Vodcast as ideating medium in STEM lesson plan in teaching heat transfer

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ABSTRACT

This study attempts to link the clay soil in the locality to the topic of heat transfer as a contextualization point. It attempted to slightly modify the seven-step science, technology, engineering, and mathematics (STEM) lesson by having the part of the prototyping be first tried by the teacher, thereby having a change-of-hat to anticipate the 'what if' questions of the students. The teacher-researcher experimentation provided critical information to scaffold the students in the prototyping part. The evaluation of experts shows that the modified STEM lesson can be an excellent tool and the vodcast has been found to be a very satisfactory component of the STEM lesson. It is described as a very useful material in teaching heat transfer and related thermodynamics concepts and is highly recommended for use in both distance learning and face-to-face modality. Further, the clay oven exploration has come up with a refined clay oven production process, wherein the clay oven prototype has the capacity for the contextualization of heat transfer. It is recommended that a formal implementation be conducted to refine and standardize the lesson delivery.

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1. INTRODUCTION

Thermodynamics plays an important role in our lives because of its natural relatedness to the physical universe. This branch of physics has many significant applications in the world; these include engines, refrigeration systems, and power generation. This is why its concepts should be grasped and understood; however, existing literature proves the opposite. Globally, students have a difficulty in visualizing basic thermodynamics concepts and in solving related problems [1]. According to Hall [2] and Junglas [3], the concepts, principles, and processes in thermodynamics are difficult to master. In fact, studies show that a number of students perceive thermodynamics as a difficult course because confusion and retention of significant misconceptions of its principles are evident even after instruction [4]–[6]. A survey study on 128 undergraduate science students showed that there are difficulties on learning thermodynamics topics such as isobaric process, adiabatic process, and heat and temperature [7]. Researchers discussed the misconceptions related to heat and temperature among students [8]–[10].

In the Philippines, the problem of thermodynamics, and the Science subject in general, is also apparent. The study of Camarao and Nava [11] reveals that students are having difficulty comprehending topics in optics, mechanics, electromagnetism, and thermodynamics. Additionally, Auditor and Naval [12] developed and validated physics modules based on the least mastered competencies among Grade 10 students; this includes heat and thermodynamics. Another study identified thermodynamics as one of the courses in physics that is least learned to most students [13]. Furthermore, the Department of Education (DepEd) Sec. Leonor M. Briones described the performance of Filipino students as "gravitating towards the low proficiency levels" especially in science, math, and English. Evidence for this is our standing in national and international tests. The data on the results of the National Achievement Test (NAT) reveals that we have a low mean percentage score (MPS) in science–that is below the standard 75% MPS [14]. Additionally, international reports provided by the Trends in International Mathematics and Science Study (TIMSS) in 2019 and the Program for International Student Assessment (PISA) in 2018 indicated that the science knowledge, skills, and competencies of Filipino students belong to the lowest rank among participating countries [15], [16].

The findings of Nguyen and Khoo [17] emphasized that there is a need for additional support in instruction, with animation and simulations-based approaches, or additional learning opportunities with visualizations specially when students take on compound, nonconcrete principles, and difficult areas. Hence, there is a need for studies that consider active learning, collaboration and maximization of digital technology towards understanding difficult topics in physics. In this study, the technology on vodcasting was integrated with physics education technology (PhET) simulations as a supplementary tool in a science, technology, engineering and mathematics (STEM) lesson on heat transfer and related thermodynamics concepts.

Studies show that vodcast has positive effects on students' academic achievement, perceptions, attitudes, and experiences. For instance, the study by Backhaus *et al*. [18] on comparing vodcast with the usual lecture set-up among medical students reported that the difference is not significant between the lecture and vodcast format of instruction but they noted that the performance of the students who underwent to the vodcast intervention significantly increased. This suggests that vodcast could undeniably supplement learning under the modular distance learning modality (MDLM) situation. This is equally proved by a study of the use of vodcast to enhance key microbial skills among microbiology students with which the majority revealed that aside from assisting their understanding of the key concepts, it also enhanced their skill development [19]. Similarly, Faramarzi *et al*. [20] conveyed that the implementation of vodcast in a learning situation plays a substantial role in supplementing the Iranian intermediate English as a foreign language (EFL) learners afforded by the large effect size on their listening comprehension skills based on the difference provided by the Eta squared statistic. The group argued that this superior result is based on three main reasons, as verified by other researchers: i) the integrative nature of the technology; ii) the logical method of instruction suited for a distance learning program; and iii) the online accessibility nature of the application. Another study on testing whether vodcast viewing would affect science vocabulary acquisition in fifth-grade learners showed that vodcast viewing sessions increased the science achievement marks of the students who participated in vodcast watching compared to those who did not which specifically suggests that vodcasts as supplemental tools have the ability to influence student learning [21]. This is also the case when vodcast is integrated with secondary physics students at a public high school in urban Ohio. Marencik [22] revealed that the use of revision vodcast significantly increases students' assessment scores although it does not support that there is an influence on students' deep approach to studying.

Meanwhile, there have been numerous positive claims on the effects of PhET sims on students' academic achievement and engagement. For instance, Ndihokubwayo *et al*. [23] presented that using PhET simulations to secondary students obtained a highly significant difference and a Cohen's D medium effect size on their conceptual understanding of geometric optics compared to students under the usual teaching methods. This indicates that teachers can deliver the instruction well with this intervention. Similarly, study by Taibu *et al*. [24] found that acquiring science/scientific skills and abilities can be achieved by implementing cooperative and inquiry-based PhET activities highlighting the statistically significant gain in the confidence level in doing science. They have also found that the students perceived that PhET simulations help learn both content and process and that the majority is positive in the usage of these simulations. The study of Rahmawati *et al*. [25] implicated that the use of PhET simulation can help teachers in explaining and visualizing the concept of chemical equilibrium. However, Yunzal and Casinillo [26] found that PhET did not significantly improve students' learning in electrodynamics courses, although there is a slight improvement in their performances from the pre-test to the post-test, and that students find playing simulations to be interesting.

On the other hand, the STEM lesson approach can enhance learning gains among students and promote a positive attitude. STEM teaching can potentially improve engagement among students through educational novelty [27], and provides a context for leading students towards problem-solving, higher-order, and critical thinking abilities, efficient use of available materials, curriculum innovation, and integration among other skills such as result from examining complex situations, building prototypes, and observing outcomes [28], [29]. Moreover, STEM education allows learners to view the world as a whole which makes it a hands-on approach [30], [31] and has the capacity to improve students' higher-order thinking skills (HOTS) ability [32]. Aurandt *et al*. [33] stressed that STEM education has the capacity to improve learning and the accomplishment of learning objectives. Student motivation and attitude [34], [35], and adaptation of the necessary 21st-century skills [36], [37] have also been evident in STEM education. In this study, the STEM lesson is based on the proposed theoretical framework of the STEM education teaching approach as an inquiry from the context-based by Sutaphan and Yuenyong [38]. This teaching approach consists of seven stages which include: i) identification of social issues; ii) identification of potential solution; iii) need for knowledge; iv) decision-making; v) development of prototype or product; vi) testing and evaluate the solution; and vii) socialization and completion decision stage.

However, even with the presented benefits of vodcasting, PhET simulations, and STEM lessons, the use of these methods has not been widely observed. Thus, there is a high necessity for studies to further establish the relevance and evidence on the use of STEM lessons, vodcast, and PhET simulation. This is to address the problem of learning the concepts of thermodynamics such as heat and temperature. That is why this aimed to develop a vodcast on heat transfer with the integration of PhET simulation to better demonstrate and explain the content and used as a substantial tool in a STEM lesson plan on clay oven development using local resources. Figure 1 shows the general concept of the research demonstrating the interplay of vodcast, PhET simulation and local resources in crafting a contextualized STEM lesson.

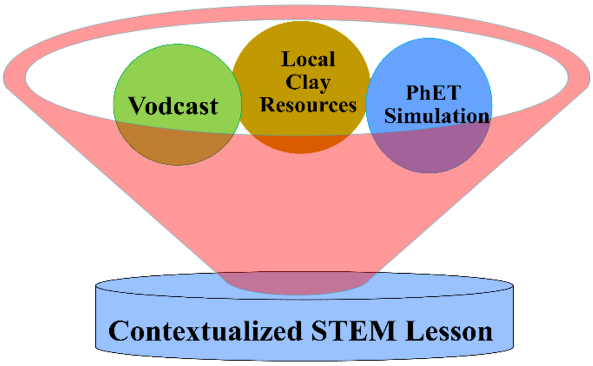

Figure 1. The general conceptualization of the research

The STEM lesson is based on the proposed STEM education theoretical framework as examining the context of each student [38]. Further, while the usual method of conducting a STEM lesson is to let the students create a prototype to solve a given social issue, this study used a different scheme. In this, the researcher first created the clay oven prototype with varying parameters to have answers to the 'what-if' questions when implemented. in the actual class setting. This idea is anchored on the context that teachers should be first knowledgeable on the content and the product for them to scaffold in a more effective way during the actual conduct of classes based on the zone of proximal development (ZPD) concept by Vygotsky where he emphasized the importance of scaffolding, which is basically working in collaboration with a skilled teacher or a more knowledgeable other (MKO) to make connections between concepts [39]. Thus, this study specifically sought to: i) develop a contextualized STEM lesson on heat transfer anchored on the observed clay oven production process; ii) explore the different parameters of clay oven production and identify crucial components of the clay oven production process; and iii) develop a vodcast integrated with PhET simulations as part of the STEM lesson.

2. METHOD

2.1. Procedure

This study utilized a developmental research design which mainly focuses on the design and development as well as its consequent evaluation of a particular created instructional intervention. The development is specifically guided by the successive approximation model (SAM) as its analytical framework. The SAM, developed by Dr. Michael Allen of Allen Interactions, is an abridged version of the analysis-design-develop-implement-evaluate (ADDIE) model designed explicitly to prompt criticism and build approaches earlier in the process, and exemplify a repetitive rather than a direct process. This model contains three main parts: i) preparation phase composed of information gathering and background; ii) iterative design phase composed of design, prototype, and review; and iii) iterative development phase composed of develop, and evaluate [40], [41]. The details of proceeding in the STEM lesson and vodcast development are presented in Figures 2 and 3.

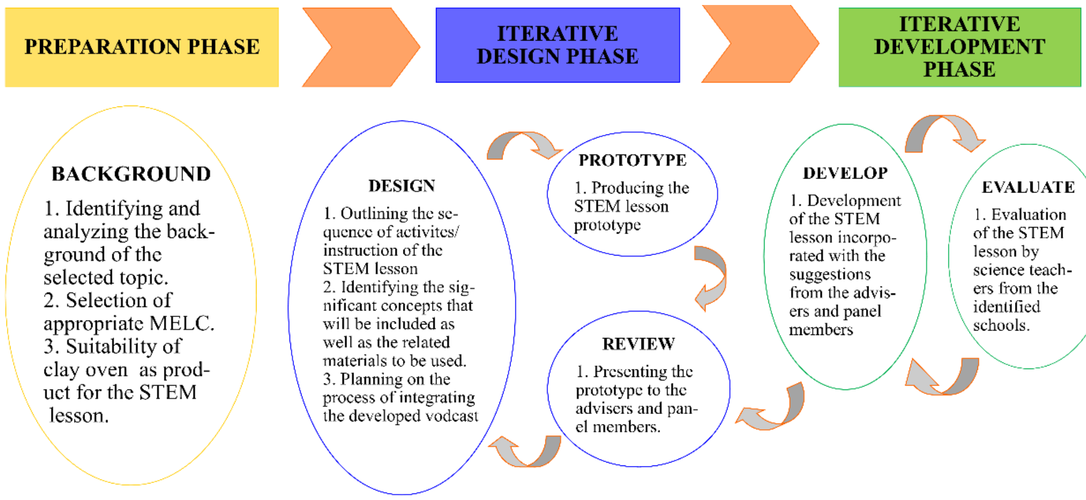

Figure 2. Step by step process of developing the STEM lesson using the SAM model

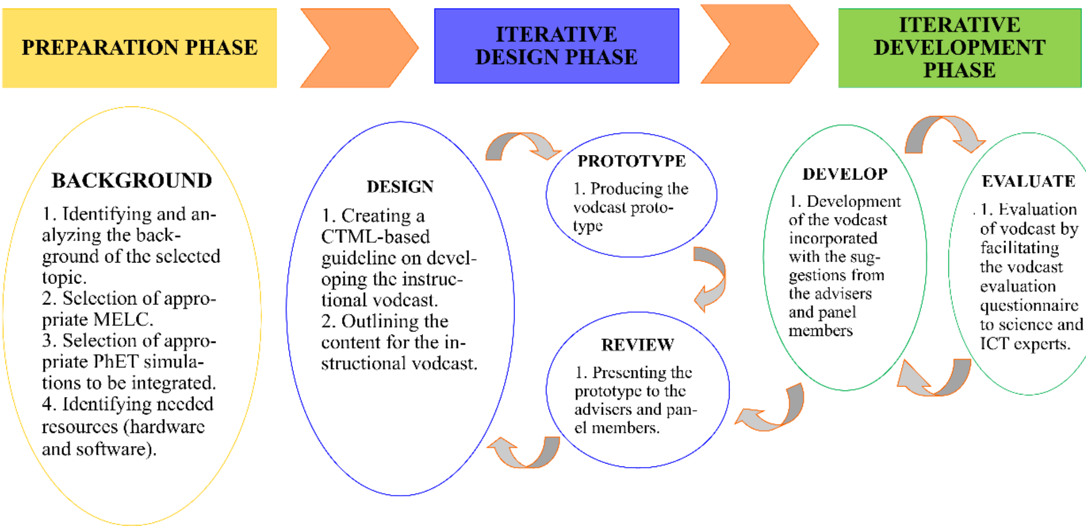

Figure 3. Step by step process of developing the vodcast using the SAM model

The evaluation phase used two instruments that were adapted and validated from previous research. The vodcast evaluation survey is a 12-item evaluation survey questionnaire adapted from [42] that is based on three indicators composed of content (4 items), delivery (4 items), and technical production (4 items) was used by 25 science and 15 information communication technology (ICT) teachers. Meanwhile, the STEM lesson evaluation survey is a 17-item evaluation survey questionnaire adopted from Tecson and Salic-Hairulla [43] that is based on four criteria composed of learning objectives (3 items), learning content (3 items), degree of contextualization (4 items), and STEM lesson stages (7 items) was used by science teachers. In the data analysis, mean and standard deviations were computed on the data gathered in the clay oven prototype exploration. On the other hand, mean scores for the survey questionnaires were computed and translated into its corresponding interpretation.

3. RESULTS AND DISCUSSION
3.1. Science, technology, engineering, and mathematics lessons
The development of the STEM lesson was guided by the SAM model. It started with the preparation phase where the background of the selected topic was reviewed based on the existing studies. It was found that there were gaps in learning thermodynamics. Part also of the preparation was the identification of the most essential learning competencies (MELCs) from the DepEd K to 12 science curriculum guide which include: i) constructing a model on proving that heat can do work; and ii) inferring how heat transfer is utilized in doing work and that it involves the release of heat. From these, the STEM lesson plan was outlined, prototyped, and reviewed during the iterative design phase.

Upon thorough examination and revision, the process entered the iterative development phase where the STEM lesson was crafted. It consisted of five learning objectives which were derived from the MELCs. The stages of lesson were based on the seven stages model by Sutaphan and Yuenyong [38] which include: First, identification of social issues stage, where the class was grouped and was tasked to think on the problems faced by most rural communities relative to cooking technologies and procedures. The situation about the price hike of petroleum products and electricity, as well as its relative possible effect on the household scenario, was also mentioned here. The teacher will then ask the learners about the possible alternative technologies that can minimize the use of petroleum products and electricity with the consideration of using available local resources.

Second, identification of potential solution stage, in which the teacher, together with the learners, conducted a buzz session and discussed the possible local resources that could be used to craft their own cooking technologies with at least zero or minimal production cost. Additionally, the class analyzed whether the usual cooking technologies present in households can be augmented with other technologies that could address the price hike of petroleum products and electricity. The possible design of cooking technology such as stoves, and ovens, which can be installed in houses, were also considered, in terms of its usability, practicality, and durability.

Thirdly, need for the knowledge stage, of which the learners will watch a developed vodcast integrated with PhET simulation on heat transfer and related thermodynamics concepts and read and browse ways of improvising cooking technologies with the consideration of using local resources. In this stage, the clay oven exploration process was also considered. This was first done by the researcher which implies that the researcher made a change-hat scheme so that the development of the prototype is made clear.

Fourth, decision-making stage, where the learners will design a manual or guide on how to make or improvise a prototype which can be used for utilizing local clay with the application of the concepts of heat transfer and other related thermodynamics concepts. This is also the time for a draft to be drawn about their proposed design on crafting a cooking technology. The draft indicates the dimensions, specific location in the house, and other specifications to be used in the development. Further, learners were to design a digital infographic promoting the use of local clay on crafting cooking technology highlighting the type of clay, the location of where the clay is gathered, and the possible production cost (if any). Finally, the learners were also required to decide on the design that they are doing to work.

Fifth, development of a prototype or product stage, in which the learners would build the clay oven prototype, and create the digital poster-infographic. In the development, the learners may look at the clay oven exploration processes presented by the teacher. Sixth, test and evaluate the solution stage, where three outputs would be presented and evaluated. First is the cooking technology prototype which will be crude-tested via pizza-cooking, bread-baking, and water boiling, and in terms of its practicality and durability. Second is the digital poster-infographics which would be evaluated using a rubric in terms of the content, graphics, formatting, and word quality. Last is the graph, which would be created by comparing the results of each group in terms of temperatures attained by the product and other crude-test findings. This graph would also be validated by the teacher in terms of correctness and accuracy.

Seventh, socialization and completion decision stage, the final stage of the STEM lesson, where the learners would present their final outputs–the prototype of a clay oven, the poster-infographic, and the graph comparing their results. They would also present how to test and evaluate the usability of the clay-based oven prototype and how to duplicate it. Lastly, they would discuss whether their prototype is a good solution to the posed problem and how it can be improved based on their findings and comments to produce the final design. The activities incorporated in the STEM lesson highlight local problems, solutions, and resources.

Table 1 exhibits the mean rating, standard deviation, and description of each indicator in the STEM lesson evaluation survey questionnaire. Results show that the overall mean of the STEM lesson is 3.47, which emphasizes that the lesson plan is excellent. This is further supported by the individual mean ratings per indicator, where all of the indicators were rated excellent. The small values of the standard deviation likewise satisfy the criterion that individual scores/ratings of the evaluators are close to each other. These findings suggest that the STEM lesson is an excellent tool that can be used in teaching the identified topic and MELCs, increasing critical thinking [44]–[46], and promoting engagement as it considers student-centeredness, integrative nature, and features authentic real-world issues [47]. However, one evaluator provided a suggestion on the identification of the social issue stage. According to this evaluator, "*On identification of social issues, you may compare the different local/indigenous cooking methods-pugon, sinung-ag, and may be on the sugnod (fuel) types such as bagol (coconut shell), palwa (coconut palm) woods.*" This comment emphasized the contextualization of not just the product to be developed but also the associated materials that are relevant to the product, such as the fuel. This further reiterates the significance of considering contextualization since the learning process becomes meaningful when students' knowledge and learnings are directly related to their personal or community interests, and directly adhere to the values assigned by society [48].

A study by Yadav and Oyelere [49] on the development of a contextualized mobile game revealed that it enhanced cognitive behavior together with the notable learning progress of the students. The paper of Eguchi *et al*. [50] on contextualizing K-12 artificial intelligence (AI) education by making it culturally responsive argued that one must be critical in the development of curriculums or lessons such as in AI literacy since it must ensure that the resources and teaching tactics incorporated are appropriate and meaningful towards the learners. These studies support the value of contextualization because through this, learners' will be able to connect their learning with their culture, tradition, or norms which will make them more engaged and interested.

Table 1. Mean rating, standard deviation, and interpretation of the STEM lesson evaluation

Indicator	Mean rating	Standard deviation	Interpretation of responses
Learning objectives	3.47	0.048113	Excellent
Learning content	3.50	0.083333	Excellent
Degree of contextualization	3.44	0.157747	Excellent
STEM lesson stages	3.46	0.081325	Excellent
Overall mean	3.47		Excellent

3.2. Clay oven exploration

During the clay oven exploration, there were certain methods that had been explored. These methods were refined and followed in the fabrication process. The clay oven development directional flow processes are presented in Figure 4. The process started with a soil sample collection, followed by the soil processing and refinement with five cyclic stages which consist of drying, pulverizing, sieving, soaking with water, and stamping. This is then followed by the actual clay oven development. The oven had an internal height and diameter of 12 inches and two thickness variations (5 and 7 inches).

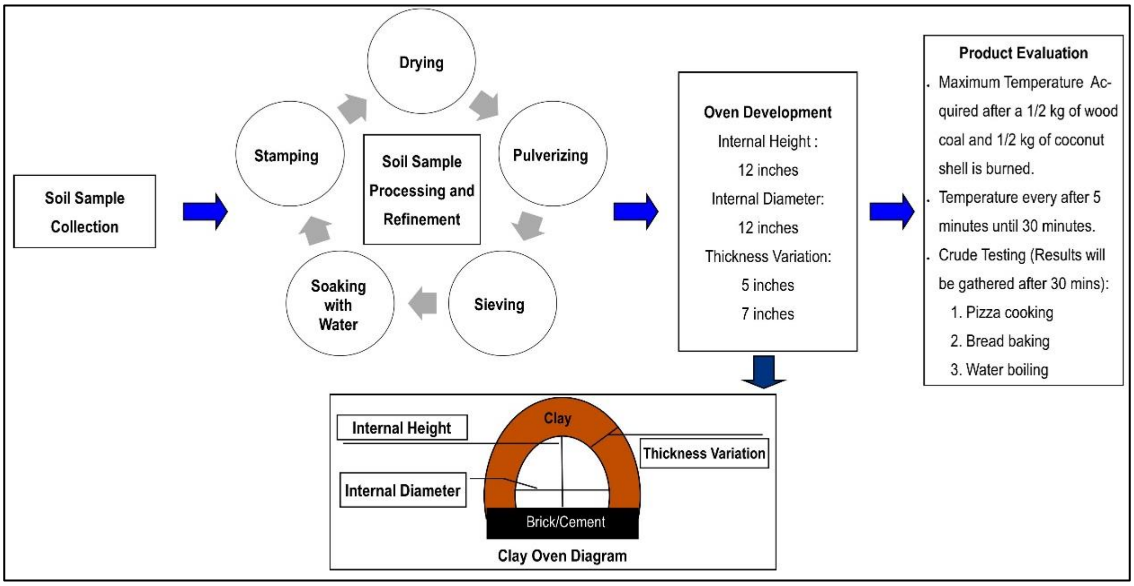

Figure 4. Development of clay oven directional flow

When the clay oven was developed, it was then evaluated by measuring the temperature after ½ kg of coconut shell and ½ kg of wood charcoal was burned for the first 30 minutes (with five minutes interval per reading). Simultaneous to the temperature reading was the cooking of pizza, baking of bread, and boiling of water. Moreover, the clay ovens that were fabricated were dried for approximately a month; after this, they underwent an evaluation process. Figure 5 shows the mean temperature readings per thickness variation. These were based on three replications for the first 30 minutes after 1 kilo of fuel was burned (½ kilo wood coal and ½ kilo coconut shell). Results show that a 5-inch-thick clay oven attained an average temperature of 192.83 ºC and a temperature of 113.57 ºC after 30 minutes. Meanwhile, the 7-inch-thick clay oven attained an average temperature of 186.67 ºC and a temperature of 122.27 ºC after 30 minutes. The difference in the temperatures of these two-thickness variations is not big, which suggests that the thickness is not a determining factor of how much heat can be obtained and stored. This is strengthened by the standard error bars indicated in the same figure.

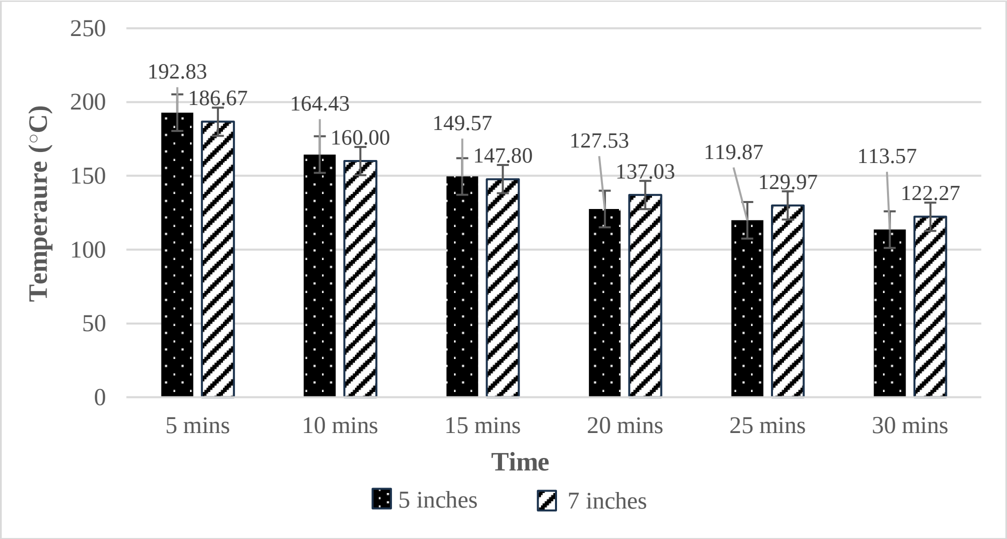

Figure 5. Recorded temperatures inside the thick oven

However, the rate at which the temperatures were decreasing implies that there should be factors that need to be addressed. These include the compactness of the oven and as much as possible there should be minimal to no cracks since the heat could be expelled from these. This is supported by Akinoso *et al*. [51], where they have reported that heat is lost through the walls, floor, and door of the oven.

Simultaneous to the temperature readings were the bread baking, pizza cooking, and water boiling. Figure 6 shows the quality of the bread and pizza before and after 30 minutes these were heated inside the clay oven. It could be observed that the bread and pizza dough attained a light brown color, which suggests that it is cooked as well as the hotdog and pizza toppings. These findings imply that the heat inside the oven is capable of baking and cooking. Similarly, 500 ml water at an initial temperature of 27.2 ºC reached up to 93.6 ºC after 30 minutes inside the oven.

Figure 6. The pizza and bread before and after they were cooked inside the oven for 30 minutes

3.3. Vodcast

The gap on thermodynamics and the selected MELCs as discussed in the preparation phase of the STEM lesson also played a role in the vodcast development. This is compounded by other parameters such as the PhET simulation and the Filmora editing software and other hardware needed. From the initial information gathered and preparations, the vodcast was designed, prototyped and reviewed. There were suggestions and comments that were considered and incorporated in the actual development. The content of the developed vodcast was composed of the definition of heat, concepts of thermal equilibrium, conservation of energy, how heat works, and the modes of heat transfer. This version of the vodcast was evaluated by science and ICT teachers.

Table 2 shows the results of the evaluation of vodcast. The data show that the vodcast had an overall mean rating of 4.37, which is described as very satisfactory. This can be interpreted that the vodcast is very useful as a supplementary learning material for the topics related to heat and is strongly recommended for use on the same topic in both in-person classes and MDLM of instruction. In fact, research shows the applicability and usefulness of vodcasts such as in skills development, complex problem solving, and knowledge acquisition [52], [53], and motivation enhancement and students interacting with their teachers [54]. Moreover, the rating of vodcast as very satisfactory is coherent with each individual indicator having a very satisfactory rating as well as closely related with each other by looking at the small standard deviation. This emphasized that the evaluators found the vodcast to have satisfied all three indicators in vodcast technology development. This result is particularly important since it is also in consonance with the study of Hashtroodi and Yazdanimoghaddam [55], where they have emphasized the need to consider quality, presenter features, technical features, scientific features, and marketing in crafting vodcasts.

Table 2. Mean rating, standard deviation, and description of the vodcast evaluation

Indicator	Mean rating	Standard deviation	Description
Content	4.53	0.048029	Very satisfactory
Delivery	4.22	0.147059	Very satisfactory
Technical production	4.37	0.205882	Very satisfactory
Overall mean	4.37		Very satisfactory

4. CONCLUSION

The outcomes of the study show that the developed contextualized STEM lesson plan was an excellent tool for teaching heat transfer and related thermodynamic concepts. This was strongly supported by the result of the clay oven fabrication which demonstrated that it can contextually show how heat works, and its related concepts, and the developed vodcast which was very satisfactory and essentially useful as a supplemental learning resource on heat and was highly commended for use on both face-to-face and MDLM modality. With these, teachers could easily utilize vodcast and local resources in STEM lessons to contextualize the teaching of heat transfer and related thermodynamic concepts. Overall, this study implies that integrating contextually responsive and technology driven learning strategies and materials can help STEM education.

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