Creative Teaching Aids, HOTS and Achievement in PISA

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Abstract

In this paper, the authors discussed that 21st century education outcomes should include the components of 4Cs: critical thinking, creativity, the ability to communicate clearly, and to be collaborative. Higher order thinking skills (HOTS) include transfer of learning in another context or situation, critical thinking and problem-solving. 21st century skills include HOTS. The authors conducted a workshop to introduce in-service teachers on how to prepare teaching aids. This article briefly discusses the methods of making three teaching aids and their purposes. The teaching aids clearly demonstrate clearly science concepts including forces and the effects of forces: such as gravity, tension in strings, friction, resultant force, and projectile motion. The respondents who are science teaechers observed that the three creative products, i.e. the "Climbing Monkey", the "Nail Motor" and the "Straw Rocket" could be used as toys to engage pupils in critical thinking and problem-solving, components of HOTS. Analysis of data was also made on the survey administered, in which science teachers agreed that these aids were useful to illustrate the laws of science, simple, inexpensive, as well as quick to make and to assemble. They also commented that pupils are likely stimulated to be more creative, and to be critical thinkers. This suggests that the making and using of creative teaching aids in active learning environment that fosters inquiry-oriented experiments, collaboration as well as communication among teacher and students will provide opportunities for students to practise and develop 21st century skills including HOTS. In addition, teachers who encourage students to make and use these teaching aids will likely enhance their own pedagogy. Developing students' HOTS and teacher pedagogy are factors that contribute to improving students' science achievements in PISA, the Programme for International Student Assessment that assesses what students can do with what they know. The authors conclude with the significance and implications of this study with suggestions for the way forward.

Keywords: Higher order thinking skills; 21st century skills; Pedagogical Content Knowledge; Creative teaching aids; PISA

Introduction

Background and Overview

Education in the 21st century is not just about retaining information of key subjects that we learn in school, as this is an era when information is so readily available from our mobiles, from Wikipedia, Youtube, Blogs, Bing. Facebook, Twitter, to name a few. In our present knowledge economy, we emphasize the 4Cs: **C**ritical thinking to evaluate what we read to obtain a conceptual understanding of complex concepts, and the ability to work with them **C**reatively to generate new ideas, new products and new knowledge. We must be able to **C**ommunicate clearly both verbally and in writing, as well as understand scientific and mathematical thinking. Our pupils need to be **C**ollaborative to be able to work with others, as much of scientific activity requires teams of workers with various skills, also they must be self-directed and able to take responsibility for their own continuing, life-long learning (OECD, 2008; Yeoh, Cazan, Ierardi, & Jacic, 2017).

Besides the 4Cs, our pupils need to gain life and career skills, as well as media and ICT skills (or in short, 21st century skills that include higher order thinking skills or abbreviated as HOTS) in order to live and interact in this 21st century (OECD, 2008; P21 Partnership for 21st century learning, 2006). HOTS comprise of three categories, including transfer (or the ability to apply what we learn and know), critical thinking (involving reflective thinking, reasoning, investigating, exploring viewpoints, comprehending, synthesizing, evaluating, comparing and connecting) as well as problem-solving (Collins, 2014).

Problem Statement and Rationale

Our country Malaysia has targeted a 60:40 student ratio for STEM (science, technology, engineering, mathematics) to non-STEM classes (Yeoh & Ierardi, 2015), but this has not yet been achieved (Chan, 2017). The quality of science teaching is an area of great concern especially over the past years with low rankings of our students' performance in Programme for International Student Assessment (PISA) exams that test reading abilities, math and science literacy (Liong, 2016). It would mean that our Malaysian schools are not preparing our pupils with knowledge and skills to be successful in a changing world that requires citizens to have scientific literacy, financial literacy and good communication skills. It would also seem that our schools are not preparing our young 15 year old students to use their knowledge and skills to navigate the challenges in the real world (OECD, 2008). According to Liong (2016), a suggestion that has been put forward was that our Malaysian students lack higher order thinking skills (HOTS). A second suggestion was that our teachers should possess good pedagogy and have sufficient pedagogical content knowledge (PCK). Teachers need to have mastery of the subject content and also the pedagogical knowledge of how students learn, how to motivate students (Yeoh & Ierardi, 2015), how students may become more self-directed and independent learners who take ownership as well as responsibility for their learning (Yeoh et al., 2017) and continue learning long after years of formal schooling (OECD, 2008).

As in other countries, teachers who have had limited science content and pedagogical content knowledge (PCK), and limited opportunities to engage in science experiments as well as investigations are less prepared and confident to engage their own students in experiments to build conceptual understanding (OECD, 2008; The National Academies Press, 2015; Wellcome Trust, 2014). Some teachers with poor pedagogic skills in science continue using only verbal explanations, without realising that science is the body of knowledge that students should discover for themselves through engaging experiments.

Furthermore, OECD (2009) clearly stated that teachers may either view the processes of acquiring knowledge by students as an active learning process where students actively participate, or as a passive process of information transmission. The first view is prevalent among teachers in northwest Europe, Scandinavia, Australia and South Korea, and least true among teachers in southern Europe, Brazil and Malaysia (OECD, 2009). The authors suggest that this correlates exactly with the difference in PISA scores that measure what students can do and apply with what they know (OECD, 2018), which happens to be the first category of HOTS as reported in Collins (2014). The OECD (2009, 2018) statements are in line with Liong (2016).

Teachers who are knowledgeable of the science content knowledge or possess pedagogical content knowledge (PCK) should have an understanding of learner characteristics, as well as how to spark interest in learning science while correcting misconceptions (Gudmundsdottir & Shulman, 1987). The authors believe that such teachers would be likely to involve students in active learning with preparation of teaching aids or models or audio visual aids that engage pupils in science learning.

The first author is aware of science learning in secondary schools where the laboratory is not used, and teachers insist on teaching in classrooms, based on their assumption that it is much easier to discipline students in the classroom than in a larger science lab. Another argument that some teachers put forward as an excuse for not carrying out experiments is that the laboratory in school does not have expensive models (to be used as teaching aids). Hence in this study, the authors will showcase that science models or teaching aids do not need to be expensive, or difficult and time-consuming to make or to assemble. Furthermore, certain teachers may have little desire to create multimedia teaching resources, but the first author found that fusing pedagogy with technology to create videos of biological processes greatly enhanced student interest, motivation to learn, and recall. An example of such a biological process is transcription of RNA (Yeoh, 2014). The video recording of the musical mnemonics for RNA transcription is available on the web as reported by Yeoh (2015).

Aims, Objectives and Justifications

This paper will discuss on how the making and using of creative teaching aids in the learning environment that foster inquiry-oriented experiments, collaboration and communication among teacher and students will provide opportunities for students to demonstrate higher order thinking skills (HOTS). Collins (2014) has already suggested that such learning environments provide a good opportunity to develop critical thinking; but the present authors extend to the possibility for students to develop HOTS and the other 21st century skills, more than just critical thinking as suggested by Collins (2014).

The following elaborations are made in response to the suggestions that Malaysian students lack HOTS, hence their poor performance in PISA exams (Liong, 2016). In this paper, the authors discuss three creative teaching aids for science, their purposes, and how to make them in an active learning environment. The three teaching aids are the “Climbing Monkey”, the “Nail Motor”, and the “Straw Rocket”. The justifications made by the authors are that the making and using of the three teaching aids will foster HOTS in our students; and teachers who approach the teaching of science with teaching aids that resemble toys to make learning fun, and relate well with students in an enjoyable learning environment that promote HOTS are employing effective pedagogy. The following are further elaborations.

1. In the first case exemplar, students are required to perform movements and observe the effects of the forces that they have applied. They are required to do and see, not just to listen or read. Students have to consciously perform the steps to create the “Climbing Monkey”. They have to tug at the strings of the “Climbing Monkey” and observe movement.

2. In the second case exemplar, students have to consciously perform the actions as described to create the “Nail Motor” and observe the magnets spinning around.

3. In the third case exemplar, students have to consciously perform all the actions to create the “Straw Rocket”. They have to blow forcefully into the launcher straw to launch the “Straw Rocket”. With the “Straw Rocket”, students are engaged to figure out the best angles to apply forces to the “Straw Rocket”. They experiment with various lengths of the launcher rocket straw, and they must exercise critical thinking to solve these problems at hand; and critical thinking is another category of HOTS (Collins, 2014). Students are analysing, synthesizing and evaluating; they are showing and exercising higher order thinking skills. They are being exposed to learning experiences that enable them to promote HOTS, and construct their own knowledge (Miri, David, & Uri, 2007).

The authors believe that doing what is closest to the real thing with these teaching aids will cause students to appreciate and be engaged in their learning even more as well as be rewarded with more knowledge recall and understanding rather than a passive method of learning by listening to the voice of a teacher (Davis & Summers, 2014). Students may even transfer this knowledge to their daily lives and apply this knowledge to solve daily academic and non-academic problems. Problem solving is a category of HOTS, just as transfer of knowledge is another category of HOTS (Collins, 2014).

Methodology and Implementation of Studies

Research Design and Sampling Technique

Case study approach is used for this piece of research with mixed-mode of data analysis involving survey questionnaire and observations. The researchers carried out a workshop with 34 in-service teachers through convenient sampling technique. All the respondents worked in groups of four or five participants. The participants made the teaching aid, and tried out how well it would work. After that, the respondents provided data on the questionnaires. The responses were collected immediately after each teaching aid was made, so that the respondents would not likely to be confused. Since this is an initial effort, the researchers only asked for a Yes/No response (This is a point can be improved in future research). The researchers facilitated the process and carried out casual discussions with the respondents to understand what they thought about the usefulness of each teaching aid, in relation to improving higher order thinking skills (HOTS) among students.

Implementation and Elaboration of Case Exemplars

This section provides a brief description of three teaching aids as case exemplars on how low cost materials can stimulate students’ thinking to learn science with fun. In each case exemplar, the authors will also discuss the methods of making the three teaching aids. The findings from surveys that were administered to obtain the opinions of science teachers concerning the teaching aids are also elaborated in the subsequent sections.

It is hoped that use of innovative teaching aids from inexpensive materials, may lead to teaching for creativity to be imbibed by pupils (Jeffrey & Craft, 2004). By using the teaching aids that make the science content relevant, pupils take ownership, responsibility and control of their learning experience. The hands-on, minds-on active engagement of students may encourage innovation and creativity besides HOTS (Collins, 2014). Our pupils may practise divergent thinking (Guildford, 1975), and wonder what other uses can plastic straws, magnets, aluminium pipes, and strings be put, to produce other innovations. The authors hope that innovative teaching may provide opportunities for our pupils to solve problems in innovative and creative ways, also develop new ideas, products and make good use of their knowledge in daily life (OECD, 2008; 2018). In the valuable time that we have with students, we want to engage them with their learning, to facilitate the development of 21st century skills and higher order thinking skills (HOTS) (Collins, 2014; Yeoh, 2017) .

Case exemplar 1: Teaching Forces with Fun Science Activities and Feedback from Tryout
The "Climbing Monkey" is a teaching aid to teach students about forces in secondary school. Students will find the teaching aid stimulating and learn about gravity, tension in the string, friction and resultant force. The authors are of the opinion that one of the traditional methods to teach resultant forces was not so interesting. The materials used for the climbing monkey (Figure 1) such as cardboard, plastic drinking straw, and a thread are low-cost materials. Hence, this is a suitable teaching aid that is easy for teachers to make, and to use it for their lessons and students also can enjoy it at their home. It appeals to humour and show that learning can be fun.

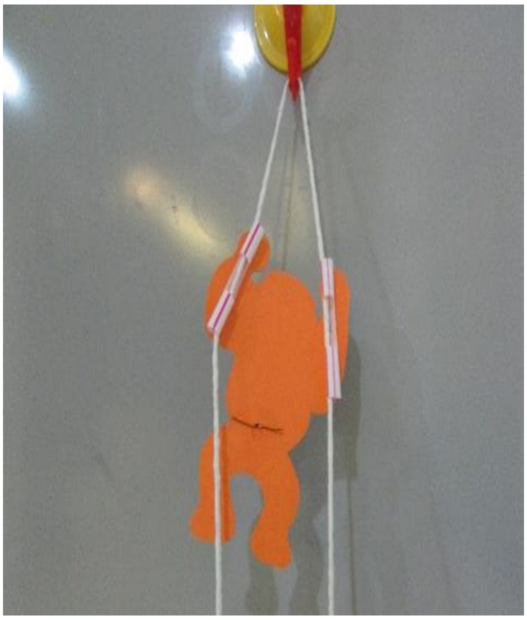

Figure 1. Assembling the "Climbing Monkey".

During implementation of activities, the authors first discussed the following method of how to make the "Climbing Monkey".

1. Cut out the picture of the monkey by cutting along the outline on a stiff card board.
2. Fix the two short pieces of plastic straw of the same length, and at the same angle as the monkey's arms on the back side of the monkey.
3. Thread the two straws and connect the both ends of the string.
4. When assembled, pull one side of string downward, and later pull the other string. Then repeat the actions. The monkey will be seen to climb up. The above Figure 1 and the following Figure 2 illustrate how this teaching aid looks like.

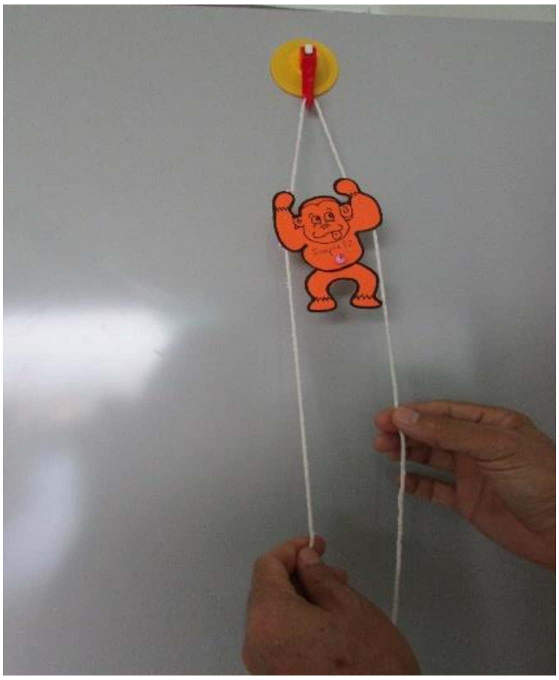

Figure 2. Pulling the strings to move the "Climbing Monkey" upwards.

When pulling the strings, students must be aware of friction, gravity and resultant force that moves the monkey upwards. They can feel the forces and observe the effects of these forces. However, the traditional method by which students were taught about resultant force was by this familiar diagram, Figure 3. With the "Climbing Monkey" teaching aid, students can feel the forces, that they would not be able to do before while listening to the teacher's verbal explanation of Figure 3. The likelihood of students recalling their ability to apply knowledge, synthesise and evaluate knowledge that is taught by the traditional method is not high, as students are not engaged in doing any actions, only listening and looking at the teacher (Davis & Summers, 2014).

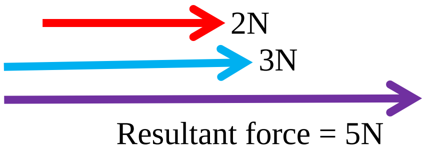

Figure 3. Traditional method of teaching resultant force.

After the lesson, a survey was administered to obtain feedback and analysis of findings will be reported in the next section.

Case exemplar 2: Teaching Fleming's Law with Fun and Feedback from Tryout
The second teaching aid is the "Nail Motor" (Figure 4). It is for teaching Fleming's law. It is interesting as a teaching aid. It is also easy and fast to assemble in class. Nowadays, we can get the small strong magnets easily at low price, at any shop selling household products. Students may find it exciting to see that the nail is spinning by using these simple three items: a nail, magnets and a dry cell. It may give a strong science impact on students' interest and motivation to learn science, as they see how a scientific law operates, before their very eyes.

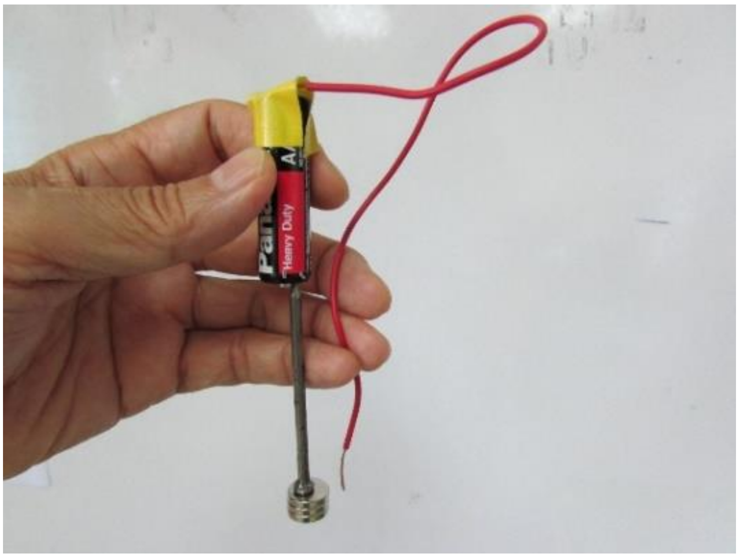

Figure 4. The “Nail Motor”.

These are the steps to make the “Nail Motor”.

1. Contact three sets of small strong magnets with the blunt (or flat) end of a nail. (The nail will be magnetized)
2. Contact the magnetized nail with the bottom (negative terminal) of a dry cell.
3. Connect a conducting wire with the top of dry cell, and then touch the other side of the conducting wire lightly at the side of the magnets.
4. The magnets will start spinning around.

The “Nail Motor” illustrates Fleming’s Left Hand Law. Fleming’s Left Hand Law states that when a current carrying conductor is placed inside a magnetic field, a force acts on the conductor, in a direction perpendicular to both the directions of the current and the magnetic field. This rule applies to the electric motor, the “Nail motor” in this case. Fleming’s Left Hand Law is described by Daware (2014), and Figure 5 illustrates the forces acting on the “Nail Motor”.

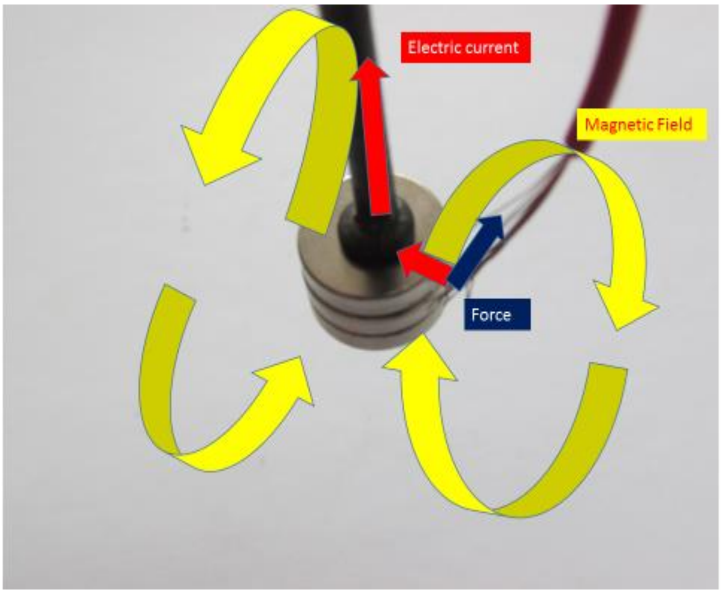

Figure 5. Forces acting on the “Nail Motor”.

After the lesson, a survey was administered to obtain feedback and analysis of findings will be reported in the next section.

Case exemplar 3: Teaching Projectile Movement with Fun and Feedback from Tryout
The third teaching aid is the "Straw Rocket". It is useful to teach projectile movement. Students can play with it. It is cheap and easy to make. Pupils can observe projectile motion in class. Students also can learn the concept of air pressure and inquire how the straw rocket will be able fly away by changing the position of fins on the straw or changing the length of the rocket.

Figure 6. The "Straw Rocket".

These are the steps to make the "Straw Rocket".

1. Prepare two straws which are slightly different in diameter. One of the straws (the thinner straw) will be a launcher, and it is better to have a tilted or bent section near the edge for blowing.
2. Push a rubber plug cut out from a rubber slipper material into the free end of the rocket straw.
3. Then, fix the fins made of paper which will control the direction, on the rocket straw.
4. Put the rocket straw into the launcher straw. Then, strongly, blow the launcher straw.
5. The rocket straw will fly off following the path of parabola shape. (Figure 7 shows pupils playing with the "Straw rocket".)

Figure 7. Pupils playing with the "Straw Rocket".

After the lesson, a survey was administered to obtain feedback and analysis of findings will be reported in the next section.

Data Analysis and Discussions

In this section, we discuss how we carried out a survey to obtain the feedback and comments of teachers who attended a workshop where the three teaching aids were shared. The teachers assembled the teaching aids, and they realized that effective teaching aids could be made from inexpensive and easily available materials.

Teachers gave their responses concerning the three teaching aids, giving a Yes/No answer to each question. The results of the survey are discussed in the next section. Table 1 is the brief feedback questionnaire provided to gauge responses of participants on each teaching aid. The content validity was confirmed by three education specialists of SEAMEO RECSAM.

Table 1.
Questionnaire for Teacher Feedback on Each Teaching Aid. Teachers Tick Their Response.

Statement	Yes	No
This teaching aid assists the teaching and learning of science.		
This teaching aid helps to teach the science content.		
This teaching aid helps students to understand the science content		
This teaching aid helps to build conceptual understanding in students.		
This teaching aid helps students to enjoy the science lesson.		
This teaching aid may motivate students to be more active in learning.		
This teaching aid may motivate students to be more creative.		
This teaching aid may motivate students to be critical thinkers.		
This teaching aid may motivate students to find uses for recycled materials		
This teaching aid is cheap to make.		
This teaching aid is easy to assemble in class.		
This teaching aid is quick to assemble in class.		

The materials for this teaching aid are easily available.
Low cost materials and/or recyclable materials can be used to make this teaching aid.
Other views….

How can we improve the teaching aid?

The number of teachers who provided feedback was 34. Tables 2, 3 and 4 show the responses of the teachers concerning the three teaching aids: the “Climbing Monkey”, the “Nail Motor” and the “Straw Rocket”.

With regards to the “Climbing Monkey” activity, 100% of the teachers agreed to all the points that the researchers considered important to the learning of science (Table 2). The comments belong to three groups namely: “Helps students to understand and enjoy science”, “Motivates students to be active, engaged, critical and creative”, and “Easy, quick and cheap to make”.

Their further comments on Table 2 showed that they agreed that the teaching aid is likely to be lasting for normal usage since it is made from hard board, and would appeal to fun-loving secondary school teenagers. One of the teachers even mentioned that the teaching aid will be enjoyed as a toy.

Table 2
Questionnaire for Teacher Feedback on the “Climbing Monkey”

Statement	% Yes
This teaching aid assists the teaching and learning of science.	100
This teaching aid helps to teach the science content.	100
This teaching aid helps students to understand the science content	100
This teaching aid helps to build conceptual understanding in students.	100
This teaching aid helps students to enjoy the science lesson.	100
This teaching aid may motivate students to be more active in learning.	100
This teaching aid may motivate students to be more creative.	100
This teaching aid may motivate students to be critical thinkers.	100
This teaching aid may motivate students to find uses for recycled materials	100
This teaching aid is cheap to make.	100
This teaching aid is easy to assemble in class.	100
This teaching aid is quick to assemble in class.	100
The materials for this teaching aid are easily available.	100
Low cost materials and/or recyclable materials can be used to make this teaching aid.	100

Other views….

1. Excellent, Impressive
2. Stable, strong (cardboard and string)
3. Easy to carry out
4. Fun activity
5. More teaching aids, please
6. More activities
7. Very interactive, students will enjoy the teaching aid as a toy.

How can we improve the teaching aid?
(None)

Concerning the "Nail Motor" (Table 3), 100% of the teachers agreed to all the points except for one individual who did not agree that it was cheap. The researchers considered it cheap, because there are no expenses spent on unnecessary equipment. We considered that the AA dry cell is inexpensive, as are the magnets, the nail and copper wire.

However, only one respondent of 34 disagreed, and felt that something was not cheap. Hence for this item, we have a 97% agreement (Table 3). This was an eye-opener to us, and we decided that it may be useful to provide a Likert scale response. Our future work will be improved in this manner.

Table 3
Questionnaire for Teacher Feedback on the "Nail Motor"

Statement	% Yes
This teaching aid assists the teaching and learning of science.	100
This teaching aid helps to teach the science content.	100
This teaching aid helps students to understand the science content	100
This teaching aid helps to build conceptual understanding in students.	100
This teaching aid helps students to enjoy the science lesson.	100
This teaching aid may motivate students to be more active in learning.	100
This teaching aid may motivate students to be more creative.	100
This teaching aid may motivate students to be critical thinkers.	100
This teaching aid may motivate students to find uses for recycled materials	100
This teaching aid is cheap to make.	97.06
This teaching aid is easy to assemble in class.	100
This teaching aid is quick to assemble in class.	100
The materials for this teaching aid are easily available.	100
Low cost materials and/or recyclable materials can be used to make this teaching aid.	100

Other views….

1. Well done, impressive
2. 'Boleh dijadikan set induksi' (can be used as set induction to engage students or induce students to learn)
3. Easy to carry out
4. Good session, creative
5. More teaching aids…
6. Impressive
7. It can improve students' understandings
8. It can increase interest of students

How can we improve the teaching aid?
(None)

With regards to the "Straw Rocket" activity, 100% of the teachers agreed to all the points that the researchers considered important as listed in Table 4. The comments were classified under three groups namely: "Helps students to understand and enjoy science", "Motivates students to be active, engaged, critical and creative", and "Easy, quick and cheap to make".

Their further comments on Table 4 showed that they agreed that the teaching aid is interesting, impressive and fun. More important to us as educators, the respondents mentioned that by doing the activity, students can improve their observation skills as well as increase knowledge and skills.

Table 4
Questionnaire for Teacher Feedback on the "Straw Rocket"

Statement	% Yes
This teaching aid assists the teaching and learning of science.	100
This teaching aid helps to teach the science content.	100
This teaching aid helps students to understand the science content	100
This teaching aid helps to build conceptual understanding in students.	100
This teaching aid helps students to enjoy the science lesson.	100
This teaching aid may motivate students to be more active in learning.	100
This teaching aid may motivate students to be more creative.	100
This teaching aid may motivate students to be critical thinkers.	100
This teaching aid may motivate students to find uses for recycled materials	100
This teaching aid is cheap to make.	100
This teaching aid is easy to assemble in class.	100
This teaching aid is quick to assemble in class.	100
The materials for this teaching aid are easily available.	100
Low cost materials and/or recyclable materials can be used to make this teaching aid.	100
Other views…. 1. Well done, impressive 2. Interesting 3. Fun, good teaching aid 4. By doing this activity, students can make observations and increase knowledge/skills 5. Interesting, fun, and can be used as TOYS 6. Can enhance higher order thinking skills (HOTS) in students, can be used as TOYS	
How can we improve the teaching aid? (None)	

A respondent mentioned that the "Straw Rocket" can enhance the higher order thinking skills (HOTS) of students who reflect on science activities. This shows that our response to what was suggested by Liong (2016) in making and using the teaching aids is also realised and appreciated by this teacher. Two of the teachers mentioned that the "Straw Rocket" can be enjoyed as a toy. The teachers have caught the understanding of our purpose for creating teaching aids that could make learning science an enjoyable activity, with teaching aids that students have fun playing with. The activities provided our teachers the opportunity to explore avenues that widen their pedagogical content knowledge (Liong, 2016). We intend to allow our students to actively make these teaching aids, so that they are engaged in exercising higher order thinking skills (HOTS) that include critical thinking, comprehending, synthesizing, analysing, reasoning, comprehending, application, and in evaluating; Our intention is to provide these science toys to engage our students with science, facilitate their understanding of science and enjoyment in learning science, so that they may be scientifically literate critical thinkers, and ready for solving real life problems in the 21st century (Miri et al., 2007; Yeoh, 2017), when scientific literacy must be applied to make decisions for our country and our world. When students are able to apply what they know (OECD, 2018), just like students in rapidly developing education systems like Singapore, Hong Kong, Japan, Canada and Finland, our PISA rankings would improve.

Conclusion

Summary and Significance

The teachers involved in the workshops to introduce three innovative teaching aids conducted by the researchers responded well to the hands-on session of making and assembling the teaching aids. They were quick to see that the teaching aids would appeal to the sense of humour and fun of students. Several teachers commented that the teaching aids could be used as toys, and playing with them would engage students, and probably improve their observations on science phenomena (including forces, directions of magnetic field, current flow and motion, as well as projectile movement). They agreed with the researchers that whatever science we teach, we need to engage our students because students who are engaged in active learning will continue to achieve the outcomes as expected in 21st century education.

It was a great privilege to open the minds of teachers to use and to make creative teaching aids that will fully engage our students and create a love of science among our students. The teachers agreed that these aids were useful to illustrate the laws of science, and that they were simple, inexpensive, and quick to make and to assemble. They also agreed that pupils were likely to become aware that learning science can be interesting, and that our pupils can be stimulated to be more creative, and to be critical thinkers, thus promoting higher order thinking skills (HOTS) fulfilling 21st century education goals as evidenced in this study as concurred with findings from the literature.

Miri et al. (2007) suggested that if teachers purposefully provide opportunities for students to deal with real-world problems and inquiry-oriented experiments, students are likely to develop HOTS. The making and using of the three teaching aids provide such opportunities. Furthermore, as students shared their experiences with their friends and cooperate to give as well as to receive feedback. They tried out good tips from friends on the best angle to place the short straws for the “Climbing Monkey”, the best length of nail for the “Nail Motor”, the best length of the rocket straw or the best angle to launch the “Straw Rocket”, they learnt to collaborate, and they are exercising and consolidating 21st century skills (Yeoh, 2017).

Limitation, Implication and the Way Forward

One of the respondents revealed on the questionnaire that s/he did not agree with us that the components of the “Nail Motor” were inexpensive, and this comment has led us to consider the use of a Likert scale response for our future research and perhaps invite suggestions if such item is not agreed upon. We will also work on the questionnaire to validate the constructs of the survey items using exploratory factor analysis and confirmatory factor analysis.

Teachers who make and use these creative teaching aids as well as witness the improvement in a student’s thinking and performance are likely to be rewarded with enhanced pedagogical skills. The authors conclude that developing students’ HOTS and teachers’ pedagogy will contribute to improved PISA rankings of the country. Hence, the implications of this study would be to provide more avenues for the Ministry of Education to improve students’ achievement and hopefully also PISA rankings in Malaysia. The pedagogy or PCK of teachers should be upgraded so that they are more passion to serve their students by using active learning methods to promote HOTS and 21st century skills. Retired teachers with excellent PCK should also be called back to service as has been practised in other countries. As an arm of the Ministry, SEAMEO RECSAM should continue to recruit personnel who constantly do research to improve practice and provide services to enhance the PCK of teachers, and facilitate the development of our education system.

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References

Chan, L. L. (2017, March 29). *Sparking interest in STEM subjects*. The Star Online. Retrieved June 11, 2017, from http://www.thestar.com.my/metro/community/2017/03/29/sparking-interest-in-stem-subjects-carnival-aims-to-make-science-technology-and-mathematics-appealin/

Collins, R. (2014). Skills for the 21st Century: teaching higher-order thinking. *Curriculum and Leadership Journal, 12*(14). Retrieved November 11, 2019, from http://www.curriculum.edu.au/leader/teaching_higher_order_thinking,37431.html?issueID=12910

Davis, B., & Summers, M. (2014). Applying Dale's Cone of Experience to increase learning and retention: A study of student learning in a foundational leadership course, QScience Proceedings (Engineering Leaders Conference 2014). Retrieved November 11, 2019, from http://dx.doi.org/10.5339/qproc.2015.elc2014.6

Daware, K. (2014). *Fleming's left hand rule and right hand rule.* Retrieved November 26, 2019, from http://www.electricaleasy.com/2014/03/flemings-left-and-right-hand-rule.html

Gudmundsdottir, S., & Shulman, L. (1987). Pedagogical Content Knowledge in Social Studies. *Scandinavian Journal of Educational Research 31*, 59-70.

Guildford, J. P. (1975). Creativity: A quarter century of progress. In J. A. Taylor, & J. W. Getzels (Eds), *Perspectives in creativity* (pp. 37-59). Chicago: Aldine Publishing.

Jeffrey, B., & Craft, A. (2004). Teaching creatively and teaching for creativity, distinctions and relationships. *Journal of Educational Studies, 30*(1), 77-87.

Liong, K. C. (2016, December 29). We can learn from falling PISA scores. *New Straits Times*. Retrieved November 12, 2019, from https://www.nst.com.my/news/2016/12/200188/we-can-learn-falling-pisa-scores

Miri, B., David, B-C., & Uri, Z. (2007). Purposely Teaching for the Promotion of Higher-order Thinking Skills: A Case of Critical Thinking. *Res Sci Educ*, *37*, 353–369.

OECD. (2008). OECD/CERI International Conference "Learning in the 21st Century: Research, Innovation and Policy". Retrieved June 11, 2017, from http://www.oecd.org/site/educeri21st/40554299.pdf

OECD. (2009). *Creating Effective Teaching and Learning Environments: Teaching practices, teachers' beliefs and attitudes (Chapter 4).* Retrieved November 12, 2019, from http://www.oecd.org/berlin/43541655.pdf

OECD. (2018). PISA 2015 Results in Focus. Retrieved November 12, 2019, from https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

P21 Partnership for 21st century learning. (2006). *Framework for 21st century learning*. Retrieved May 18, 2017, from http://www.p21.org/our-work/p21-framework

The National Academies Press. (2015). Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts. Retrieved June 11, 2017, from https://www.nap.edu/read/21836/chapter/6

Wellcome Trust. (2014). Primary science: is it missing out. Retrieved June 11, 2017, from https://wellcome.ac.uk/sites/default/files/primary-science-is-it-missing-out-wellcome-sep14.pdf

Yeoh, M. P. (2014). Musical mnemonics to facilitate the learning of Transcription of RNA. *Learning science and mathematics, 9,* 24-34.

Yeoh, M. P. (2015). Transcription of RNA (video recording). Retrieved June 14, 2017, from https://www.researchgate.net/publication/270876540_Transcription_of_RNA_video_recording

Yeoh, M. P. (2017). *21st Century Education and Pedagogical Content Knowledge of School Teachers.* Retrieved July 16, 2017, from https://www.researchgate.net/publication/318440733_21st_Century_Education_and_Pedagogical_Content_Knowledge_of_school_teachers

Yeoh, M., & Ierardi, E. (2015). Motivation and achievement of Malaysian students in studying Matriculation Biology. *International Journal of Advanced Research, 3*(11), 966-978.

Yeoh, M. P., Cazan, A., Ierardi, E., & Jacic, L. (2017). Facilitating self-directed learning (SDL) and satisfaction with SDL among pre-university students. *Educational Studies.* DOI 10.1080/03055698.2017.1343711

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