation survey questionnaire [18] which was composed of content quality, delivery quality, and technical quality was used by 25 science teachers and nine teachers in the field of information and communication technology (ICT). The researchers also used 15-item multiple-choice item test, vodcasts perception questionnaire [35] and the student's perception questionnaire [36]. In the analysis of data, means scores were computed in the ratings yielded from the survey questionnaires and interpreted, accordingly.

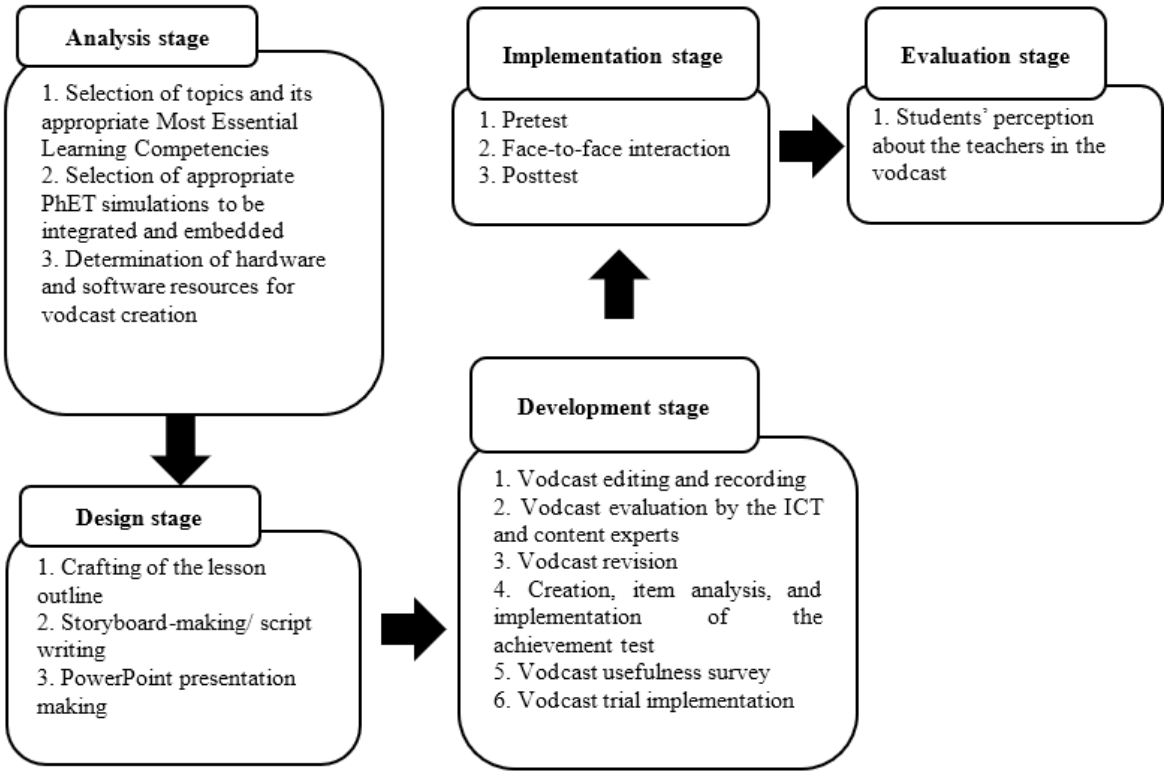

Figure 1. Developmental stages of the vodcast following the ADDIE model

2.2. Normalized gain

To get insight into how the vodcast affected the grade 12 STEM students' conceptual comprehension, the normalized gain score was calculated. An increase from the pretest to the posttest is represented by the normalized gain value which a positive gain would be associated with a low, medium or high gain. A negative sign would suggest that the intervention was ineffective or even detrimental, whereas a zero gain would point to a stable response. By using normalized gain, it may better provide understanding whether students require additional support based on their gain score or determine whether the intervention is effective because there is no negative gain.

2.3. Means

The mean scores were utilized according to the data collected in the study. First is the mean score of the vodcast evaluation survey by the content and ICT experts which corresponds to the expert evaluation of the developed vodcasts in terms of its science content and its multimedia aspect. Secondly, the mean scores of the pretest and posttest scores are used as basis for the conceptual comprehension of the learners in using the developed vodcast. This study also included the means from the vodcast usefulness survey result. And lastly, the means from the students' perception on the teachers in the vodcast by the STEM students. The mean yield was then interpreted according to the descriptions provided.

3. RESULTS AND DISCUSSION

3.1. Analysis and design stage

One of learners perceived difficulties in learning physics is the mastering of the fundamental concepts [37], of which vector is one of the essential components of the mathematical language of physics [3] vector concepts that learners found to be most difficult include the unit vectors, as well as the graphical addition and subtraction of vectors [38]. Three topics were presented namely, vector and scalar quantities, addition of vectors, and vector in component form. Vodcast content was designed based on prescribed content standards and learning competencies from the Department of Education presented in Table 1.

Table 1. K to 12 basic education curriculum (STEM-general physics 1) specialized subject-vectors

Content	Content standard	Learning competencies	Code
Vectors	Vectors and vector addition	Differentiate vector and scalar quantities	STEM_GP12V-Ia-8
		Perform addition of vectors	STEM_GP12V-Ia-9
		Rewrite a vector in component form	STEM_GP12V-Ia-10

The researchers made use of the modified vodcast assessment instrument adapted from Ulla *et al*. [18]. Under the categories of content quality, delivery quality, and technical quality, indicators of good quality vodcast were identified. Following the vodcast planning, scriptwriting and the creation of PowerPoint storyboards were completed. In the initial creation of the vodcast, PhET for simulation, open broadcaster software (OBS) software for recording, and Vegas Creative Software for editing were used. To get the most ideal vodcast version, several iterations were required for every tiny change.

3.2. Vodcast development

Table 2 shows the survey's combined mean rating for the evaluation of the developed vodcast. It was rated by the science content and ICT experts with the use of vodcast assessment tool. The mean rating for content quality as evaluated by the 34 evaluators, twenty-five science content experts and nine ICT experts, was 4.22 and interpreted as very satisfactory. For delivery quality, the mean rating was 4.10 (satisfactory) and a mean rating of 4.13 (satisfactory) for technical production. The overall mean rating by the experts was 4.15 (satisfactory). As an additional, comments and suggestions were given by the evaluators. English language was fully utilized which was appreciated by a content evaluator. ICT experts also highlighted the colors, pictures and shapes, and minimal sound effects was used in the vodcasts. An overall mean rating of 4.21 was rated by the content expert's evaluation which they see the vodcast as useful in supplementing the lesson in vectors. The final length of the created vodcast was 6 minutes and 25 seconds which is considered as a medium-length video by Afify [39]; however, shorter videos achieve higher cognitive performance compared to those who watch medium or long video. Part of the developmental part was crafting the questions for the pretest and posttest. 25 item questions were initially formulated by the researchers. The questionnaire was pilot-tested among grade 12 STEM students of Liceo de Cagayan University-Senior High School Department through the use of Quipper, an online learning platform used by the school. Out of 25 questions, 15 questions were selected and retained for the final achievement (pretest and posttest). The adapted and modified vodcast perception survey questionnaire from Liwanag *et al*. [35] was crafted during the developmental stage.

Table 2. Vodcast evaluation mean rating

Indicators	Mean rating	Description
Content quality	4.22	Very satisfactory
Delivery quality	4.10	Satisfactory
Technical production	4.13	Satisfactory
Overall mean	4.15	Satisfactory

Similar results were also observed in the study of Treagust *et al*. [12] that the usage of English medium as well as representations like illustrations, graphical representations, simulations, and multimedia elements are very effective in communicating science concepts to the learners. Additionally, learners nowadays have a shorter attention span so it is important to tailor vodcasts and other audio-visual learning materials in a shorter time duration [40].

3.3. Vodcast implementation

Student respondents received orientation on the procedures involved in conducting the study on the first day of implementation. The following day, the researcher conducted the lesson through the utilization of the developed vodcast with PhET simulation to the 77 grade 12 STEM students who answered the consent and assent form in a face-to-face setting. To ascertain the effectiveness of the vodcast, the researchers delimit not to identify the high, average and low performers. The developed vodcast was also uploaded on their Google Classroom so that they can access it. It was implemented for 1 week which follows the specific duration provided by the Department of Education.

The results of the pretest and posttest were further explored to generate enhanced outcomes knowing that the vodcast positively influenced the respondents' performance on the test. The normalized gain score is calculated based on the students' pretest and posttest results. As shown in Table 3, overall, the respondents yielded an average gain score on the topic about vectors. The pretest mean score was recorded 6.455 while the posttest mean score was recorded 12.260. Following the normalized gain score formula, the overall normalized gain score was computed to be 0.676 and is interpreted as average.

Table 3. Normal gain score analysis

Results	Mean	Normalized gain (g)	Description
Pretest	6.455	0.676	Average
Posttest	12.260		

In other studies, utilizing vodcasts in teaching science concepts, their findings also suggest performance improvement among the learners [13], [14]. It is also a similar case in the utilization of PhET simulations in teaching science concepts [24]–[27]. In terms of normalized gain scores, low to medium scores were also observed in other studies utilizing vodcasts to teach physics concepts and science related topics in the Philippines like light, thermodynamics, reflection, and refraction [18]–[20]. Hence, the use of vodcasts incorporated with PhET simulations in this study generated improved performance scores among the student respondents.

3.4. Vodcast evaluation

Following the posttest, 77 students responded to the vodcast usefulness survey and students' perception on the teachers' survey. This is to share their thoughts, emotions, and experiences from when the created vodcast was being implemented. According to the results, means of their responses suggest that the respondents perceive the vodcast as useful to them. Furthermore, Table 4 shows that the 77 STEM students in grade 12 gave voice quality a mean rating of 3.56 (strongly agree). For language it was 3.53 (strongly agree), and the knowledge of the subject was 3.55 (strongly agree). According to the students' perception of the teachers in the vodcast, the aggregate mean rating was 3.55 (strongly agree). It suggests that the teacher is still present, students continue to observe the vodcast and are motivated to study. Similar results are also observed in the study of Bolliger *et al*. [41] indicating that the students were moderately motivated after using podcasts and vodcasts in their classes.

Table 4. Students' perception on the teachers in the vodcast

Indicators	Average mean	Description
Voice quality	3.56	Strongly agree
Language	3.53	Strongly agree
Knowledge of the subject	3.55	Strongly agree
Overall mean	3.55	Strongly agree

These factors are strong indicators that further support the performance results as well as usefulness of the vodcasts among learners. In the study of Javier [36], voice quality, language, and knowledge of the subject were regarded as reasons that determine the efficiency of the teachers and the learning engagement of the students.

For the voice quality, the tone of the teacher's voice serves as a motivation for the students to listen, watch, and learn from the vodcasts [42], [43]. On the other hand, the use of English language as the mode of communication improves understanding among learners due to its familiar use and easy incorporation in giving instructions. And lastly, knowledge of the subject indicates the accuracy and the coherence of the lesson [32]. With an overall mean that corresponds to "strongly agree", the results in the performance scores and usefulness of the developed vodcasts were the outcome of its effective use indicating the autonomy of the learners.

The results of the other studies concentrated on the use of vodcasts to teach other physics concepts also align with the outcomes of this study suggesting the usefulness of vodcasts about vectors [15]–[22]. In addition to this, the respondents in the study of Villaruz *et al.* [19], recommended that vodcasts may also be used as a stand-alone material to teach courses in physics. This further strengthens the recommendations of these studies to establish an archiving system to store readily-available vodcasts in physics including other STEM fields to leverage Philippines science education.

4. CONCLUSION

Based on the study's findings, it can be said that grade 12 STEM Students required a clear visual representation of the ideas of vectors, and that vodcast integrated with PhET simulation could provide just that. The vodcast that the researchers developed can be used as a supplementary instructional material to enhance learning in vectors. Additionally, it facilitates the teacher's job during the teaching process. By making the most of technology, educators may create and execute vodcast that are customized to the requirements, interests, and first language of the students. The study's baseline data may be used by administrators to support the creation of a school improvement plan or school policy on the development of instructional materials that would direct and support teachers in creating technology-based materials like vodcast.

ACKNOWLEDGEMENTS

The authors would like to thank the Liceo de Cagayan University-Senior High School Department for the academic support throughout the development and implementation of this study.

FUNDING INFORMATION

This study was conducted without any financial support from funding agencies in the public, commercial, or not-for-profit sectors

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Jas Felicisimo A. Cane	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kim Burns	✓	✓		✓	✓		✓			✓	✓		✓	✓
Erniel Ghrizcer G. Ecle		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Rachel M. Tacubao				✓	✓		✓			✓	✓		✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

INFORMED CONSENT

The researchers ascertained that all respondents signed voluntarily the consent form. The content of the consent form was clearly discussed and explained to the learners during the orientation. All participants

involved in this study were informed about the purpose, procedures, potential risks, and benefits of the research. Informed consent was obtained prior to participation in accordance with the institutional and ethical guidelines.

ETHICAL APPROVAL

This study involving human participants was carried out in accordance with applicable national laws and institutional guidelines, and aligned with the ethical principles outlined in the Declaration of Helsinki. Approval for the research was granted by the Ethics Committee of Liceo de Cagayan University (LDCU), and all required institutional clearances were duly obtained.

DATA AVAILABILITY

The data supporting the results of this study can be obtained from the corresponding author, [JFAC], upon reasonable request. However, due to privacy concerns and in compliance with the Data Privacy Act, the datasets are not publicly accessible as they contain sensitive information that may compromise the confidentiality of the research participants.

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BIOGRAPHIES OF AUTHORS

Jas Felicisimo A. Cane been a science and mathematics teacher both junior and senior high school, he holds a bachelor of science of secondary education major in physics and a master's degree in science education major in physics at Mindanao State University-Iligan Institute of Technology. A licensed professional teacher. He has mentored STEM students in developing robotics and automation project. His research interests include robotics, STEM education, science instrumentation, physics education, and educational pedagogies. He can be contacted at email: jasfelicis.cane@g.msuiit.edu.ph or jasfelicisimo.cane@msunaawan.edu.ph.

Kim Burns been a science teacher for 4 years and a science and mathematics tutor for 3 years. She is a graduate of bachelor of secondary education major in physical sciences from University of Science and Technology of Southern Philippines and is currently writing her thesis for her masters in chemistry education in the same university. A licensed professional teacher. Her research interests include STEM education, educational pedagogies, and curriculum development. She can be contacted at email: kburns@liceo.edu.ph.

Erniel Ghrizcer G. Ecle is a higher education biology instructor of Mindanao State University at Naawan and a former STEM teacher. He is a degree holder of bachelor in secondary education major in biology which he earned from Mindanao State University-Iligan Institute of Technology. He also holds a degree in masters of science education major in biology earned from the same institution. As a science education advocate, his research interests include science education, biology education for teachers, inquiry and problem-based approaches, as well as research development and instrumentation. He can be contacted at email: ernielghrizcer.ecle@msunaawan.edu.ph or ernielghrizcer.ecle@g.msuiit.edu.ph.

Rachel M. Tacubao is a STEM teacher at Liceo de Cagayan University-Senior High School Department, and an Extension and Service-Learning Program Coordinator from academic school years 2022-2024. She earned her bachelor of secondary education major in biological sciences at Xavier University-Ateneo de Cagayan. Her research interests include Biology education, methods and strategies in teaching Science, and service learning in STEM education. She can be contacted at email: rtacubao@liceo.edu.ph.