DYNAMIC TRANSFER AND LEARNING USING A CONSTRUCTIVIST-BASED CURRICULUM

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 a large public university in the Philippines, with six students. We drew on the constructivist philosophy and employed a phenomenographic approach as the underlying framework. The dynamic transfer model 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 (Goldberg, 1997) is a popular curriculum used for furthering science education. *The wave and sound unit*, cycles I and III, were pilot tested at a large public university in the, Philippines. This paper reports on six senior undergraduate teacher education students' learning while interacting with cycle I. The CPU pedagogy cycle is shown in figure 1. (Goldberg, 2005)

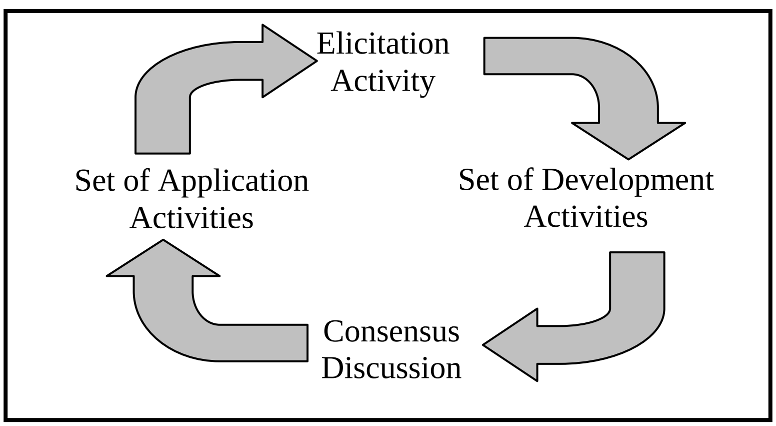

Figure 1: Outline of the CPU Pedagogy Cycle

Every cycle begins with an *elicitation activity* that draws on prior experience to invent 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 and in this paper we will report on one of them – *Wave and Sound I: how do waves behave on a spring*? This activity comprised phase II of the research. At the end of the development activities, students contribute to the *consensus discussion activity*; this activity was the unit of analysis of phase I of our research. During the *application activities* students apply the class consensus ideas in a wide variety of situations. The learning cycle described above was videotaped. Additionally, all students' activity sheets, individual journals and written group consensus ideas were used to triangulate information. Our research questions were:

1. To what extent is the constructing physics understanding (CPU) curriculum effective in the particular environment?
2. How do students develop intellectually as they interact with the constructing physics understanding (CPU) unit?

Methodology

We adopted the social constructivist learning theory. The CPU pedagogy, as briefly described earlier, affords opportunities for students to interact with the materials and with their peers. Also the CPU unit builds from one activity to another that forms a scaffolding which is consistent with the notion of Vygotsky's zone of proximal development. (Vygotsky, 1978)

A phenomenographic approach is used in order to study the students' experience of their learning as well as their experience of the context of the learning. (Marton, 1986; Trigwell, 2000) The phenomenographic approach aims to identify variations in experience of a phenomenon, which in this case is the interaction of the students with the CPU materials and their group members. It is for these reasons that the social constructivist view and the phenomenographic approach are utilized in order to answer the above research questions.

We used the 'dynamic transfer model' (Rebello et al., 2005) as per which transfer is a dynamic creation of associations between *target tools* read out form *external inputs* and *source tools* activated form the long term memory. Readout, activation and associations are mediated by the students' *epistemic state*.

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 were comprised of 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 instead to ensure that the *group consensus* was ultimately productive. Indeed, during cc-i they redid *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**. **Activity-disparity** *is the disagreement of results between two activities for which both groups have 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** -- was between groups who draw different conclusions from the same activity. For example in the spring activity group 1 found that as "amplitude increases the wave speed increases" whereas group 2 found that "wave speed is amplitude invariant." Another example would be the notion that "frequency affects wave speed" as supported by the *spring activity* for group 1 where "frequency does not affect the wave speed" as supported by the same *spring activity* for group 2. Both groups having performed the same activity reach different results.

One of the objectives of doing a class consensus was for the students to come to an agreement on wave properties and resolve any disparities. We have identified major themes that helped resolve the disparities:

- Linear equation (y = mx + b),
- Speed-wavelength-frequency equation ($v = \lambda f$),
- Use of the simulator, and
- Use of analogies.

These themes were not discussed by the students chronologically but were picked out throughout the class consensus transcript using the dynamic transfer analytical framework. For instance, 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 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, the linear equation and the question which 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 these concepts 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 constant. The conversation is quoted below.

Student 1: Student 2 was telling us about the formula (writes the formula on paper). So, if we transfer λ so that v/λ = f and if we separate these two we will have: v* (1/cm) = f . And 1/λ, as you (referring to student 2) said 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 a measurable…isn't this not real?

Student 1: Yeah…this is not real ...

The shaded area in figure 2 represents our model that students first associate '*not measurable'* with '*not changing,'* i.e. '*constant'* thus, a '*not measurable*' quantity must be *constant*. Hence, wavelength (λ) is constant. The dynamic transfer model facilitated our understanding of students' fine grain knowledge structures and helped gauge the extent of student achievement of the CPU goals for cycle 1. We also compared the two groups' class consensus ideas and found them to be mainly in accordance with the CPU goals.

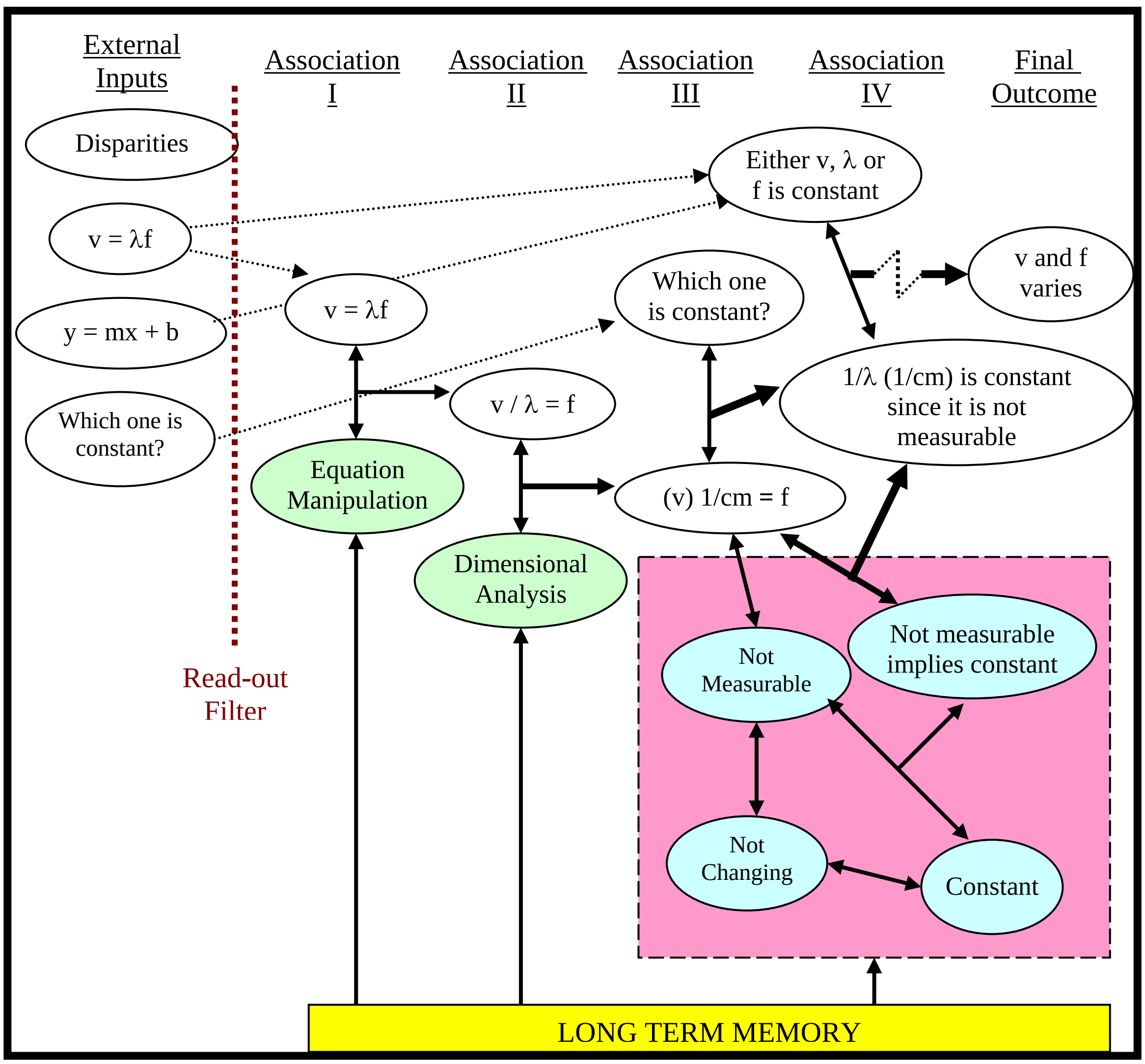

Figure 2 An example of read out from external inputs into target tools and associations from memory.

Phase II

The CPU *development activities* are key to research question 2. We have decided to study the *spring activity* and focus on a single group. The *spring activity* created the group disparity mentioned in phase I; but 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 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 other's ideas that fit to their knowledge structures**. This occurred for instance 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 would 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.

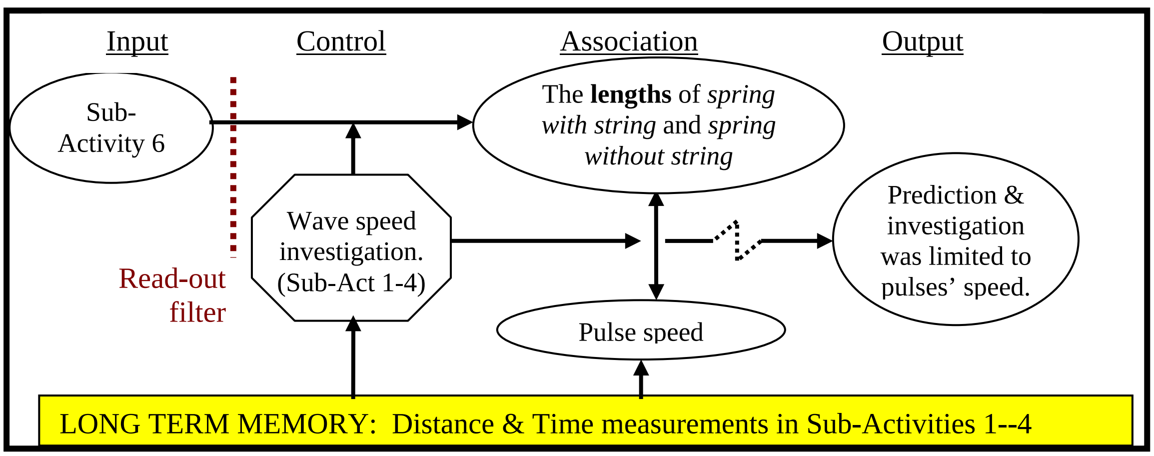

Figure 3 Influence of sub-activities 1 through 4 on the interpretation of sub-activity 6.

The external input was sub-activity 6 in the *spring activity*. The students were asked to predict the effect on wave properties having a spring with a string and a spring without the string as a pulse went through it. Prior to this activity they had made successful investigations into the relationship between pulse speed and an increasing longitudinal or transversal disturbance. Students recall of these wave speed investigations in sub-activities 1-4 thereby became the controlling factor mediating the knowledge construction in sub-activity 6. Recalling 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 without noticing some other relevant factors affecting wave properties such as change in the medium. This episode is an example of students not being able to accomplish the target idea of an activity because they focused on an aspect of the activity that was not relevant to this target idea.

Conclusions

Overall the CPU unit was effective in helping the students accomplishing the goals of cycle I. We note, however, that this was a pilot study and the students were closely mentored by the instructor (the first author of this paper) who provided constant scaffolding to guide the students' knowledge construction process. The effectiveness of this unit of the CPU curriculum may decrease if it was given to a larger class since the teacher's time will be spread out and we did identify some trouble spots in the activity. Therefore, one has to make sure that the activities are within the zone of proximal development of the students. The dynamic transfer model framework of analysis helped in mapping out students' knowledge elements and associations as well as evaluated the CPU curriculum.

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