Learning and Dynamic Transfer Using the 'Constructing Physics Understanding' (CPU) Curriculum: A Case Study[$]

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Abstract. This research investigated the effectiveness of the Constructing Physics Understanding (CPU) curriculum in fostering student understanding of mechanical wave properties. The research was conducted at University of San Carlos, Philippines with six students. We draw on the constructivist philosophy and employ a phenomenographic approach as the underlying framework. The dynamic transfer model developed at KSU was the analytical framework used to map out students' intellectual development and gauge the effectiveness of the CPU curriculum.

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INTRODUCTION

The Constructing Physics Understanding (CPU) curriculum [1] is a popular curriculum used in furthering science education. The *Wave and Sound* unit (Cycles I and III) was pilot tested at the University of San Carlos, Philippines. This paper reports on six senior undergraduate teacher education students' learning while interacting with Cycle I. The six students were divided into two groups. The CPU pedagogy cycle is shown in Figure 1.

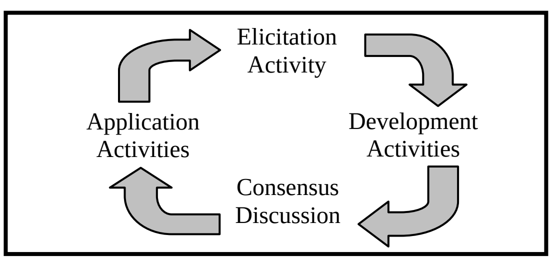

FIGURE 1. Outline of the CPU Pedagogy Cycle

Each cycle begins with an *elicitation activity* that builds upon 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.* In Cycle I the students worked on four activities. In this paper we will report on one of these activities –*Wave and Sound I: How do waves behave on a spring?* At the end of the development activities, students contribute to a *consensus discussion activity*. During this consensus discussion the instructor engaged the students in 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 pedagogical cycle described above was videotaped. In addition, all students' activity sheets, individual journals and written group consensus ideas were used to triangulate the information presented in this paper.

RESEARCH QUESTION

The research question that we seek to address within the relatively narrow context of a single CPU Unit – *Waves & Sound* is the following:

> *What are the processes through which students generate and share ideas as they attempt to reach a consensus in a group while completing the activities in the unit?*

We recognize the relatively narrow scope of the study in that it based on results of small group of students at a single university working on a small segment of the curriculum. Nevertheless, we believe it provides some interesting and useful insights of the potential issues that students could face as they work through with this type of curricular material.

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METHODOLOGY

The CPU pedagogy, as briefly described earlier, affords opportunities for students to interact with the materials and with their peers. Consistent with the notion of Vygotsky's Zone of Proximal Development (ZPD), the CPU unit builds from one activity to the next to form scaffolding. [2] A phenomenographic approach was used to examine the variation in experiences of a student's interaction with the CPU materials and with the other members of their group [3, 4] in order to answer the research questions listed above.

We divided the study into two phases. In Phase I, we analyzed the first cycle of the Wave and Sound unit. We compared students' class consensus ideas in Cycle I with the CPU target ideas. To gain a better understanding of these ideas we analyzed the transcripts that led to the development of these consensus ideas. Our analysis focused on the process of attaining the consensus ideas rather than the ideas themselves. In Phase II, to gain insights into students' intellectual development, we conducted a detailed investigation of a group's interaction with an activity in Cycle I – *Spring Activity*. In both phases we used the 'dynamic transfer model' [5] in the analysis of the transcripts. The model will be elucidated in later examples.

RESULTS AND DISCUSSION

Phase I

The unit of analysis in Phase I was the class consensus stage of Cycle I. Ideally, the *Class Consensus* (CC-I) would occur only after each group had arrived at *Group Consensus* on wave properties emerging from the development activities that comprised the *Spring Activity*, *Tuning Fork Activity*, *Ripple Tank Activity* and *Simulator Activity*. However, the *Ripple Tank Activity* did not go as planned, so we decided to proceed with CC-I to ensure that the *Group Consensus* was ultimately productive. Thus, during CC-I they redid the *Ripple Tank Activity* and completed investigations on the *Simulator Activity* that enabled them to come to a group consensus regarding wave properties. We note here that the two groups worked independently except for the ripple tank activity since there was only one ripple tank available at that time.

We have classified students' disagreements into two types: **activity-disparity** and **group-disparity**. An **activity-disparity** is a disagreement of results between two activities for which both groups have the arrived at the same conclusion. For example the *Simulator Activity* supported the idea that "wave speed is directly proportional to wavelength" while the *Ripple Tank Activity* supported the idea that "wave speed is inversely proportional to wavelength." In another example the *Simulator Activity* provided evidence that "frequency does not affect wave speed" but the *Ripple Tank* and *Spring Activities* provided evidence that "frequency affects wave speed."

The second type of disagreement -- **group-disparity**, is between groups that draw different conclusions from the same activity. For example in the *Spring Activity*, Group 1 found that as "amplitude increases the wave speed increases" while Group 2 found that "wave speed is amplitude invariant." Another example is the idea that "frequency affects wave speed" as supported by the *Spring Activity* for Group 1 while "frequency does not affect the wave speed" as was found in the same activity for Group 2. Both groups which performed the same activity reached different results.

One of the objectives of the class consensus activity was for the students to arrive at an agreement on wave properties and resolve any disparities. We have identified major themes that helped resolve the disparities. These themes were not discussed by the students chronologically but were chosen throughout the class consensus transcript using the dynamic transfer analytical framework. Figure 2 shows an analysis of two students' knowledge associations. The unit of analysis was the group because students within a group were extending each others' ideas. In a sense, the knowledge was "owned" by the group and identifying individual knowledge structures would be futile.

As shown in Figure 2 the external inputs were the disparities, velocity-wavelength-frequency equation, linear equation and the question that asked students to find out which of the wave properties were constant. The shaded bubbles are the *source tools* activated from long term memory. The students did not mention these concepts explicitly but they were implied from their statements. The first association constructed by the students was between the *source tool* of 'equation manipulation' and the *target tool* '$v = \lambda f$' resulting in an output '$v / \lambda = f$'. This reformulation became the new *target tool* and was next associated with a *source tool* -- 'dimensional analysis.' Association II gave an output which emphasized the unit '1/cm'. This output was in turn associated with the question, "Which is constant?" and gave the output that 1/cm is constant because it is not measurable and therefore not real and hence constant. The conversation is quoted below.

Student 1: Student 2 was telling us about the formula (writes the formula). So if we transfer λ so that's v/λ = f, and if we separate these two, we will have: v* (1/cm) = f. And 1/λ, as you said (referring to student 2) is not possible because we cannot measure distance of 1/cm or…(pause) that's what Student 2 is telling me. So, because this (1/cm) is not possible… (Asks student 1)?

Student 2:... this (1/λ) should be constant. This is not measurable…isn't this not real?

Student 1: Yeah…this is not real, ...

The shaded area in Figure 2 represents the model that students first associate as '*not measurable*' with '*not changing,*' i.e. '*constant*' Thus, a '*not measurable*' quantity must be *constant*. Hence, wavelength (λ) is constant. Further association with this new knowledge made them conclude that v (velocity) and f (frequency) are varying. This example shows that students possess prior knowledge and are capable of constructing their knowledge and the CPU pedagogy gives them an opportunity to do so.

We employed the same kind of analysis throughout the class discussion transcripts that helped us identify the disparities as well as the themes that resolved these disparities.

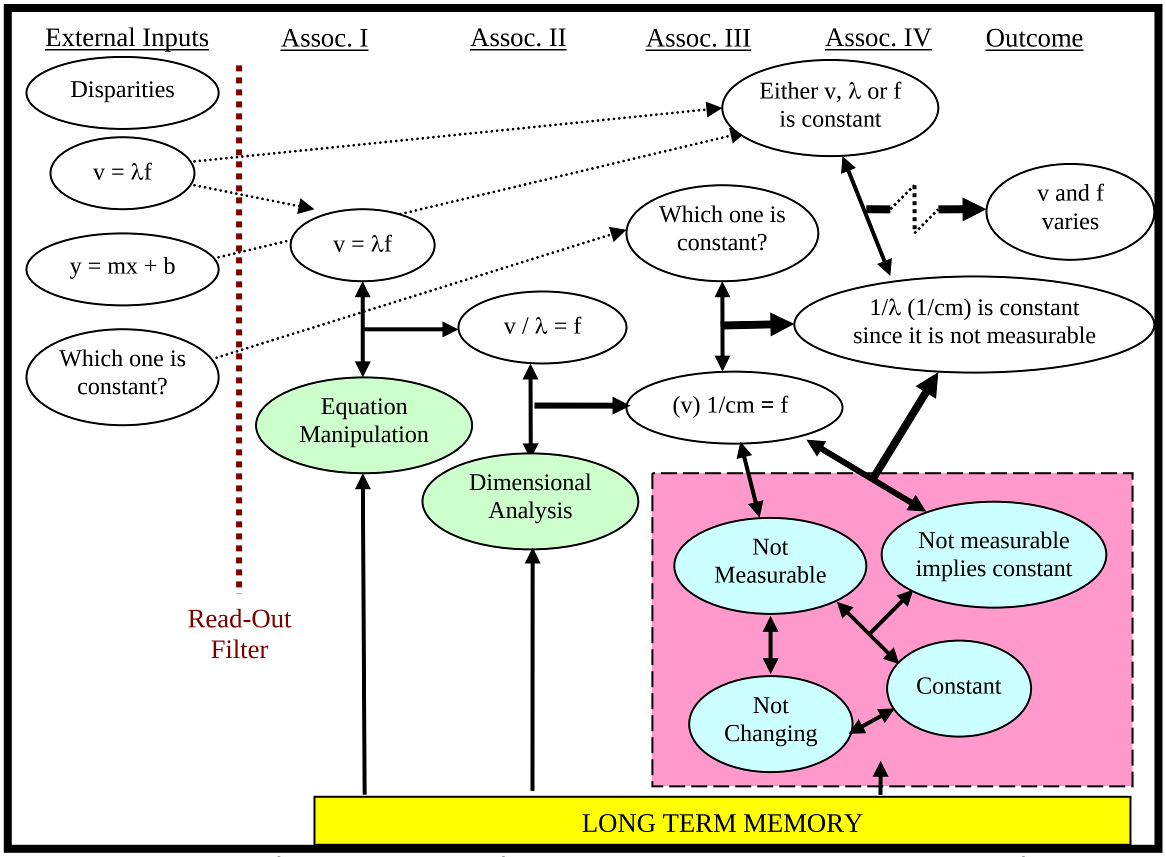

FIGURE 2. An example of two students read out from external inputs into target tools and associations from memory.

Phase II

The CPU *Development Activities* are key to Research Question #2. We decided to study the *Spring Activity* and focus on a single group. The *Spring Activity* created the **group-disparity** mentioned in Phase I although the students did not redo the activity. However, they cited the *Spring Activity* as evidence for the wave properties during another class consensus.

We will discuss the themes (data trends) emerging from our analysis of the *Spring Activity*. These themes could either be productive or unproductive in facilitating student conceptual learning. One important theme is that **students extend others' ideas that fit their knowledge structures**. For instance this occurred when a student extended another student's illustration to fit her concept that an increase in amplitude increases the wavelength. There were numerous examples that show **students' predictions being controlled by prior knowledge or activities** and the **filtration of inputs into target concepts** that would limit students' perception of an activity. Figure 3 illustrates these themes.

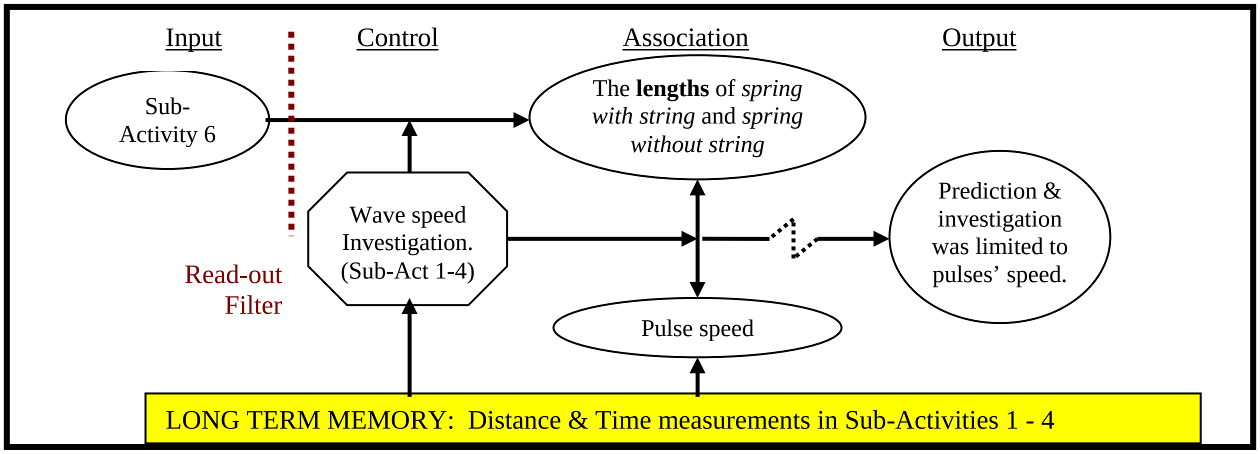

FIGURE 3. Influence of Sub-activities 1 through 4 on the interpretation of Sub-activity 6.

The external input was Sub-Activity 6 in the *Spring Activity*. The students were asked to predict the effect on wave properties when having a spring with a string and a spring without a string as a pulse went through it. Prior to this activity they had made successful investigations on the relationship between pulse speed and an increasing longitudinal or transversal disturbance. Students' recollections of these wave speed investigations in Sub-Activities 1-4 thereby became the controlling factor mediating the knowledge construction in Sub-Activity 6. Their recollections of the wave speed investigation prompted students to focus on the length of the spring and string in Sub-Activity 6 and associate these lengths with the pulse speed. As a result of these associations, students' later investigations were limited to wave speed while they did not notice other relevant factors affecting wave properties such as change in the medium. This is an example of students being unable to accomplish the target idea of an activity because they focused on an aspect of the activity that was irrelevant to the target idea.

LIMITATIONS OF STUDY

As mentioned earlier, this case study is rather limited in scope. However, we do believe that it is valuable in that it uncovers some interesting phenomena that can influence the ways in which students work collaboratively using an activity-based curriculum based on constructivist pedagogy.

CONCLUSIONS

In addressing the research question raised at the beginning of the study we find that students' working together through the CPU unit can potentially lead to creation of disparities of ideas generated between activities and groups. These disparities often occur primarily due to the lack of adequate working equipment (e.g. the Ripple Tank) and guidance in using the equipment. Such disparities could potentially pose barriers to achieving the target ideas.

The activities do appear to foster students' intellectual development as students work collaboratively to extend each others' ideas leading to both productive and unproductive outcomes. We also find that perceptions of questions and instructions may be filtered out based on prior knowledge or previous activities, and can affect the outcome of the activity. These observations point to the fact that instructors need to facilitate student intellectual development through interactive strategies such as Socratic dialog.

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