Evolution of Students' Ideas on Screen Illumination by an Extended Light Source

Nelson A. Rosaroso, PhD
Assistant Professor, Science and Mathematics Education Department, School of Education, University of San Carlos, Cebu City, Philippines
nelson_rosaroso@yahoo.com

Date Received: August 6, 2015; Date Revised: September 17, 2015

Abstract *–This is a qualitative research where a case study of three student participants in an inquiry-based Physics course was used. The main purpose of this study was to investigate the college students' evolution of ideas about light in a Physics classroom using Constructing Physics Understanding (CPU) materials, an inquiry-based instructional approach. The student participants' initial ideas on how light leaves and travels from an extended light source and illuminates the screen were documented using transcripts of videotaped small group discussions, daily learning journal, interview transcripts and worksheets' responses. Aside from these, participant observations were used where the researcher also acted as the Physics teacher facilitator.*

Findings revealed that the Constructing Physics Understanding (CPU) materials and its learning strategies provided a learning environment where student participants developed the scientific ideas on light. The small group discussions enhanced meta-cognitive awareness of student participants' own conceptions where they appreciated other ideas and at the same time reflected their own learning. Awareness of their own learning was developed among the student participants.

Keywords – case study, CPU materials, inquiry-based instructional approach, metacognitive awareness

INTRODUCTION

There are very few studies conducted on Physics topics that are focused on the detailed descriptions on how students' knowledge about scientific phenomena have evolved starting from their prior knowledge leading to the actual learning process. This is not surprising for reasons that such studies are extremely labor intensive. With this scenario, this study was conducted to investigate how students' knowledge on a scientific phenomenon evolved starting from their prior knowledge to intermediate conceptions and finally towards scientific conceptions in a physics course using guided inquiry-based instructional approach with Constructing Physics Understanding (CPU) materials[1]. Guided inquiry-based physics courses explicitly involve students in the development of conceptual ideas. The major goal is to help students think of physics not as an established body of knowledge, but rather as an active process of inquiry where they can participate in class activities[2].

The teaching strategy used in the study involved the application of inquiry-based approach with CPU materials designed using a learning cycle pedagogy [3]as shown in Figure 1.

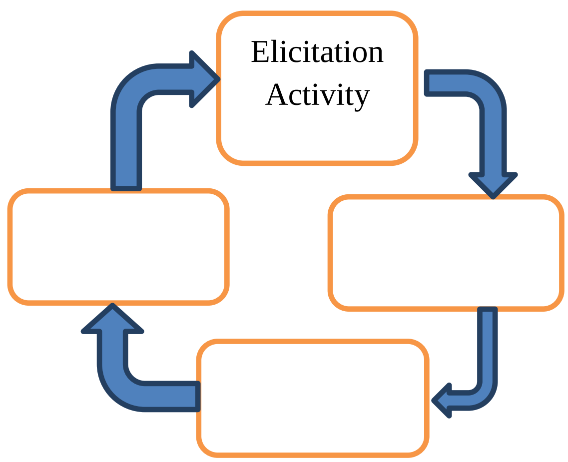

Figure 1. CPU Learning Cycle

The cycle begins with an *elicitation activity* that builds upon students' prior experience to formulate an initial explanation for a phenomenon. Following the elicitation activity, each group of students tests and modifies their initial ideas by working through a series of several *development activities.* At the end of the development activities, students contribute to a *consensus discussion activity.* During this consensus

P-ISSN 2362-8022 | E-ISSN 2362-8030

discussion the instructor engaged the students in a Socratic dialogue and gave short lectures when necessary. During the *application activities* students applied the class consensus ideas in a wide variety of situations.)

The students' prior knowledge utilized in the learning situation provided them opportunities to make their prior knowledge explicit which was then subjected to teacher and peers' evaluation. Students used this prior knowledge as mental (personal) models to explain the observed physical phenomenon. However, these mental models were markedly different from scientific models

Extensive literature and reviews supported the fact that learning was a process of constructing and reconstructing personal models [4]. This means that a conceptual change is necessary for the students to develop scientific models which are essential in understanding Physics concepts[5]. This fosters an avenue for constructing meaning in the classroom.

OBJECTIVES OF THE STUDY

This study aimed to ascertain student participants' initial ideas and its evolution towards the scientific ideas on how light leaves and travels from an extended light source to illuminate the screen.

METHODOLOGY

This is a qualitative research employing a case study method on three students in a guided inquiry-based Physics course.According to Yin [6], a case study method is appropriate to use when: (a) the focus of the study is to answer "how" and "why" questions; (b) you cannot manipulate the behaviour of those involved in the study; or (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study. The research method allowed the researcher to document the evolution of ideas and how students' interactions and other factors contributed to the significant changes of these ideas. The study utilized participant observations, videotaped small group discussions, students' daily learning journal, students' responses to worksheets and other lesson materials, and interviews as sources of data. Three students were involved as participants to document in details the conceptual changes through out the implementation of the study.The participantswere purposively chosen based on their willingness to express their thinking verbally since they themselves not the instructor, developed the ideas. Researcher's class observations from the students' class performances prior to the conduct of the study served as additional reasons for the selections of the participants. Furthermore, the whole class was informed that their Physics course was subjected to the research study after permission was secured from the Chair of the Physics Department. Students' consent was likewise obtained prior to the conduct of the study . Pseudonyms were used for the three case students

Alvin, one of the participants used to lead the group's discussion and played the role of an organizer. He used to initiate the discussion by asking other members' ideas and acted as a peer tutor to his group. However, his ideas were not at all times recognized to represent the group's ideas. Alvin showed willingness to change his way of thinking after the discussion with other group members.

Shirley, the second participant was very articulate in both written and oral communication. She could easily explain her thinking to her group. In a group discussion, her contribution was characterized by completing each other's utterances accurately with one idea followed by another leading to the correct explanation.

Kate, as the third participant lacked confidence and most of the time unsure of her expressed ideas. Kate showed the lowest level of initial understandings on the concepts promoted in the lesson materials. However, she was not hesitant to ask questions and showed persistence in looking for answers when the other members seemed not to agree with the response.

Further, the researcher acted as the instructor during the second half of the introductory Physics course for first-year teacher education students where the research was conducted. During the first half of the course, the researcher joined the class sessions to familiarize with the students while another instructor facilitated the teaching activities of different topics**.** Initially**,** two video cameras were strategically positioned in the classroom for students to get accustomed with. During the second half of the course, the researcher took over the class and started teaching using the CPU materials for three weeks in two 3-hour sessions per week. Students were given an orientation on the study. They were informed that all their works were course requirements and would serve as bases for grading.

P-ISSN 2362-8022 | E-ISSN 2362-8030

The main role of a CPU teacher was to guide the whole class discussions and to make sure that students are making the appropriate observations. The teacher provided very little direct information involving the content of physics. He generally provided assistance to students when they encountered problems with laboratory apparatus and to see to it that they were on the right track on the day's activity. Students' questions were mostly answered by guided counter questions from the teacher, not by direct answers.

The topics involved in the study were contained in Cycle I of the Light and Color Unit of the CPU lesson materials. Cycle I focused on geometrical optics phenomena and was intended to engage students in myriad experiences with hands-on equipment and extensive small group and whole class discussions to help them modify their existing ideas and construct new ideas on the behavior of light that would explain on how light leaves and travels from an extended light source to illuminate the screen.

The process of evolution of students' ideas, which was the central concern of the study, was traced from the Elicitation to the Development Phase during the teaching of the unit. Data from students' written responses (in diagrams or in words) and videotaped small group discussions pertaining to the different activities/tasks in the unitt were collected and analyzed.

The students' concept development process usually started after the teacher had performed the Elicitation Activity as a demonstration infront of the class. Most students were surprised to observe that the experiment's outcome was entirely different from their prediction. The students were asked to come up with an idea to explain the outcome of the experiment. At this point the students had introduced some modifications, set aside their initial ideas, or invented new ideas to make sense of the experiment's outcome. The developed new ideas were contrasted with the formal physics knowledge in terms of its core concepts and main ideas.

During the Development Phase, students worked with a series of different activities with increasing complexity designed to develop their understanding of the target ideas promoted in each cycle. The experiments involved in these activities had different roles in the students' conceptual development process. One of them was to create students' cognitive conflict. The resolution of the conflict led students to construct the scientific ideas. The other role played by experiments was to provide students with contexts, in which they could test and discuss their ideas regarding the target concepts. As the group worked throughout the different Development Activities, they recorded the changes on their ideas made as idea journal entries. The idea journal helped students keep important notes on the idea and monitored the history of their evolution.

The verbal and diagrammatic ideas the students used in responding to different tasks and its subsequent development activities were identified and described in terms of the core concepts and main ideas. The inferred ideas were obtained by reviewing the videotapes and the transcribed segments where students explained his/her reasoning with regard to the various activities. These data were re-analyzed to understand the transition of ideas at different points of time in the learning process. The results from this analysis were cross-validated with data analysis from the idea journal.

RESULTS AND DISCUSSION

In an activity, student participants were asked to predict and explain what they would expect to see on screen if a clear bulb with a long, straight filament was placed in front of it when turned on. The purpose of the activity was to ascertain student participants' initial ideas on how light leaves and travels from an extended light source that illuminates the screen. Figure 2 presents the experimental set-up for the activity.

P-ISSN 2362-8022 | E-ISSN 2362-8030

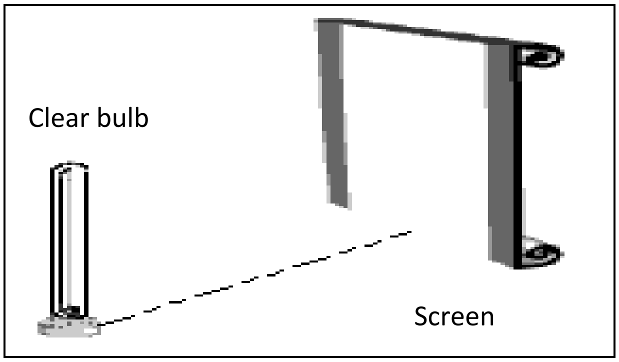

Figure 2: Experimental Set-up for the Activity

The excerpts from the student participants' discussions transcribed from the video and journal entries that further explained their initial thinking on the activity written in the individual worksheets are also discussed below.

In Alvin's worksheets, he described his initial thinking verbatimly:

> "Nothing will be observed on the screen except that it is illuminated. The screen will be illuminated in all directions. And since thescreen is white in color, it will reflect most of the light."
>
> "The light from the bulb will spread in all directions. Light (most) that hits the white screen will be reflected."

Alvin's prior knowledge on how a screen was illuminated revealed a more scientific understanding on the existence of light in space compared with those of his two groupmates, Shirley and Kate. His explanation, "The light from the bulb will spread in all directions. Light (most) that hits the screen will be reflected," conveyed a dynamic directed illumination conceptualization of light having a spatial entity. He even represented this conceptualization diagrammatically on Figure 3, by drawing straight lines from the different parts of the bulb going to the screen.

Alvin's drawing conveyed his thinking that light traveled in a straight-line path, although this idea was not revealed explicitly from his written responses. At the same time, his drawing did not show the graphical representation of a light ray, which consisted of a straight line with an arrow that indicated the direction to which light traveled from the source. This was also what the other two student participants in this study presented in their individual worksheets.

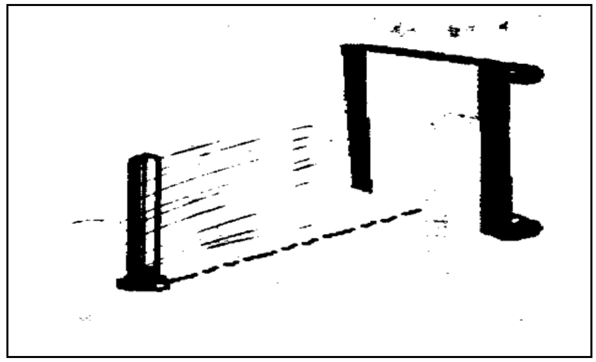

Figure 3. Alvin's drawing showing parallel beam of light leaving from the source to the screen**.**

However, in Figure 3, Alvin did not show the different directions explicitly as light traveled in straight line from the source to the screen and showed that light was leaving from each source point in only one direction. At this point it can be inferred that there was a pictorial misrepresentation of what he meant by light traveling in straight lines in all directions. Parallel straight lines were drawn instead of straight lines radially outward from each source point.When his group was discussing the activity, Alvin showed inconsistency in his conception on the idea that light travels in all directions. In the following discourses, parenthetical comments are included to help clarify the situation. The transcripts show the quoted Cebuano dialect (in italics) used by the student participants together with its English translation.

Alvin**:** *Saako-a, ang light mo-travel gyudug straight line in all directions.* (From my point of view, light will travel in all directions. (pointing to his drawing, in Figure 3)).

Shirley: *Ang i-focus man gudnatodirikung unsay makit-an natosa screen. (*Our focus here is what we are going to see on the screen. What is it anyway?)

Alvin*: Kung angmga light rays mo-leave sa source in parallel. (*If there are light rays leaving from the source, they will be in parallel. (as he retraced the parallel lines drawn in his diagram)).

Shirley: *Kung ana, ang center sa screen maoy kina-bright tan kay parallel man kaha or directly tungod man sa source ang screen (*Isn't it that the center (of the

P-ISSN 2362-8022 | E-ISSN 2362-8030

screen) would be brighter since it is parallel or directly infront of the light source?)

Alvin: *Sakto sad ka. Pero, I don't know. Tungod man gudna light travels in all directions, ang whole scree ma-illiminatedgyud.* (You have a point there. But, I just don't know. Because light spreads in alldirections and this will make all parts of the screen illuminated).

From the above discussion, Alvin was saying that light traveled in all directions causing the whole screen to be illuminated and yet he meant a beam of parallel light rays leaving from the bulb. This conception was made more evident when he acknowledged Shirley's comment that there would be a brighter illumination at the center of the screen if light traveled in parallel direction. From his gesture, verbal and diagrammatic representations of his thinking showed that Alvin visualized the propagation of light as bundles of parallel lines rather than divergent lines.

It was evident from their discussion that Alvin had the idea that light traveled in all directions in parallel manner only. That conception led him to predict that the whole area of the screen would be uniformly illuminated. However, at the end of their discussion, Alvin adopted the idea proposed by Shirley.

Shirley:It would be illuminated equally since light travels in all directions. (She made some hand gestures pointing to different directions to convey her idea that the whole screen was uniformly illuminated.)

Alvin: Whole portion is illuminated. It would be better if we say that light travels in all directions since this portion here is not theonly part that is illuminated. The whole portion is illuminated.

However, Kate, the third member of the group expressed a different way of thinking on how light leaves and travels from an extended light source and illuminates a screen. In her worksheet she drew in Figure 4 her prediction on what would be seen on the screen if a clear bulb with a long, straight filament was turned on.

Kate described her prediction, as "image of light would be of the same length as the filament if the distance from the light source to the screen is equal to or lesser than the filament."

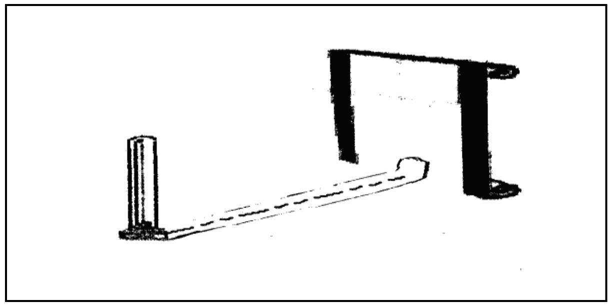

Figure 4: Kate's drawing of her prediction how the screen is illuminated

At this point it was not clear what was her initial thinking on the behavior of light that led to her prediction since no further written explanation was found in her activity sheets. What could be inferred from her drawing when she mentioned "image of light . . .," was a distinct illumination having similar shape but much longer than the bulb that started from the bottom of the bulb and extended partly to the screen.

During their group discussion, Kate explained her thinking. The following are excerpts of their discussion which were transcribed from the video:

Kate: Thought I am predicting its direction. (Pointing to her drawing in Figure 3 where she labeled image of the light and gestured with her thumb and the forefinger of her left hand parallel to each other.) . . . this line here is really brighter than the others.

Shirley: Light travels in a straight path. (She placed the tip of her forefinger at the top of the bulb and the thumb at the bottom, moved them toward the screen.) This shaded part here (pointing to her drawing in her activity sheet, Figure 5) is brighter than the rest of the screen.

P-ISSN 2362-8022 | E-ISSN 2362-8030

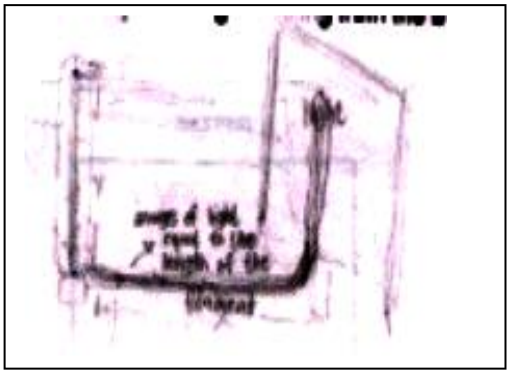

Figure 5: Kate's drawing explaining her idea on how the screen will be illuminated.

Kate: So, the screen is fully illuminated? That's right! There will be thin lines that would reach on the screen. It is not obvious because it is brighter here (pointing to her drawn image of the source). If it is dark you will surely see something like this…

The discussion above revealed what Kate meant on the image of light written in her worksheets. She thought light leaving from each part of the source in a parallel-like beam causing the whole screen to be illuminated with greater concentration of light on the central part of the screen directly infront of the bulb. A brighter pattern similar to the shape of the bulb at the center of the screen and less brightness on other parts of the screen were observed.

Kate also explained that the long narrow shape "image of light" drawn from the bottom of the bulb in her prediction was caused by the illumination of the parallel beam of light on the surface (table), leaving from the bottom of the bulb to the screen and the extended illumination on the screen was caused by the rest of the upper parallel beam of light. Kate's drawing made during the discussion to explain further her prediction is shown in Figure 5.

Although Kate had somewhat agreed to the idea that light from a source traveled in all directions, she held strongly to her own idea that light was leaving from each part of the source in a parallel-like beam of light causing a shape of illumination on the screen similar to the shape of the filament of the source.This was reflected in her learning journal written after the elicitation activities. She wrote, ". . . I have predicted that light would travel parallel from the light source. That a light would travel and is obvious with the same length of the given filament."

On the other hand, Shirley had predicted a non-uniform illumination of the screen. In explaining her prediction, she wrote in her worksheets:

> "The light from the bulb travels and illuminates the screen. The screen is not uniformly illuminated. The part of the screen directly across the bulb is fully illuminated while the slightly illuminated part is where light coming from the bulb is not directly focused on it."

Shirley's conception of non-uniform illumination of the screen was similar with Kate's but she only thought that the central region of the screen would be a little brighter than the outer edges hence, there was no brighter pattern in the shape of the bulb appearing on the screen. Her drawing of what the screen would look like is shown in Figure 6.

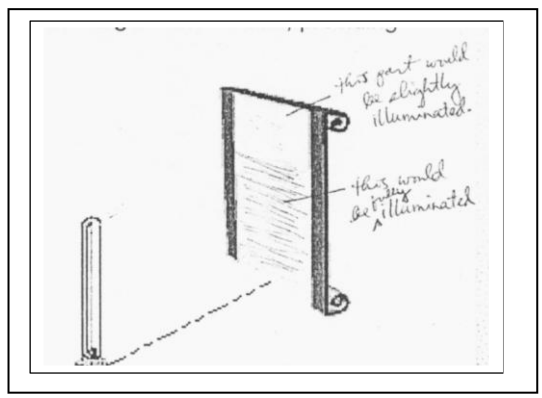

Figure 6.Shirley's drawing on how the screen would be illuminated

Both her drawing and written explanation did not reveal explicitly how light travels from the bulb to the screen. During her discussion with Kate it was revealed that she had in her mind the initial conception that light traveled in a straight-line when she said:

> "Light travels in a straight path in all directions. (She placed the tip of her forefinger at the top of the bulb and the thumb at the bottom, moved them toward the screen.) This shaded part here (pointing to her drawing in her activity sheet, shown in Figure 6) is brighter than the rest of the screen."

P-ISSN 2362-8022 | E-ISSN 2362-8030

Shirley's hand movement to show how light travelled from the extended source to the screen revealed her thinking that light leaving from the source was confined to the length of the light source. It could also be inferred that when she placed her forefinger at the tip of the bulb and the thumb at the bottom of it then moved them toward the screen, implied that light rays leaving from each point on the source were parallel. Different sets of parallel light rays along the length of the bulb were leaving from it in different directions to the screen.

At the end of their extensive discussion on how an extended light source illuminated a screen, the group came up with the best prediction and idea for the activity.

Shirley: It would be illuminated equally since light travels in all directions. (She made some hand gestures pointing to different directions to convey her idea that the whole screen was uniformly illuminated).

Alvin: Whole portion (screen) is illuminated. It would be better if we say that light travels in all directions since this portion here is not the only part that is illuminated. The whole portion is illuminated.

Although as a group, they had viewed that light must travel in all directions and as implied from their hand gestures, *"light diverges in all directions as it leaves from an extended light source,"* they failed to recognize that each point on the extended light source could be treated as a point light source where light diverges in all directions. Instead, they thought light leaving from the entire source radially and presented this by drawing a single line leaving from each point. Figure 7, shows a comparison of the ray diagrams on how light travels from an extended light source to the screen developed by the student participants in this study and its scientific conception.

Thus, Alvin and his group retained the conception of flashlight-like beams as they agreed on their best group's idea on how light is emitted from a source. If this is how students conceived light emanating from a source as flashlight-like beams, it is not surprising that in their diagrammatic representation they tend to show only single lines going outward from individual points on the bulb

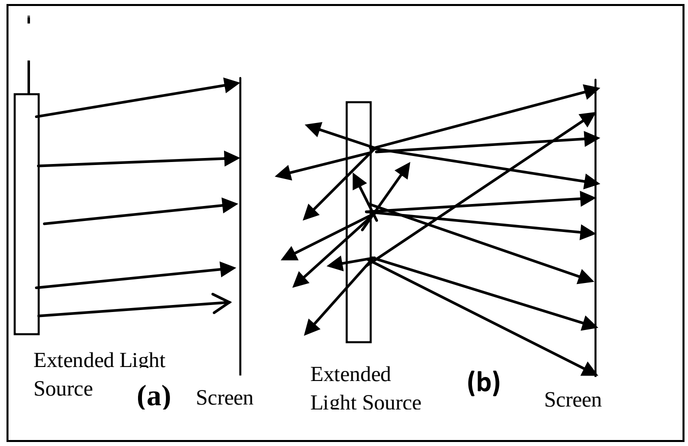

Figure 7. (a) Alvin's group diagram showing how light leaves from a light source. (b) Accurate ray diagram on how light leaves from each point on light source

FINDINGS

The student participants' best idea on the activity revealed that light travels in all directions. As implied from their hand gestures, light diverges in all directions as it leaves from an extended light source and represented this by drawing a single line leaving from each point.

The idea," light travels in a straight line in all directions," was presented orally and in written forms by the student participants. However, their diagrammatic representations of this idea were not congruent with their oral and written explanations. Their drawings did not show the graphical representation of a light ray, which consists of a straight line with an arrow indicating the direction to which light travels from the source. Parallel straight lines were drawn instead of straight lines radially outward from each point on the source.

CONCLUSIONS

Student participants presented correctly their ideas in both oral and written forms that light travels in a straight line in all directions, but their diagrammatical representations did not convey the same concept.

The student participants' conception on the idea that light travels in all directions is dependent on the type of light source provided. In a point light source, several diverging straight lines were drawn while in an extended light source, light travels in parallel lines and perpendicular to the shape of the light source.

P-ISSN 2362-8022 | E-ISSN 2362-8030

An extended light source was treated as a single light source and not composed of several, closely spaced point light sources.

RECOMMENDATIONS

In teaching geometrical optics in college Physics, teachers should not expect that some basic optics ideas like "light travels in a straight-line in all directions," were fully understood by the students from their high school Physics class. Assessment of students' preconceptions along with proper monitoring of their evolving conceptions should be done.

A research-based teaching strategy focused on conceptual change should be adopted in the local setting where teacher's modification and adaptation are required. Since the implementation of conceptual change strategies might be found ineffective in other classroom settings, teachers should be flexible enough in modifying and adapting them. This process requires intensive research.

Teachers should motivate students to participate in the "practice of science" and "construct meaning" for themselves. Students active involvement in science activities and their applications in daily life should be integrated in the teaching of science concepts. Moreover, the provision for individual reflection and analysis in constructing meaning for science concepts should be part of classroom activities where students become independent learners.

The CPU instructional lesson materials should be utilized in other Physics classes in other different programs.

An evaluation on the use of CPU lesson materials should be conducted from both subject teachers and students to gather feedback in terms of its strengths and weaknesses.

A quantitative research on student learning of science should be conducted where the importance of a learning environment on the students' academic performance is emphasized and the development of scientific ideas through experimentation, discussion and reasoning among students is the primary goal.

REFERENCES

[1] Goldberg, F. (1997).Constructing Physics Understanding in a Computer-Supported Learning Environment, in The Changing Role of Physics Departments in Modern Universities: Proceedings of ICUPE, E.F. Redish, Ridgen, J. S., Editor. 1997, AIP Publishing.

[2] McDermott, L and Physics Education Group at the University of Washington (1996). Physics by Inquiry. John Wiley & Sons, New York, NY

[3] Goldberg, F. (2005). Some Roles of Computer Technology in Helping Students Learn Physics: Computer Simulations. Paper presented at the International Conference on Computer and Information Technology in Physics Education, Manila, Philippines.

[4] Glynn, Yeany, and Britton (1996).The psychology of learning in science

[5] Posner, G. &Strike, K., Hewson, D. & Gertzog, W. (1982).Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66 (2), 211-227

[6] Yin, R (2009).: Case Study Research. Design and Methods Sage Publications, Thousand Oaks, 4th ed. 2009, pp. 240

P-ISSN 2362-8022 | E-ISSN 2362-8030