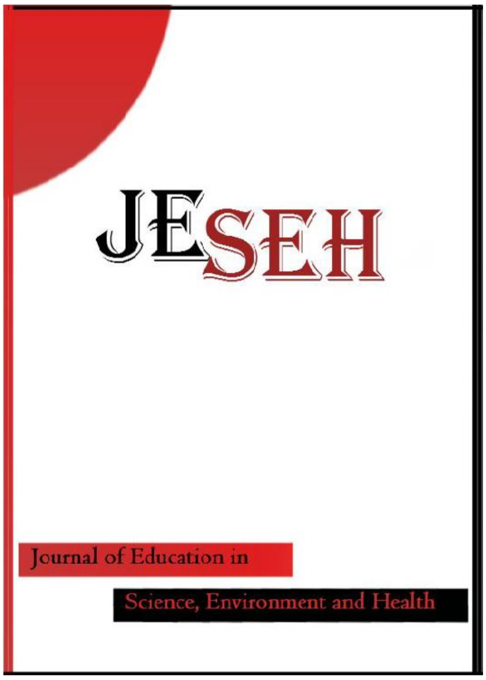

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Students' Generated Animation: An Innovative Approach to Inculcate Collaborative Problem Solving (CPS) Skills in Learning Physics

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Abstract

Inculcating collaborative problem solving (*hereinafter* CPS) skills to help develop students' knowledge, especially for problem solving (PS) involved in the subject of physics is of utmost importance in the 21st century. It was on such grounds that in the present study, physics PS learning was innovated by engaging students' generated animation within the recent CPS learning framework process. Next, the effectiveness of the steps in this innovative approach, which was developed as Lensmation CPS Module, in inculcating CPS skills was determined. Seventy respondents were involved in this quasi-experimental study, in which one treatment group was exposed to the module whereas the control group practised the conventional PS learning. In the course of completing their PS tasks, the students who were involved in this study had their CPS skills assessed using the CPS Proficiency Rubrics. MANOVA analysis revealed significant effects on CPS skills between the two groups. It is concluded that the innovative PS learning approach which tapped into students' ICT literacy in physics CPS learning was effective in inculcating CPS skills among the students.

Introduction

CPS skills have over the years been considered as critical and necessary across various educational contexts and workforce. More importantly, a growing interest has been observed in CPS skills in the 21st century. A closer look at inculcating CPS skills reveals that it facilitates both the division of labour and the integration of information from various sources of knowledge, perspectives and experiences. Additionally, CPS skills may equally enhance the creativity and quality of solutions created by means of effective teamwork. At present, the learning framework process is based on the one propagated by the *Organisation for Economic Co-operation and Development* (OECD) (OECD, 2013). Such a paradigm transition from PS to CPS is a result of scholars' disposition towards exploring collaboration owing to its distinct advantages over individual PS. In addition, related previous studies have revealed that the PS skills paradigm may limit the capacities of individuals who work alone to resolve problems. It was also found that in individual PS, the method of solution was not immediately obvious to the individual engaged in the PS task (OECD, 2010).

It was owing to such drawback that the OECD has alternatively considered CPS (OECD, 2013). In this regard, the defined CPS as the capacity of an individual to effectively engage in a process, in which two or more agents (i.e. human beings or computer-simulated participants) attempt to solve a problem by both shared understanding and efforts required to find a solution. More specifically, such a process may involve pooling their knowledge, skills and efforts to reach such a solution. As presented in Table 1, there are three major CPS competencies which are crossed with the four-major individual PS processes from the PISA 2012 PS framework (OECD, 2010) to form a matrix of specific skills for CPS framework (OECD, 2013). The specific skills have associated actions, processes, and strategies that define what it means for the student to be competent.

In line with such a definition, the infusion of CPS skills among communities may help overcome the present PS work challenges. It is worth highlighting that the transition from manufacturing to a service economy which is more information and knowledge-based has culminated in wider availability of networked computers. In such a scenario, individuals are expected to work with diverse teams using collaborative technology. Considering the level of transformation as discussed in the foregoing paragraphs, there is a growing need for CPS skills in civic contexts such as social networking, volunteering, participation in communal activities, transactions, administration and public services. In this regard, students upon leaving schools and stepping into the workforce and public life may have to equip themselves with CPS skills as well as the ability to engage in such a collaboration using appropriate technology. In line with such a view, the present study focuses on inculcating students' CPS skills in PS learning. In addition, it is believed that the inculcation of CPS skills not only develop individual PS skills among students, but also enhance their social interaction, teamwork and ICT literacy in the course of the PS learning process (OECD, 2013).

Table 1. Matrix of CPS framework (OECD, 2013)

		CPS Competencies		
		(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organisation
Problem Solving (PS) Skills	(A) Exploring and Understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve problem
	(B) Representing and Formulating	(B1) Discovering perspectives and abilities of team members	(B2) Identifying and describing tasks to be completed	(B3) Describe roles and team organisation (communication protocol/rules of engagement)
	(C) Planning and Executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement, (e.g., prompting other team members to perform their tasks)
	(D) Monitoring and Reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organisation and roles

Note: The 12 skill cells have been labelled with a letter-number combination referring to the rows and columns for ease of cross- referencing later in the document (OECD, 2013).

Physics PS Learning in Malaysian Secondary Schools

It is noteworthy that the application of CPS skills in PS learning has been dominated by Western countries for over a decade. Such a development does not mean that it is acceptable for a developing country like Malaysia to lag behind in inculcating its potential workforce with the CPS skills. Thus, in order to address the challenges within the global economy, Malaysia may have to aim to produce students who are capable of solving problems, particularly the ones which are related to fundamental physics. Physics PS skills are strongly required as one of the most important components to help construct students' knowledge, which in turn may help contribute to the nation's development in the area of science and technology.

Notwithstanding, a comprehensive review of the related literature reveals that the development of physics-based PS skills in Malaysia lags both in paradigms and ICT applications in comparison with its Western and other Asian counterparts, including Singapore, Korea, and Japan. A closer look at the Malaysian context revealed that in the past decade, the learning approach of PS skills for physics subject has been practiced among individuals (Zulkepli Mohamad, 2010) and groups (cooperative)(Muzaitulakmam Abdul Mutalib, 2014; Zurida, Mohd Ali, & Ahmad Nurulazam, 2005). It can therefore be argued that individual and group (i.e. cooperative) PS methods may have failed to inculcate students' PS skills owing to the possibility that there is a mismatch between the pedagogical theories and the actual realities in classrooms (Halim, Halim, Meerah, & Osman, 2010). In reference to Neo (2005), the researcher reported that all the activities and processes relevant to PS within the Malaysian context were still directed by the teachers. Consequently, the teaching and learning (T&L) models on PS skills have mostly been dominated by the teachers and hence the development of students' PS skills has been limited during their learning process.

Furthermore, DeWitt, Alias, & Siraj (2013) argued that despite the learning method being employed revolving around social interactions, it was conducted at low cognitive levels. Futhermore, other factors such as unstructured learning methods, passive interaction, lack of collaboration, minimal inquiry, and limited time allocated for discussion may have further deteriorated the quality of solution. In addition, the teachers have been directed to carry out intensive exercises in their respective classes, which is the least effective method. It is considered so because physics intensive exercises may only help familiarise students with answers to questions of conventional format. In such a case, in the event of having to face questions which may challenge their PS skills, the majority of students may fail to resolve the problems (Sulaiman, Abdullah, & Ali, 2007). Thus, in solving the problem the students' PS strategies may remain novice (Zamri, 2016). In addition, the conventional intensive exercise method may also force the students to memorise the contexts, which eventually result in a rather boring learning environment, culminating in the lack of interest, non-interactivity (Ishak, Bakar, Lani, Salam, & Shahbodin, 2011), and inability to synthesize or think in a scientific manner (DeWitt, Alias, & Siraj 2013) among the students.

Over the years, the documents that were developed to carry out the qualitative analysis among physics students at the Malaysian Certificate of Examination (MCE) level frequently reported the inability of students in solving problems accurately (Lembaga Peperiksaan Malaysia, 2013). Moreover, as highlighted in the PISA report in the year of 2012 (Zamri, 2016), the PS skills among the students of Malaysia dropped below the average score that was set by the OECD. Such developments both at the local and international levels clearly indicate that the teaching methodology of the physics PS skills has been inadequate. It can also be argued that such a methodology may have failed to improve and develop the students' PS skills and the CPS skills. In order to address such a critical problem, the integration of ICT into the Malaysian education system, as targeted by the Malaysia Education Blueprint, is an imminent requirement (Ministry of Education Malaysia, 2013).

Despite the clear indication of the potential benefits of integrating ICT applications or even tapping into students' ICT literacy for the physics PS skills development, the integration of ICT however has not drawn widespread attention among scholars. Nonetheless, it is encouraging to note that there is at least one study by researchers Noor Izyan and Abdullah (2012) which involved at the implementation of ICT in the PS skills development of physics subject. It is worth highlighting that the ICT integration conducted by the reseachers Noor Izyan and Abdullah (2012) only focused on the usage of Microsoft PowerPoint for content presentation by the teachers. In this regard, the educational report by the organisation UNESCO (2013) revealed that ICT implementation in the Malaysian education system is too limited and did not explore anything more than the usage of word-processing applications as a teaching platform. In reality, students may be encouraged to apply their ICT knowledge to solve problems more actively (Jones, 2005).

Students' Generated Animation and CPS in Learning of Physics

A comprehensive review of reports of both local and international studies clearly indicates that the development of PS skills' learning in physics education in the context of Malaysia is lagging behind the current requirement of PS skills which have globally evolved from the individual PS to group (cooperative) PS, and more recently into the collaborative PS. In line with such a development globally, in the present study, an improvement to the existing PS learning method is proposed to inculcate CPS skills through the integration of current CPS learning framework process (OECD, 2013) and tapping into students' ICT literacy. Apart from that, the proposed method has also cultivated the sampled students' potential in both the construction and the exploration of computer based-evidences. It was discovered from the needs analysis that students would choose the animation platform as a medium to help apply their ICT literacy in the most difficult physics PS subtopic that is Lens. As indicated by the review of literature, slowmation is the simplest technique and a new form of stop motion animation which may allow the students to easily synthesize the complex processes that underpin the animation production based on minimal picture frame (G. F. Hoban, 2007).

Thus, the steps of integrating CPS and students' generated slowmation have been developed in the form of the Lensmation CPS Module. Figure 1 illustrates the Lensmation CPS framework, which is an innovative PS learning method that contains twelve processes of CPS (OECD, 2013) and five steps of students' generated slowmation that was adapted from the 5R Model (G. Hoban & Nielsen, 2010).

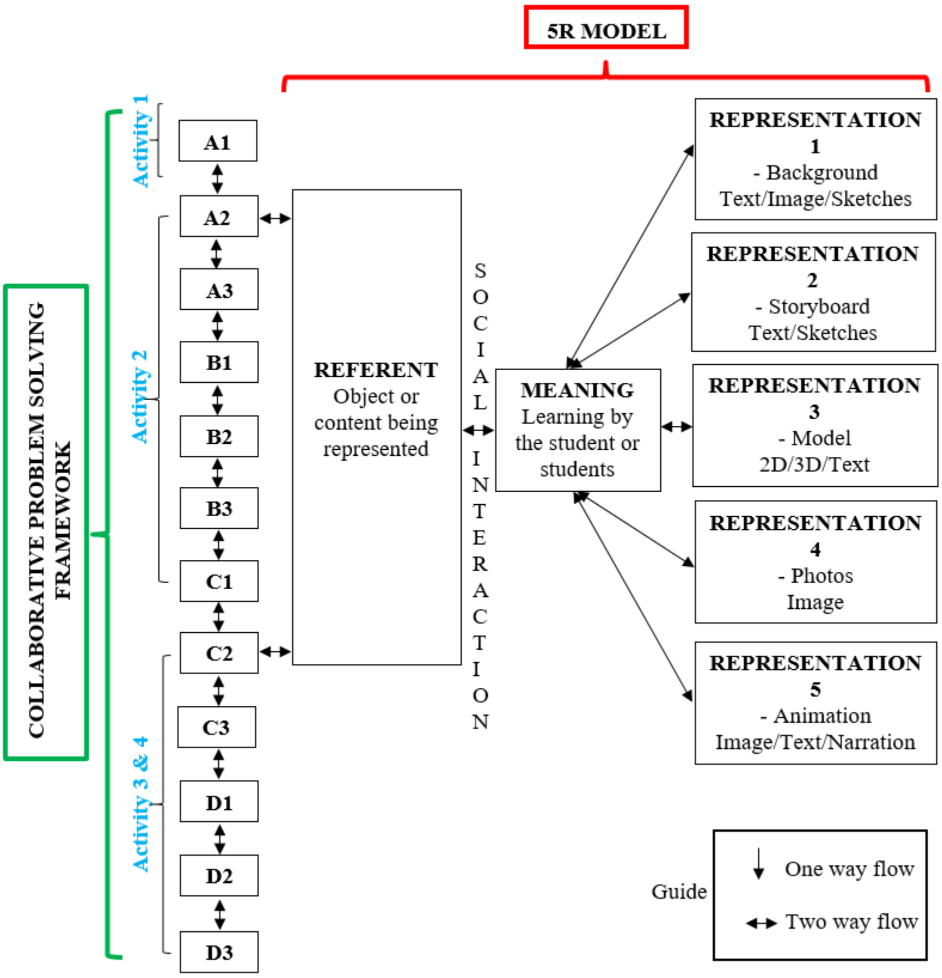


Figure 1. Learning steps in Lensmation CPS framework

Note: The letter-number combination refers to the CPS framework in Table 1.

It is widely believed that the proposed innovate approach may create a platform to help increase the students' ability in solving physics related problems and inculcating their CPS skills, particularly through structured teamwork interaction and ICT application.

Research Aim

The aim of the present study was to assess the effectiveness of the Lensmation CPS Module in inculcating CPS skills for PS learning of the Lens subtopics in the context of Malaysia. Researchers have recommended the implementation of this module in physics PS learning at the secondary school levels. It is believed that the implemention of this module may help expose students to the current PS learning approach learning and inculcate CPS skills among the students.

Method

Research Design

The present study employed a quasi-experimental approach with a non-equivalent control group research design. The study was conducted in two schools in Malaysia. Each school consisted of a control group which used the conventional approach module and a treatment group which used the Lensmation CPS Module.

Respondents

A total of 70 respondents (i.e. Form Four equivalent to 16 years old) participated in the study, of which the control group consisted of 29 students and the treatment group consisted of 41 students respectively. It should be noted that the respondents were drawn from schools which were randomly selected based on zones, the competency level of the students (i.e. based on their Mid-Year Physics Form Four Examination results), school bands and the number of student population in each school.

Instrument and Procedures

The CPS skills were measured using the Rubric of CPS Proficiency adapted from the organisation OECD (2013). The rubric contained 12 domains with a score of 0 to 2 and its description is presented in Table 2. The scores are given in line with the indicator of CPS skills acquired by the students when they underwent PS learning such as actions or communications.

Table 2. Description of CPS skills scores

CPS Skills Score	Description
0 (Below CPS skills standard)	The student: • responds to or generates information that has little relevance to the task. • contributes when explicitly or repeatedly prompted, student’s actions contribute minimally to achieve team goals (example: they may pursue random or irrelevant actions). • operates individually, often not in concert with the appropriate role for the task. • actions or communications seldom help the team to resolve potential obstacles.
1 (At CPS skills standard)	The student: • responds to most requests for information and prompts for action • generally, selects actions that contribute to achieve team goals. • participates in assigned roles and contributes to the overall strategies for solving the problem • good team member but is not always proactive and on occasion initiates actions. • good team member but does not always proactively take the initiative to overcome difficult barriers in collaboration.
2 (Above CPS skills standard)	The student: • responds to requests for information and prompts for action and selects actions that contribute to achieving team goals. • proactively takes the initiative in requesting information from others, initiates unprompted actions and effectively responds to conflicts, changes in the problem situation and new obstacles to goals. • acts as a responsible team member when the situation requires and proactively takes the initiative to solve difficult barriers in collaboration.

The rubric was translated into Malay language through 'back translation' process (Brislin, 1970), by two credible language experts. Prior to administering the rubric in this study, three research assistants (i.e. experienced physics teachers) who acted as observers were given briefings and detailed description about the interpretation of each score based on students' actions and communication.

Data Analysis

The quantitative data obtained from the CPS skills instrument were analysed by means of descriptive and inferential statistics. All data were compiled and summarized in table form for analysis report. Descriptive analysis was carried out to get the mean scores estimation and standard deviation of the CPS skills score. On the other hand, MANOVA analysis was employed to measure the effects of the Lensmation CPS Module in cultivating CPS skills. The analysis involved two study groups (i.e. control and treatment) and twelve constructs of CPS skills as presented in Table 3 below.

Table 3. Constructs of CPS skills scores

CPS Skills Code	CPS Skills
A1	Discovering the perspectives and abilities of team members
A2	Discovering the type of collaborative interactions to solve the problem
A3	Understanding roles to solve problems
B1	Building a shared representation and negotiating the meaning of problems
B2	Identifying and describing tasks to be completed
B3	Describe roles and team organizations
C1	Communicating with team members about the actions to be or being performed
C2	Enacting plans
C3	Following rules of engagement
D1	Monitoring and repairing the shared understanding
D2	Monitoring results of actions and evaluating success in solving the problems
D3	Monitoring, providing feedback and adapting the team organization and roles

Results

MANOVA analysis was employed to analyse the data to determine the effects of the Lensmation CPS Module on inculcating CPS skills. Results are shown in Table 4. The findings revealed that there was a significant group effect on CPS skills [F (12,55) = 31.655, p < 0.05] with an effect size of 0.874.

Table 4. Multivariate test

Effect	*Pillai's Trace Value*	F	df	p	*Partial Eta Squared*
Group	0.874	31.655	1	0.000	0.874

Significance level = 0.05

Further analyses were made to obtain a more detailed picture of the CPS skills construct. Results of the analysis shown in Table 5 indicated that there was a significant effect between groups on A1 construct [F (1,66)] = 6.382, p < 0.05] with an effect size of 0.088, A2 construct [F (1,66)] = 17.730, p < 0.05] with an effect size of 0.212, A3 construct [F (1,66)] = 45.919, p < 0.05] with an effect size of 0.410, B1 construct [F (1,66)] = 60.382, p < 0.05] with an effect size of 0.478, B2 construct [F (1,66)] = 132.175, p < 0.05] with an effect size of 0.667, B3 construct [F (1,66)] = 188.729, p < 0.05] with an effect size of 0.741, C1 construct [F (1,66)] = 76.088, p < 0.05] with an effect size of 0.535, C2 construct [F (1,66)] = 88.738, p < 0.05] with an effect size of 0.573, C3 construct [F (1,66)] = 100.631, p < 0.05] with an effect size 0.604, D1 construct [F (1,66)] = 12.538, p < 0.05] with an effect size of 0.160, D2 construct [F (1,66)] = 113.095, p < 0.05] with an effect size of 0.631 and D3 construct [F (1,66)] = 118.755, p < 0.05] with an effect size of 0.643.

Table 5. Test of between-subjects effect

Effects	Dependent Variable	Squared Total	df	Mean Squared	F	p	*Partial Eta Squared*
Group	A1	1.036	1	1.036	6.382	0.014	0.088
	A2	2.671	1	2.671	17.730	0.000	0.212
	A3	15.593	1	15.593	45.919	0.000	0.410
	B1	9.894	1	9.894	60.382	0.000	0.478
	B2	14.752	1	14.752	132.175	0.000	0.667
	B3	16.774	1	16.774	188.729	0.000	0.741
	C1	8.174	1	8.174	76.088	0.000	0.535
	C2	26.522	1	26.522	88.738	0.000	0.573
	C3	24.392	1	24.392	100.631	0.000	0.604
	D1	3.260	1	3.260	12.538	0.001	0.160
	D2	19.298	1	19.298	113.095	0.000	0.631
	D3	27.743	1	27.743	118.755	0.000	0.643

Significance level = 0.05

Due to the effect between groups on the constructs' mean scores, the comparison for mean scores was also carried out. Table 6 indicates an expected mean margin for CPS skills constructs by group.

Table 6. Mean margin for CPS skills' constructs by group

Constructs	Group	Mean	Standard Deviation	Confidence Interval 95%	
				Lower	Upper
A1	Control	1.617	0.075	1.467	1.766
	Treatment	1.866	0.064	1.737	1.995
A2	Control	1.517	0.072	1.373	1.661
	Treatment	1.918	0.062	1.793	2.042
A3	Control	0.969	0.108	0.753	1.185
	Treatment	1.938	0.093	1.751	2.124
B1	Control	0.979	0.075	0.828	1.129
	Treatment	1.750	0.065	1.621	1.879
B2	Control	0.964	0.062	0.840	1.088
	Treatment	1.906	0.053	1.799	2.013
B3	Control	0.964	0.055	0.854	1.075
	Treatment	1.969	0.048	1.873	2.064
C1	Control	1.174	0.061	1.052	1.295
	Treatment	1.875	0.052	1.770	1.980
C2	Control	0.686	0.102	0.483	0.889
	Treatment	1.949	0.088	1.774	2.123
C3	Control	0.550	0.091	0.367	0.733
	Treatment	1.761	0.079	1.604	1.919
D1	Control	1.381	0.095	1.192	1.570
	Treatment	1.824	0.082	1.661	1.987
D2	Control	0.798	0.077	0.644	0.951
	Treatment	1.875	0.066	1.743	2.007
D3	Control	0.586	0.090	0.406	0.765
	Treatment	1.878	0.077	1.723	2.032

Based on Table 6, it can be concluded that the treatment group exceeded the control group for the twelve constructs of CPS skills. It is clear that A1 construct for the treatment group (mean = 1.866, SD = 0.064) is higher than A1 construct for the control group (mean = 1.617, SD = 0.075), A2 construct for treatment group (mean = 1.918, SD = 0.062) is higher than A2 construct for the control group (mean = 1.517, SD = 0.072), A3 construct for the treatment group (mean = 1.938, SD = 0.093) is higher than A3 construct for the control group (mean = 0.969, SD = 0.108), B1 construct for the treatment group (mean = 1.750, SD = 0.065) is higher than B1 construct for control group (mean = 0.979, SD = 0.075), B2 construct for treatment group (mean = 1.906, SD = 0.053) is higher than B2 construct for the control group (mean = 0.964, SD = 0.062), B3 construct for the treatment group (mean = 1.969, SD = 0.048) is higher than B3 contruct for the control group (mean = 0.964, SD = 0.055), C1 construct for the treatment group (mean = 1.875, SD = 0.052) is higher than C1 construct for the control group (mean = 1.174, SD = 0.061), C2 construct for the treatment group (mean = 1.949, SD = 0.088) is higher than C2 construct for the control group (mean = 0.686, SD = 0.102), C3 construct for the treatment group (mean = 1.761, SD = 0.079) is higher than C3 construct for the control group (mean = 0.550, SD = 0.091), D1 construct for the treatment group (mean = 1.824, SD = 0.082) is higher than D1 construct for the control group (mean = 1.381, SD = 0.095), D2 construct for the treatment group (mean = 1.875, SD = 0.066) is higher than D2 construct for the control group (mean = 0.798, SD = 0.077) and D3 construct for the treatment group (mean = 1.878, SD = 0.077) is higher than D2 construct for the control group (mean = 0.586, SD = 0.090). Figure 2 compares the mean score estimation of CPS skills' constructs according to group.

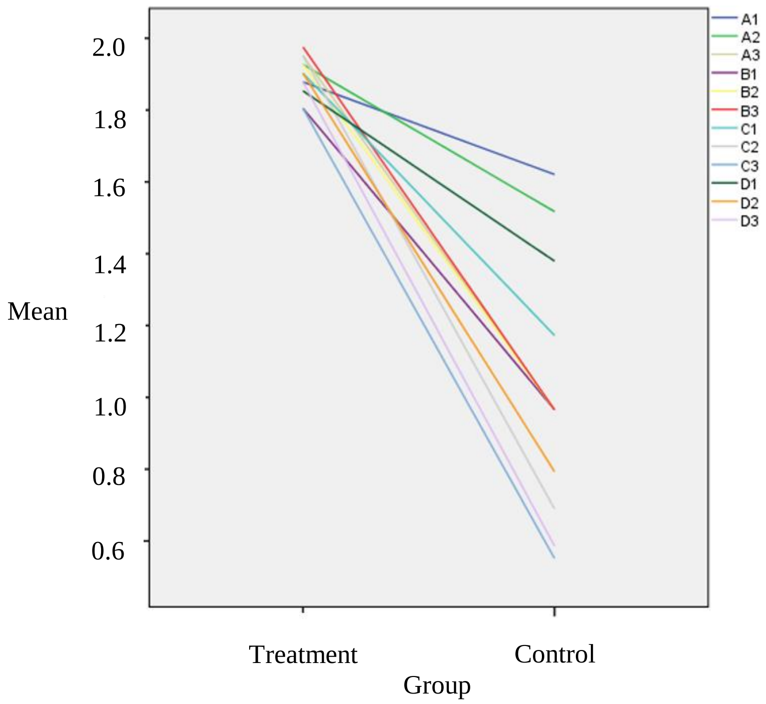


Figure 2. Comparisons of CPS skills constructs' mean score according to group

Based on the data analysis, it was found that the Lensmation CPS Module brought about positive effect on the overall CPS skills and its constructs. Therefore, it can be argued that the Lensmation CPS Module has inculcated CPS skills among the students in PS learning better than the conventional methods.

Discussion and Implication

Research Method

As regards the Malaysia Education Blueprint (2013-2025), Ministry of Education (MOE) has always strive to raise and improve the existing curriculum by engaging in innovation in the teaching and learning of science, especially in physics education. The innovation of PS learning method is expected to have an impact on the inculcation of CPS skills among students, which may contribute to the country's economic transformation in the 21st century. In reference to OECD (2013), the researchers deemed that CPS skills may be inculcated by means of integrating the current PS learning process, which is comprised of CPS theory and ICT applications.

It has to be noted that the success of inculcating the CPS skills among the students through the use of Lensmation CPS Module in the present study is attributable to several reasons. Firstly, it is due to the change of the PS learning method and the approach used by the students in the treatment group. In addition, the innovative approach has created an active learning environment because of the activities which guided the students to solve problems in a collaborative manner, through which, the students generated slowmation in structured steps.

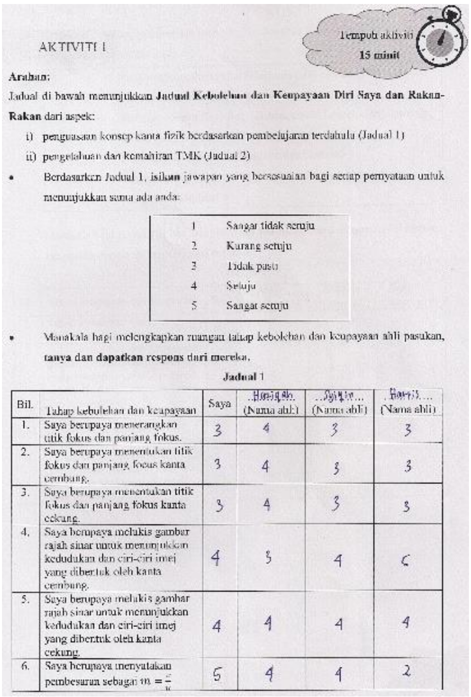
The backbone of the Lensmation CPS Module is the innovative learning model that integrated the 5R model (G. Hoban & Nielsen, 2010) which explained the systematic procedure of construction via slowmation with CPS framework (OECD, 2013). With regards to the innovative learning model, the students learnt strategically in a structured manner by means of using the module. In addition, the process involved in this innovative learning has improved the CPS competency and core skills (i.e. PS and collaborative skills). It is worth highlighting that other factors such as students' background (i.e. prior knowledge and characteristics) and context (i.e. characteristics of tasks, problem scenario, medium, and team composition) were also taken into consideration in the Lensmation CPS Module. Report in OECD (2013) has confirmed that consideration of those factors may inculcate students' CPS skills.

Thus, students from the treatment group were exposed to the Lensmation CPS Module activities which contained learning processes such as CPS, team communication, collaboration, teamwork and slowmation-generated animation. In order to guide the students in the process of acquiring and inculcating CPS skills, over twelve learning objectives with four student-centred activities were employed. Table 7 demonstrates the content of Activity 1.

Table 7. Content of Activity 1

Activity No.	Time	Content of Activity	Students Outcomes	CPS Skills
Activity 1	15 minutes	1. Students fill in the Table of Ability and Capability of Myself and Friends by sharing the information and views about themselves with the others. 2. The student asks the team members' abilities, perspectives and other related information.	- Table of Ability and Capability of Myself and Friends	Discovering perspective and abilities of team members (A1)

It is noteworthy that this activity (i.e. filling in the Table of Ability and Capability of Myself and Friends) of the Lensmation CPS Module may enhance A1 sub-skill score among students. The students need to fill in information such as the level of mastery of the concept of physics' Lens subtopic and their level of knowledge and ICT skills based on the discussion the students had with their respective team members. Figure 3 and Figure 4 show the photo and worksheet related to the discussion in Activity 1.


AKTIVITI 1

Tempoh aktiviti
15 minit

Arahan:

Jadual di bawah menunjukkan **Jadual Kebolehan dan Keupayaan Diri Saya dan Rakan-Rakan** dari aspek:

i) penguasaan konsep kanta fizik berdasarkan pembelajaran terdahulu (Jadual 1)

ii) pengetahuan dan kemahiran TMK (Jadual 2)

- Berdasarkan Jadual 1, isikan jawapan yang bersesuaian bagi setiap pernyataan untuk menunjukkan sama ada anda:

1	Sangat tidak setuju
2	Kurang setuju
3	Tidak pasti
4	Setuju
5	Sangat setuju

- Manakala bagi melengkapkan ruangan tahap kebolehan dan keupayaan ahli pasukan, **tanya dan dapatkan respons dari mereka.**

Jadual 1

Bil.	Tahap kebolehan dan keupayaan	Saya	[illegible] (Nama ahli)	[illegible] (Nama ahli)	[illegible] (Nama ahli)
1.	Saya berupaya menerangkan titik fokus dan panjang fokus.	3	4	3	3
2.	Saya berupaya menentukan titik fokus dan panjang focus kanta cembung.	3	4	3	3
3.	Saya berupaya menentukan titik fokus dan panjang fokus kanta cekung.	3	4	3	3
4.	Saya berupaya melukis gambar rajah sinar untuk menunjukkan kedudukan dan ciri-ciri imej yang dibentuk oleh kanta cembung.	4	5	4	5
5.	Saya berupaya melukis gambar rajah sinar untuk menunjukkan kedudukan dan ciri-ciri imej yang dibentuk oleh kanta cekung.	4	4	4	4
6.	Saya berupaya menyatakan pembesaran sebagai $m = \frac{v}{u}$	5	4	4	2

Figure 3. Students discussing in their team to fill in the worksheets of Activity 1

Figure 4. Table of Ability and Capability of Myself and Friends completed by the students

Throughout the PS learning method, the treatment group showed higher CPS skills in discovering the perspectives and abilities of their team members (i.e. A1) in comparison to the control group. This is because most of the students in the treatment group demonstrated their abilities as presented in Table 8 below.

Table 8. List of A1 sub-skill shown by the students

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
A1	Discovering perspective and abilities of team members	The student: (a) shares information and perspectives about one's self and others when asked but does not (b) inquire about the abilities, perspectives, and other information about other team members when completing Table of Ability and Capability of Myself and Friends.	The student: (a) shares information and perspectives about one's self and others when asked and (b) inquires about the abilities, perspectives, and other information about other team members when completing Table of Ability and Capability of Myself and Friends.

In Activity 2, it was found that the Lensmation CPS Module enhanced the A2, A3, B1, B2, B3 and C1 sub-skills score. Throughout this activity, the students were encouraged to ask, respond and understand the role of each team member. These actions were triggered when they completed the Work Planning Flow worksheet, which is comprised of:

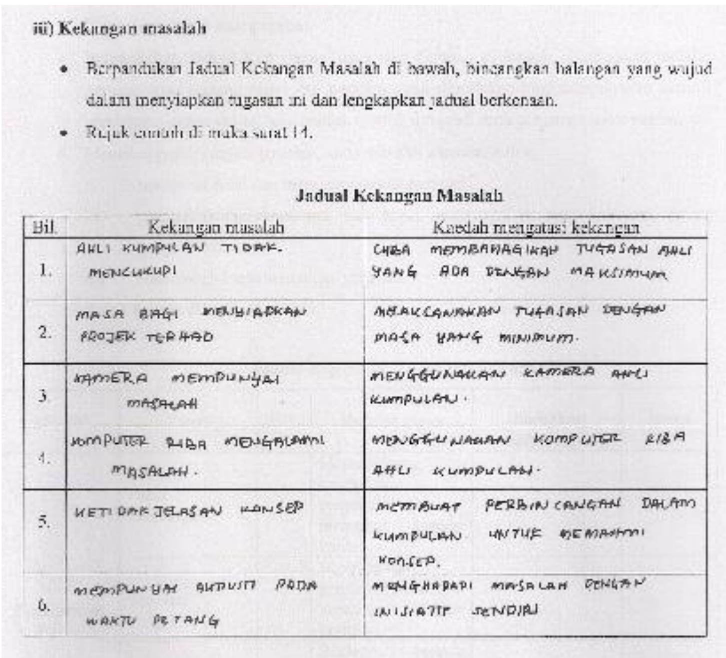
i) Interaction type: students discussed the methods of interaction that they applied during the activity.
ii) Goal of the problem: students and their team members summarized the information and PS in the form of texts, notes and images as Representation 1.
iii) Problem constraints: students discussed the obstacles that exist in the completed task by filling in the Table of Problem Constraints.
iv) The needs of the task and role: students discussed and completed the Table of Task Requirement and Role.

Table 9 presents the content of Activity 2.

Table 9. Content of Activity 2

Activity No.	Time	Content of Activity	Students outcomes	CPS skills
Activity 2	55 minutes	1. While completing the Work Planning Flow worksheet, aspects such as interaction type, goal of the problem, problem constraints and needs and roles of team members were discussed. 2. Texts, notes and images for Representation 1 (R1) were recorded as artifacts and research results to the PS task given.	- Work Planning Flow worksheet. - Representation 1 (R1).	- Discovering the type of interaction to solve the problem, along with goals (A2). - Understanding roles to solve problem (A3). - Building a shared representation and negotiating the meaning of the problem (B1). - Identifying and describing tasks to be completed (B2). - Describing the roles and team organisation (team protocol) (B3). - Communicating with team members about the actions to be and being performed (C1).

Figure 5 and Figure 6 illustrates the examples of the completed worksheets and Representation 1 constructed by the students during Activity 2.


iii) Kekangan masalah

- Berpandukan Jadual Kekangan Masalah di bawah, bincangkan halangan yang wujud dalam menyiapkan tugasan ini dan lengkapkan jadual berkenaan.
- Rujuk contoh di muka surat 14.

Jadual Kekangan Masalah

Bil.	Kekangan masalah	Kaedah mengatasi kekangan
1.	AHLI KUMPULAN TIDAK MENCUKUPI	CUBA MEMBAHAGIKAN TUGASAN AHLI YANG ADA DENGAN MAKSIMUM
2.	MASA BAGI MENYIAPKAN PROJEK TERHAD	MELAKSANAKAN TUGASAN DENGAN MASA YANG MINIMUM.
3.	KAMERA MEMPUNYAI MASALAH	MENGGUNAKAN KAMERA AHLI KUMPULAN.
4.	KOMPUTER RIBA MENGALAMI MASALAH.	MENGGUNAKAN KOMPUTER RIBA AHLI KUMPULAN.
5.	KETIDAK JELASAN KONSEP	MEMBUAT PERBINCANGAN DALAM KUMPULAN UNTUK MEMAHAMI KONSEP.
6.	MEMPUNYAI AKTIVITI PADA WAKTU PETANG	MENGHADAPI MASALAH DENGAN INISIATIF SENDIRI

Figure 5. Completed worksheets constructed by the students during Activity 2

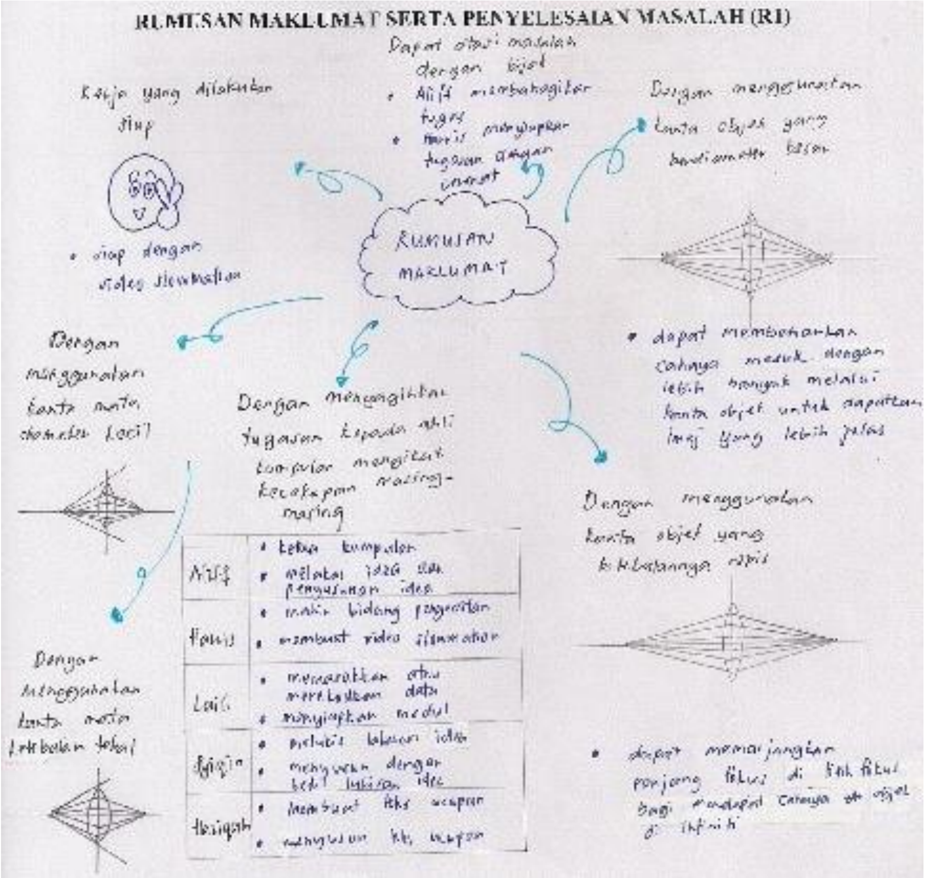


Figure 6. Representation 1 constructed by the students during Activity 2

In comparison, the treatment group showed higher CPS skills in A2, A3, B1, B2, B3 and C1 than the control group during PS learning. This is due to the fact that most of the students in the treatment group demostrated their abilities as shown in Table 10 below:

Table 10. List of A2 to C1 sub-skills shown by the students

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
A2	Discovering the type of interaction to solve the problem, along with goals	The student responds to requests but does not inquire about the actions, tasks, and plans to be completed by members of the team to solve the problem.	The student responds to requests and inquires about the actions, tasks, and plans to be completed by members of the team to solve the problem.
A3	Understanding roles to solve problem	The student acknowledges but does not inquire about roles take by other team members. The student's actions and communications reflect awareness that student is part of a team attempting to solve the problem.	The student both acknowledges and inquires about roles take by other team members. The student's actions and communications take the initiative in understanding the different team roles that need to be taken to solve the problem.
B1	Building a shared representation and negotiating the	The student responds to but does not initiate requests for clarification of the problem	The student both responds and initiates requests for clarification of the

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
	meaning of the problem	goals, problem constraints, task requirements, and roles taken by different team members.	problem goals, problem constraints, task requirements, and roles taken by different team members.
B2	Identifying and describing tasks to be completed	The student: (a) acknowledges or confirms the tasks to be completed when prompted but does not (b) take the initiative to identify, propose, describe, or change the tasks.	The student both: (a) acknowledges or confirms the tasks to be completed when prompted and (b) takes the initiative to identify, propose, describe, or change the tasks. The student takes the initiative to propose modifications to plans and tasks when there are changes in the problem or when there are major obstacles in the solution.
B3	Describing the roles and team organisation (team protocol)	The student: (a) acknowledges or confirms the roles of the student and other team members when prompted but does not (b) take the initiative to identify, propose, describe, or change the roles of the student and other team members.	The student both: (a) acknowledges or confirms the roles of the student and other team members when prompted and (b) takes the initiative to identify, propose, describe, or change the roles of the student and other team members. The student takes the initiative to propose reassignments in roles when there are changes in the problem or when a team member is not contributing as planned.
C1	Communicating with team members about the actions to be and being performed	The student: (a) communicates with team members (when asked) about the completion and results of tasks assigned to the student but does not take the initiative to (b) proactively communicate with other team members about the completion and results of tasks assigned to the student and (c) ask other team members about the completion and results of their tasks.	The student: (a) communicates with team members (when asked) about the completion and results of tasks assigned to the student and also takes the initiative to (b) proactively communicate with other team members about the completion and results of tasks assigned to the student and (c) ask other team members about the completion and results of their tasks.

Based on Activity 3 and 4, the researcher deemed that the Lensmation CPS Module may increase C2, C3, D1, D2 and D3 sub-skills score. In both activities, the students were facilitated by the teacher to:

i) Take action to:

- create Flow Chart of Idea Sketch
- produce storyboard as Representation 2 (R2)
- build model and texts as Representation 3 (R3)
- run photography of model and texts as Representation 4 (R4)
- generate slowmation by using Microsoft Movie Maker and Microsoft Movie Player as Representation 5 (R5)

All the above-mentioned actions were in accordance with the task distributions as planned in Activity 2 which are listed below.

ii) Solve problems through re-planning of PS strategies or team organisation or role.

iii) Encourage team members to complete the PS tasks through their assigned roles.

iv) Take initiatives or actions to resolve the gaps or errors.

Table 11 shows the content of Activity 3 and 4.

Table 11. Content of Activity 3 and 4

Activity No.	Time	Content of Activity	Students outcomes	CPS skills
Activity 3	45 minutes	1. Based on Representation 1 in Activity 2, the Flow Chart of Idea Sketch is completed. Then, the team produced a storyboard (i.e., Representation 2). 2.Students builtmodel and texts (i.e., Representation 3) parallel to the storyboard.	- Flow Chart of Idea Sketch. - Representation 2 (R2). - Representation 3 (R3).	- Enacting plans (C2). - Following rules of engagement (e.g. Taking actions to fulfil team goals and prompting other team members to perform their tasks) (C3). - Monitoring and repairing the shared understanding (D1). - Monitoring and describing the results of the actions, evaluating success in solving the problem (D2). - Monitoring, providing feedback and adapting the team organisation and roles (D3).
Activity 4	45 minutes	1. Students run photography of text and model guided by the storyboard. 2. Finally, they generated slowmation (i.e., evidence) to present their solutions of PS task (i.e., Representation 5).	- Representation 4 (R4). - Representation 5 (R5).	

Figure 7, Figure 8, Figure 9 and Figure 10 demonstrate examples of completed worksheets and Representation 2, 3, 4, and 5 constructed by the students during Activity 3 and 4.

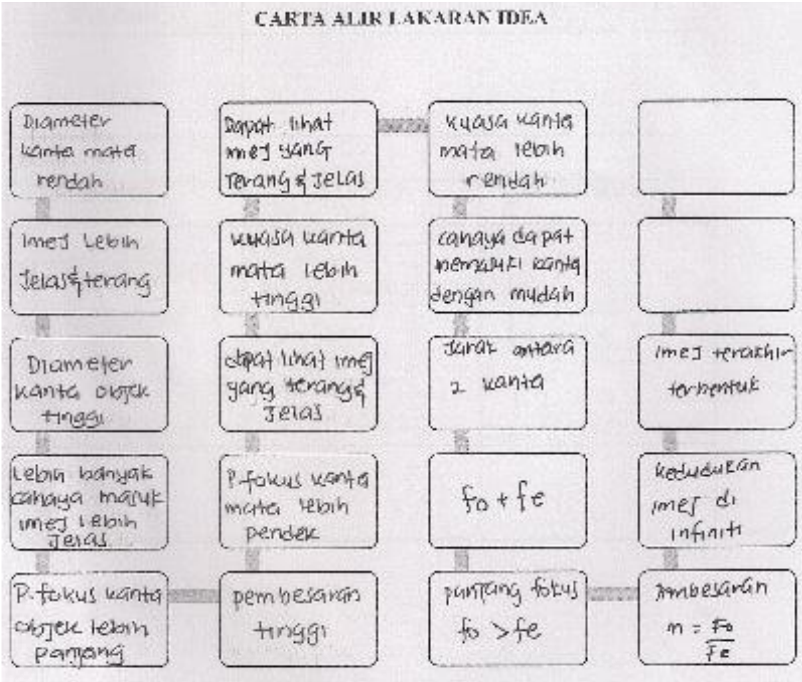


Figure 7. Completed Flow Chart of Idea Sketch constructed by the students during Activity 3

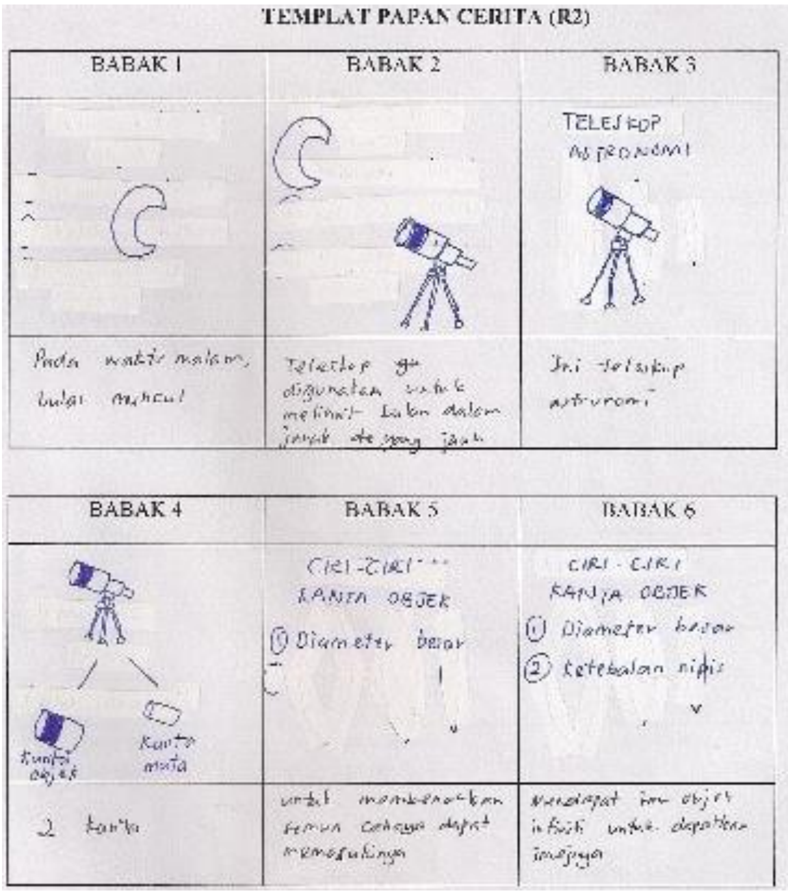


Figure 8. Storyboard (i.e. Representation 2) constructed by the students during Activity 3

Figure 9. Students built and run photography for model and texts for Representation 3 and 4

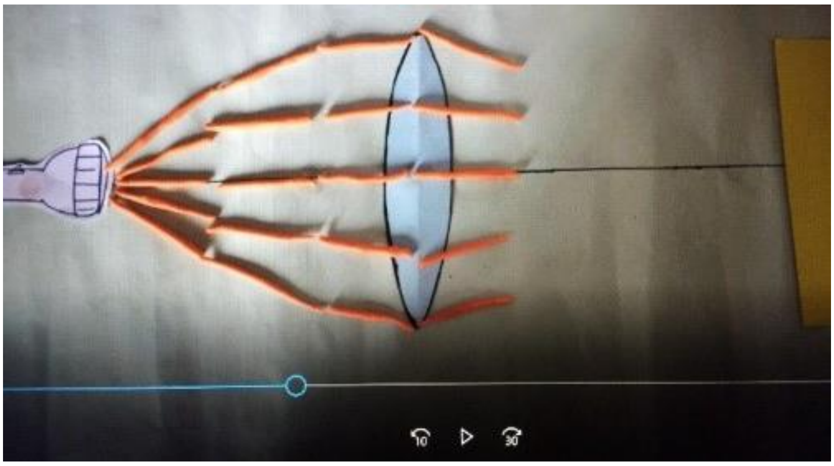


Figure 10. Students generate slowmation as artefact for Representation 5

The treatment group exhibited higher CPS skills in C2, C3, D1, D2 and D3 compared to the control group owing to the fact that most of the students in the treatment group demonstrated their abilities as in Table 12 below:

Table 12. List of C2 to D3 sub-skills shown by the students

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
C2	Enacting plans	The student takes actions that comply with the planned distribution of tasks but does not take actions to solve unexpected obstacles to the team plan.	The student takes actions that comply with the planned distribution of tasks and takes actions to solve unexpected obstacles to the team plan.
C3	Following rules of engagement (*e.g.* Taking actions to	The student takes actions that: (a) follow the planned tasks	The student takes actions that: (a) follow the planned

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
	fulfil team goals and prompting other team members to perform their tasks)	for particular roles and (b) responds appropriately when asked to complete the student's role assignment. However, the student does not take the initiative to prompt other team members to complete their assignments for particular roles.	tasks for particular roles and (b) responds appropriately when asked to complete the student's role assignment. The student also takes the initiative to prompt other team members to complete their assignments for particular roles.
D1	Monitoring and repairing the shared understanding	The student: (a) acknowledges or confirms deficits (gaps or errors) in shared understanding when prompted, but does not (b) take actions that troubleshoot potential gaps or errors in shared understanding and (c) take the initiative to repair deficits in shared understanding.	The student: (a) acknowledges or confirms deficits (gaps or errors) in shared understanding when prompted, (b) takes actions that troubleshoot potential gaps or errors in shared understanding, and (c) takes the initiative to repair deficits in shared understanding.
D2	Monitoring and describing the results of the actions, evaluating success in solving the problem	The student: (a) acknowledges or confirms obstacles in the PS process when prompted and (b) describes or otherwise expresses the occurrence of obstacles, but does not (c) take actions that troubleshoot potential obstacles and (d) take actions to replan the PS strategies to overcome the obstacles.	The student: (a) acknowledges or confirms obstacles in the PS process when prompted, (b) describes or otherwise expresses the occurrence of obstacles, (c) takes actions that troubleshoot potential obstacles, and (d) takes actions to replan the PS strategies to overcome the obstacles.
D3	Monitoring, providing feedback and adapting the team organisation and roles	The student: (a) acknowledges or confirms problems in the team organisation or roles when prompted, (b) describes or otherwise expresses problems in the team organisation or roles, but does not (c) take actions that troubleshoot potential problems in team organisation or roles, and (d) take actions or communicate with team members to change the team organisation or roles.	The student: (a) acknowledges or confirms problems in the team organisation or roles when prompted, (b) describes or otherwise expresses problems in the team organisation or roles, (c) takes actions that troubleshoot potential problems in team organisation or roles, and (d) takes actions or communicates with team members to change the team organisation or roles.

Based on Activity 1 to 4, the students implemented CPS skills at the standard level of proficiency and above the standard level of proficiency. Hence, it is evident that the innovative PS approach inculcated CPS skills among the students since they were able to implement three major CPS competencies as proposed in OECD (2013). The three major CPS competencies are:

1) Establishing and maintaining shared understanding:

During Activity 1 (i.e. A1 sub-skill was applied), Activity 2 (i.e. B1 and C1 sub-skills were applied) and Activity 3 and 4 (i.e. D1 sub-skill was applied), the students had identified their mutual knowledge. This indicates that each of the team member gained knowledge about the problem, was able to identify the perspectives of other team members during the collaboration and established a shared vision of the problems stated, as well as the activities. Apart from that, it is also believed that the students were able to monitor their abilities, knowledge and perspectives through their interaction with the other team members in relation to the given task. In the report from OECD (2013), as cited in Clark (1996) and Clark and Brennan (1991), theories of discourse processing embedded in the CPS theory have highlighted the importance of establishing common ground. Notably, it is a significant element in achieving effective communication and most of the key elements in CPS skills.

Throughout the activities, the students have shown that they had established, monitored and sustained the shared understanding. This is evidenced in the students' actions and communication in responding to requests for information, giving important information about tasks completed, establishing or negotiating shared meanings, verifying each other's knowledge and taking actions to repair deficits in shared knowledge. Moreover, the students showed their own self-awareness with regards to their proficiency level in performing the task, recognised their own strengths and weaknesses in relation to the task (i.e. metamemory) and recognised the team members' strengths and weaknesses (i.e. transactive memory).

2) Taking appropriate action to solve the problem:

In Activity 2 (A2 and B2 were applied) and Activity 3 and 4 (C2 and D2 were applied), the students had identified the type of CPS activities (consensus building) that was needed to solve the task and followed the proper steps to obtain a solution to the problem. As regards those activities, it is believed that the students had shown their efforts to understand the problem constraint, build team goals for the solution, act on the tasks and monitor the results in relation to the team and problem goals. In addition, the students were able to transfer complex information and perspective besides achieving more creative or optimal solution; the students were able to explain, justify, negotiate, debate and argue. Furthermore, the students were also guided to be proficient collaborative problem solvers who were able to recognise constraints in consensus building, follow relevant rules of engagement, troubleshoot problems and evaluate the success of the PS plan within those activities.

3) Establishing and maintaining group organisation:

In Activity 2 (A3 and B3 sub-skills were applied) and Activity 3 and 4 (C3 and D3 sub-skills were applied), the students were guided to build a team that can function effectively by means of team organization and adaption of structure to the PS task. The students were found to be able to understand their own role and the other team members' roles based on their knowledge of who is skilled at what in the team (i.e. transactive memory). Thus, based on their role, they tried to follow the rules of engagement and monitor the group organisation. If changes were needed, they exhibited actions to handle communication breakdowns, obstacles to the problem and performance optimisation. The problem situations experienced by each student may facilitate the other students to become a stronger leader in the team, as the process involved to solve the problem may require more democratic organisations. Moreover, the problem situations in this module were designed to educate the students to be a competent leader, in which they have to take steps to ensure that the team members are completing tasks and important information are being communicated. During the activities, the students were guided in order to provide feedback and reflections on the achievement of the team organisation in solving the problem.

Besides PS learning activities and steps that inculcate CPS skills, other factors that contributed to the findings of the present study are the students themselves, who are digital natives. Hence, they have the tendency to apply their ICT literacy to solve problems, especially problems related to their daily routine. According to Adolphus, Alamina and Aderonmu (2013), Basu et al., (2015) and Tissenbaum, Lui and Slotta (2012), students as young as 12 years old are capable of generating high level thinking skills through the aid of a computer. These students are able to design and generate the subject contents if they were given the appropriate support (Chang &

Quintana, 2006). Consequently, the implementation of the Lensmation CPS Module may guide students to apply their ICT literacy for PS learning and thus, inculcate CPS skills. As indicated by reference OECD (2013), the students' ability to apply their ICT literacy may contribute towards inculcation of CPS skills.

This finding has imperative implications for the researcher in putting forward a proposal or suggestion to the MOE, which is to update the physics PS learning process and approaches besides focusing on inculcating CPS skills among students. This may be accomplished by shifting the focus to CPS learning process and the idea of manipulating students' ICT literacy. In addition, the innovative approaches employed in the new pedagogy as suggested above may be integrated into physics curricula to inculcate CPS skills. The inculcation of CPS skills among students may facilitate them to relate what they have learned in physics PS learning to their daily lives and future work place. This in turn, may increase their interest in physics PS and most importantly, they may be able to see the relevance of education in their daily lives.

The human resource factor plays a vital role in order to enable an effective application of the above-mentioned modifications. The researcher believes that new and experienced physics teachers must be exposed and trained in inculcating CPS skills and knowledge in module implementation. Apart from that, teachers should be able to relate their skills and abilities of physics CPS to students' daily life. It should be noted that when learning is associated with current methods and is parallel with students' lifestyles and characteristics, the PS learning process becomes more effective, especially in inculcating CPS skills. Consequently, this may directly reduce negative feelings and enhance the level of confidence among teachers and students towards PS implementation, communication, teamwork and ICT application in learning.

Conclusion

It is noteworthy that the present study has reported significant issues of related to physics PS learning in secondary schools in Malaysia. One of the issues is that, in the current PS learning approach, physics students are at risk of being left behind. At the same time, they have had a lack of exposure to CPS computer-orientated learning and CPS skills. Subsequently, this may contribute to the low level of students' abilities to solve physics problems and may result in the heighten perception that physics PS is difficult. Therefore, the researcher deems that teachers should expose students to the current and innovative approaches of PS learning which take into consideration the students' learning styles and characteristics. It should be noted that students who were born in this era (i.e. the millennials) are able to solve problems by means of their ICT literacy in structured and collaborative manner.

As regards the findings of this research, Lens PS learning may improve by implemention of the Lensmation CPS Module, which effectively inculcates CPS skills than the conventional approach. A better understanding of how students solve problems collaboratively and manipulate their ICT literacy by generating animation to present their solutions may be expanded to all physics teachers and curriculum developers. Improvements and prompt actions to address issues in relation to teachers' role as facilitators to guide students in physics CPS learning with appropriate approach are deemed necessary. Future research should be focused on utilizing the slowmation as evidences generated by the students to be analysed in terms of the quality of their CPS solutions. One method suggested by the OECD is the emphasis on the quality of CPS solutions for assessing the inculcation of CPS skills.

In a nutshell, it is of utmost importance to consider several efforts in improving the learning process of physics PS, specifically in inculcating CPS skills. Notably, the mismatch of physics PS learning approach at the secondary level need to be solved so that current and innovative learning process can be implemented effectively which subsequently could contribute to enhancing a high level of ICT literacy among students.

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