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Design and Evaluation of Demonstration Tools for Newton's Law of Motion

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Abstract In the absence of readily available teaching resources and laboratories, science teachers are often challenged to improvise instructional tools and materials. This study is aimed to design and evaluate indigenous toy carts intended for teaching Newton's Law of Motion. Fifteen science teachers from two public high schools were asked to evaluate the developed indigenous toy carts using an evaluation form. A randomly selected intact class of Grade 8 students was also asked to perform a physics activity using the instructional tools developed by the researchers and evaluate the experience using an adopted Intrinsic Motivation Inventory. The demonstration tools were rated at most as acceptable by science teachers on constructional appearance and economy; ease of construction and scientific rigor and usability. Majority of the Grade 8 students found the activity with the indigenous carts interesting and enjoyable. It is recommended that science teachers be given more training and workshops on instructional tools and materials development to enhance the science experience of students.

Keywords: *instructional tools, teaching aids, group activity, cooperative learning, collaborative learning, experiential learning, physics activity*

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1. Introduction

Students' perception of the difficulty of science and their discouraging experience in the science classrooms may affect their development of science identities, participation and aspiration in science, engineering and medicine [1]. Moreover, there are very few science advocates at school and at home to encourage students to pursue science. The absence of interest for science among high school students can be translated to under subscription of science degree programs in the tertiary level. This could mean few future scientists and technologists to help fuel economic growth. The country does not only need to increase the number of its citizens who are involved in different science careers, there is also a need to improve the scientific literacy of the general public.

Scientific literacy is helpful in making wise choices in consumer products as well as for taking good care of the environment. Thus, a good science education is essential for all. This is something that science educators must address in their classrooms. There are already a number of researches that aimed to determine how students become interested in science and how they learn better. For example, students are strongly motivated to study physics if the science teacher is inspiring; students are already interested in a career in science and there are opportunities for collaborative learning [2].

Collaborative learning in a physics class is usually in the form of group activities where in students perform experiments or do inquiry tasks. The researchers observed that there is a lack of functional physics laboratory in most public high schools to support classroom activities and demonstrations of physics concepts. Physics teachers are resourceful in the sense that they provide for the materials that they can use to teach a concept. Unfortunately, some science educators may find it burdensome to always dip on their pockets to buy ready-made instructional tools aside from the challenge of finding a supplier that offers affordable science demonstration kits.

Students learned by doing and when learners are engaged in activities that include manipulatives, they understand and retained the concept better than just hearing about it. Instructional materials add elements of reality by providing concrete examples to learning. In science class, particularly in Physics, teaching aids and laboratory apparatus are needed to supplement the teacher's lecture discussion to provide students with meaningful learning experiences. The researchers considered this as a problem that can be easily addressed.

This study is focused on the design and evaluation of demonstration tools to teach Newton's Law of Motion to high school students enrolled in a public school. The materials for such demonstration tools are actually indigenous or recyclables to address affordability and exercise creativity. The researchers designed toy carts from various materials which are readily available and intended for disposal. The study is anchored on the guiding principles of science education curricula that say school science should nurture interest in learning and science is both content and process [3].

It is also anchored on the Experiential Learning Theory. The philosophy of experiential learning focuses on experience as the most important tool for learning. The premise of experiential learning is that individuals are capable of creating their own knowledge through the transformation of their lived experienced into existing cognitive frameworks, thus causing individuals to change the way they think and behave [4]. According to the experiential learning theory, "learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming of experience". Unlike traditional classroom situations such as those using highly structured instructions where students tend to compete with one another or become uninvolved or unmotivated, students in experiential learning situations are engaged in cooperate and collaborative learning in a more semi-structured approach. Instruction is designed to engage students in direct experience which are tied to real world problems and situations which the instructor facilitates rather than directs students' progress. The focus of this principle is placed on the process of learning and not the product of learning. Proponents of experiential learning assert that students will be more motivated to learn when they have a personal skill in the subject rather than being assigned to review a topic or read a textbook chapter.

1.1. Objectives of the Study

In this study, the researchers intended to utilize locally available materials to produce demonstration kits such as toy carts that can be used to conduct practical lessons for Newton's Law of Motion and demonstrate the concepts. Therefore the study aimed to design and evaluate the resulting improvised apparatus intended for teaching physics lessons particularly Newton's Law of Motion.

The objectives of the study are:

1. To design and construct an improvised apparatus that will help students understand Newton's Law of Motion.
2. To develop a student's activity and teachers' or user manual for the developed apparatus
3. To evaluate the improvised apparatus be determining its acceptability in terms of:
   3.1 constructional appearance and economy
   3.2 convenience and rigor
   3.3 usability
4. To determine the reflections and insights of Grade 8 students of the prepared activity using the developed toy carts.

2. Methods

The study used mixed qualitative and quantitative research design. There are three stages in the study. The first stage included the identification of physics topics, design of improvised demonstration kit and construction of toy carts. The researchers designed five carts made from different materials such as plastics, wood, rubber, tin cans and other recyclable materials that can be useful in making a functional cart for demonstrating Newton's Law of Motion. The second stage is focused on the pilot testing of the developed toy carts for its appropriateness to the physics topic and activity. The third stage is the presentation of the developed toy carts to teachers from two public high schools for evaluation using an adopted evaluation instrument. The instrument made used of a four point Likert scale (4 for very acceptable, 3 for acceptable, 2 for moderately acceptable and 1 for not acceptable) on the following areas: construction appearance and economy; ease and scientific vigor; and usability. Mean and standard deviation were used to describe the data gathered from the evaluation. Grade 8 students enrolled in a public high school were asked to perform a physics activity using the developed toy carts. The Grade 8 students were also asked to answer an adopted inventory on their perceptions about the science activity performed. The Intrinsic Motivation Inventory which is guided by Self-Determination Theory of Deci and Ryan allowed the students to rate their experience with the activity in terms of the three criteria: (1) interest and enjoyment, (2) value and usefulness and (3) perceived choice. The data was scored and interpreted based on the scoring guide provided for the inventory. The researchers did the data analysis and interpretation.

2.1. Research Respondents

The respondents of the study were fifteen science teachers in public high school A and public high school B together with the randomly selected intact class composed of Grade 8 high school students of public high school A. The researchers sought the permission from the school principals and the evaluation was conducted separately for the two public high schools during an in-service training of science teachers. The students' consent to participate in the study was also sought as required by the Division Office of the Department of Education.

2.2. Research Environment

The science teachers who evaluated the instructional tool came from two public high schools. Public High School A has 78 teaching and non-teaching staff, twenty (20) of whom are males and fifty eight (58) of whom are females. The school has one (1) Master Teacher II, two (2) Master Teacher I, nine (9 Teacher III and 61 Teacher I. Among the 78 teachers, 76 teachers met the desired competencies based on the National Competency-Based Teaching Standards (NCBTS). The school-based in-service training that is usually conducted during May and October as a mechanism to improve teacher's competencies is given priority in the school's budget. Among the training needs of the teachers are the following: Technology in Teaching and Learning Process, Action Research and Teaching Strategies. On the other hand, Public High School B is located near the coastline of Macajalar Bay. It is about one (1) kilometer from the nearest private elementary and secondary school. It is also less than one hundred (100) meters away from the nearest public elementary school. Public High School B has a total of 1,027 students. There are thirteen (13) classrooms with an average class size of 79 students. There are forty-one (41) teachers with 5 male and 36 female teachers employed at present. All teachers are nationally-funded, meaning their salary is drawn from the national government. There are no master teachers in this high school. All teachers have met the teaching standards. There were also interventions implemented to improve the competencies of the teachers in the form of in-service training conducted regularly.

3. Results and Discussions

The challenging part for this particular study is on the design and choice of materials to construct it with. The researchers also consider the physics topic and what concept the toy will cart will demonstrate. If the toy cart is supposed to carry weights, what kind of body and wheels should it have? It must be sturdy enough as weight-bearing cart. Dimensions were also considered and if ever ramps will be used in particular physics activity. Moreover, the toy cart must be well-balanced so that it will not easily topple during the activity. Additional challenge is the availability of a good cutting tool for precision and accuracy of proposed dimension. Designing and creating the actual product are problematic for a science teacher who did not have a formal training for it. Below are some of the sample designs. Other designs can be found in the appendix.

The researchers thought of making the cart attractive for Grade 8 students in physics. Young people are normally attracted to colorful designs and unusual look. Nevertheless, the researchers ensure that the car or carts can still function properly when pushed across the floor or made to slide down a ramp.

Figure 1. Toy Cart Design 1

Figure 2. Toy Cart Design 2

3.1. Teachers' Evaluation of the Toy Car/Cart

The 15 science teachers were given the evaluation instrument that contains the evaluation criteria. They were allowed to closely examined the toy cart and check for its functionality and durability. Some of the teachers also asked on the duration or time needed to construct the toy cart from the recycled materials.

Table 1 shows that majority of the teachers rated highly on the innovativeness, availability and affordability of the materials. However, the science teachers only rated the over-all appearance and compactness and portability of the toy cart as "acceptable".

Table 1. Results of Science Teachers' Evaluation of the Toy Cart

Criteria	Mean	SD	Interpretation
Constructional Appearance & Economy			
1. The device is an innovation	3.6	.51	*Very acceptable
2. The device is compact and portable	3.4	.65	Acceptable
3. Overall appearance of the Device	3.4	.65	Acceptable
4. Materials used are locally available	3.9	.26	Very Acceptable
5. Materials used are affordable	3.9	.26	Very Acceptable
Overall	3.7	.38	Very Acceptable
Ease of Construction and Scientific Rigor			
1. Ease for preparation	3.3	.59	Acceptable
2. Duration to set up the device	2.9	.88	Acceptable
3. Helpful for learning Newton's Law of Motion	3.2	.56	Acceptable
4. Effective in demonstrating the concepts of Newton's Law of Motion	3.3	.79	Acceptable
5. Helpful to other lessons such as work and energy	3.5	.64	Very Acceptable
Overall	3.3		Acceptable
Usability			
1. The device enables the concept to be efficiently explained to and understood by the student.	3.5	.64	Acceptable
2. The design can be presented and demonstrated in a simplified manner.	3.4	.63	Acceptable
3. The toy cart is appropriate as instructional materials	3.4	.63	Acceptable
4. The toy cart is useful for science activities that can be used as a supplement to traditional lecture.	3.8	.41	Very Acceptable
5. The toy cart may helped students retained the concepts of Newton's Law of Motion better	3.7	.59	Very Acceptable
Overall	3.3		Acceptable

*3.5-4.0 Very acceptable 1.50- 2.49 – Moderately Acceptable
2.50 -3.49 – Acceptable 1.00- 1.49 – Not Acceptable.

During the informal discussion, some of the science teachers commented that the toy carts are “too colorful” and “seemed big” especially the wheels (discarded compact disks were used in one design).This might be because these science teachers expected the design to closely resemble commercially available toy carts or toy carts. They were not very comfortable with the ‘flamboyant” design. The science teachers also rated almost all of the items under ease of construction and scientific rigor as “acceptable” except for its usefulness for other topics such as work and energy. This might because they also believed that coming up with improvised teaching materials can be tedious especially the challenges in the design and construction. It would be very easy to just buy any commercially available toy cart that can be used to demonstrate Newton’s Law of Motion.

In terms of usability, the science teachers rated highly its usefulness for science activities and helping students retain the concept. This could be because the carts were very attractive and might appeal to Grade 8 students in physics. The researchers believe that learning is more possible once the students enjoy the activities in the science classroom.

3.2. Students’ Evaluation of the Science Activity

The students answered the adopted 25 item Intrinsic Motivation Inventory (IMI) where they would rate their experience with the activity in terms of the three subscales: (1) interest and enjoyment, (2) value and usefulness and (3) perceived choice using the scale below:

1 2 3 4 5 6 7
Not at all times somewhat true very true

The Intrinsic Motivation Inventory (IMI) is described as a multidimensional measurement device intended to assess participants’ subjective experience related to a target activity in laboratory experiments. The interest/enjoyment subscale often has more items on it than the others. It is said that the perceived choice and perceived competence concepts are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation.

Table 2 displays the results of the students’ evaluation of the activity using the toy cart.

Table 2 reveals that majority of the Grade 8 students rated highly the constructs interest and enjoyment and value and usefulness. The items on “perceived choice” was found to be confusing by the students as they usually would do what the science teachers would instruct them to do in the classroom. However, these statements should be taken as “being willing to be engaged” rather than being forced to perform the science activity. Maybe some of the students will be hesitant at first due to lack of motivation, but the researchers observed that the Grade 8 students were excited as they manipulate the colorful indigenous carts for the group activity. For most public high school, class size can be as big as 78 students in a classroom designed to contain 50 students. Getting everybody to be actively engaged in learning science concepts may be difficult at most times especially if delivered through lecture discussion. Fortunately the colorful toy carts attracted the Grade 8 students and made them curious to try the activity. The excitement was contagious and soon everybody was engaged in the activity. It was like play time in a science classroom.

Table 2. Students’ Evaluation of the Activity

Statement	Mean
Interest & Enjoyment	
1. While I was doing this activity, I was thinking about how much I enjoyed it.	6
2. This activity was fun to do.	6
3. I enjoyed doing this activity very much.	6
4. I felt like I was enjoying the activity while I was doing it.	6
5. I thought this was a very boring activity.	6
6. I thought this was a very interesting activity.	6
7. I would describe this activity as very enjoyable.	6
8. I would describe this activity as very fun.	6
Value and Usefulness	
9. I believe that doing this activity could be of some value for me.	6
10. I believe that doing this activity is useful for improved concentration.	6
11. I think this activity is important for my improvement.	6
12. I think this is an important activity	6
13. It is possible that this activity could improve my studying habits.	5
14. I am willing to do this activity again because I think it is somewhat useful.	6
15. I believe doing this activity could be somewhat beneficial for me.	5
16. I believe doing this activity could help me do better in school.	6
17. I would be willing to do this activity again because it has some value for me.	6
Perceived Choice	
18. I believe I had some choice about doing this activity.	5
19. I really did not have a choice about doing this activity.	5
20. I did this activity because I wanted to.	5
21. I felt like I had no choice but to do this activity.	5
22. I felt like I had to do this activity.	5
23. I did this activity because I had to.	5
24. While doing this activity I felt like I had a choice.	5
25. I felt like it was not my own choice to do this activity.	5

This kind of disclosure from students is an inspiration to provide for more experiential learning episodes in science classrooms. The more the students enjoy their science classes, the higher would be the change to promote a lasting interest to pursue a science career.

Motivational processes were found as strongest predictor of learners' commitment to science and choices of science-related college majors and careers [5]. These processes include efficacy beliefs and task valuing. Efficacy beliefs encompass students' ability to master science content; ability to perform well during science tests; and confidence in the ability to learn science. Task valuing, on the other hand, refer to students' finding science is interesting, useful and important to learn. In addition, hands-on activities can positively influence students' interest in science activities as quality of hands-on experience and interest are positively correlated [6].

Although teachers play a significant role in motivating students for science, it is the students who must exert active roles in the classroom and not merely go through the motion of participating in the class activity for compliance sake [7,8]. Active participation comes in the form of asking questions, volunteering answers to questions asked by the teacher and making presentation of outputs to the class. This emphasized that science teachers should include targeting the affective domain on top of pedagogy and content. After all, learning experiences are strong moderator in the development of science interest [7,9]. Achievement is also said to improved when there is intensive practice through active learning exercises involving peer interaction and exchange of ideas as well as development of higher order thinking skills [10,11,12,13]. We must not forget that students go for a career in science as a personal choice and not because of cognitive abilities [14,15,16].

It was discovered that students' interest in science can be awakened by hands-on and active learning activities [17]. Science educators, however, should exercise caution in the choice of activity to demonstrate the concepts as students tend to focus on the form of activity rather than the concepts or content and the learning objectives. This is reflected in the evaluation results from Grade 8 students and validated in the after activity discussion. Many of the students expressed that they like the activity because they found the toy carts fun to manipulate. While the evaluation form contains the construct, "interest and enjoyment", some researchers argued that interest is not the same with "enjoyment while learning" for enjoyment can occur for many reasons and interest is only one of these probable reasons [18]. Interest may be associated to the context, content and science activities and involves cognitive and emotional construct. Teachers must work to sustain the initial interest of the students to make its stable enough to significantly influence science career choice. In order to this, repeated enjoyable learning experiences may be provided in the science classroom involving varied modalities and strategies in teaching.

The researchers believe that it would be more helpful if the learning objectives be written on the board and explained to the students before the start of the activity. Moreover, the learning objectives should remain prominently displayed and be used as a guide during the after activity discussion and when giving the learning assessment to ensure that the students can stay focused on the concepts that must be learned. This study is limited to the design and construction of indigenous toy carts that may be used to teach Newton's law of Motion and evaluated by science teachers and Grade 8 students in a physics class. The study did not include evaluation on the effect of the science activity using the developed toy carts on the conceptual understanding of Newton's Law of Motion.

4. Conclusion

This study was able to establish the possibility of designing instructional tools that can be useful and acceptable in teaching physics concepts in public high schools. Provision of more trainings and workshops for the design and development on teaching tools and materials for science teachers are recommended. Teachers need support in terms of high quality sustainable professional development on constructivist-oriented learning process and technology integration that will show detailed evidence of student learning to ensure improvement in science education [19,20]. The creation of an Instructional Tool and Materials Committee in every public high school may also be considered to establish quality and standards for developed materials.

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Appendices

Sample Toy Car/Cart Designs

Figure 3. Toy Cart Made from Wood and Tin

Figure 4. Toy Cart Made from Tin Can

Figure 5. Toy Cart Made from CD and Sticks

Figure 6. Toy Cart Made from Various Material