Multi-Layered Concept Maps for the Analysis of Complex Interview Data

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Concept maps were first used by Novak and Gowin [1] to understand and describe student conceptions about physical phenomena based on interview transcripts. We have used features of this technique in the analysis of interviews with physics faculty aimed at understanding their conceptions of several interrelated aspects of the teaching and learning of physics. Concept maps have several advantages in the analysis of complex interview data. These advantages include: (1) reflecting, as much as possible, the interviewee worldview; (2) providing a powerful representation tool to show complex interrelations between conceptions; (3) forcing the researchers to be explicit about claimed interrelations in the data; and (4) establishing a transparent link between the results and the raw data. In this paper, we use concrete examples from our study to explain the procedures that we used to go from the interview transcripts to the final concept maps.

I. Introduction

Multi-layered concept maps can be used in the analysis of many types of interview data. The goal of this type of analysis is to use interview transcripts to understand what conceptions[*] a group of people have about some phenomena. These goals are consistent with phenomenological [3, 4] or phenomenographic [5, 6] research studies. Throughout this paper clarifying examples will be given from our study, which was designed to understand how six research university faculty conceive of the teaching and learning of problem solving in the context of an introductory calculus-based physics course. [7-13] We hope that other researchers can benefit from our experiences.

II. What is a Multi-Layered Concept Map?

A multi-layered concept map is a hierarchically arranged set of ideas and can be developed based on research participants' discourse during an interview. There are four basic layers: a main map, composite child maps, participant child maps, and participant statements.

Main Map

The main map is the highest layer and consists of the important features of the way that the interview participants conceive of the phenomena and how these features are related. For example, in our study, there were 14 important features represented on the main map. Figure 1 shows two of these important features and how they are related. Important Feature 1 indicates that the instructors have the conception that only some college students are capable of achieving the desired course outcomes. Important Feature 2 indicates that the instructors have conceptions about the problem-solving process. The Main Map also shows the relationship between these two important features. Taken together, it represents the instructors' conception that "some college students learn how to solve physics problems".

[*] In our study and in this paper, the term *conception* is used as a broad term to describe beliefs, knowledge, mental images, preferences, and similar aspects of cognition. [2]

The main map also indicates which of the interview participants' conceptions of the phenomena could be described by each of the important features. In our study, almost all of the important features and their relationships described all instructors. Thus, notation for individual instructors was only used when a feature or relationship was not representative of all instructors.

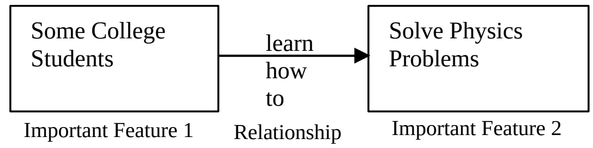

Figure 1: Example of two main features and their relationship from the Main Map.

The complete main map from our study is shown in Figure 2. This map was partly affected by the way the interview was structured. Several important features are closely linked to the interview in the sense that the interview was structured around these features. For example, in the interview we asked instructors about what they expected students to know or be able to do at the end of the course. Their responses, along with data from other parts of the interview, formed the important feature of Appropriate Knowledge. Other important features (e.g., Some College Students) and the relationships between important features originated from the instructors' discourse. Notice that even from this highest layer map we have useful information about the ways these instructors conceive of the teaching and learning of problem solving. For example, they all believe that only some of the students in their classes will learn. The details about which students they believe can learn are found in the child maps.

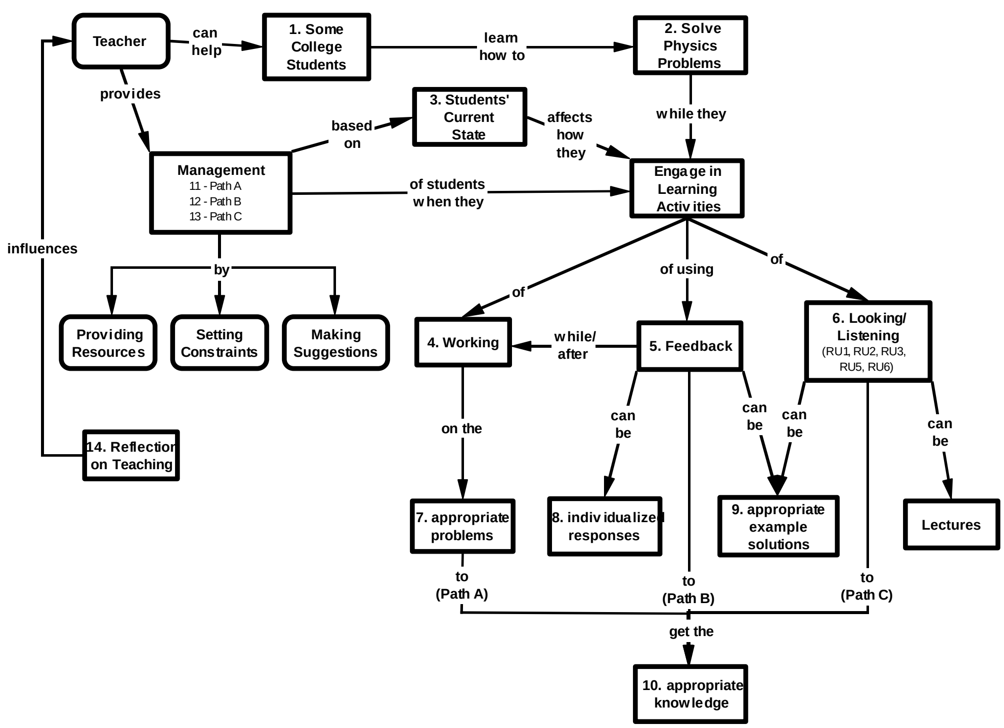

Figure 2: Main map from our study. The numbered boxes indicate important features that are elaborated in a child map. For some of the important features (e.g., lectures) there was not enough information available from the interviews to construct a child map.

Composite Child Maps

A composite child map contains the details about how all participants conceive of a particular important feature. Figure 3 shows a simplified composite child map that shows the details for the important feature of Some College Students. This map represents the instructors' conceptions of the differences between college students who can learn how to solve physics problems and those who can not. It shows a fairly strong agreement among the instructors that students can learn if they have enough natural ability as well as characteristics beneficial to learning. This map also identifies two types of students that these instructors believe will not learn. There are some students who do not have the ability to learn and then there are other students who have enough ability, but have other characteristics that prevent learning. These characteristics, such as not working hard, are included in the complete composite child map (Figure 8).

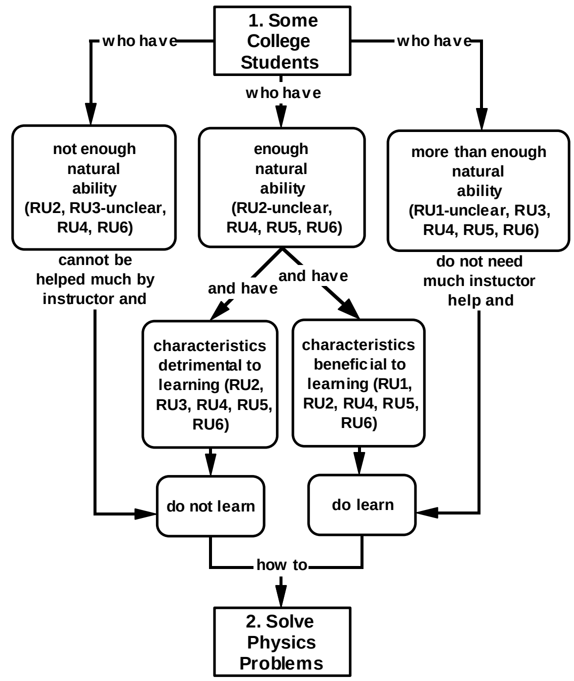

Figure 3: Example of a composite child map for the important feature of Some College Students.

Notation in each of the boxes (e.g., RU1, RU2, etc.) indicates which of the participants expressed a particular conception. The notation "unclear" is used when the researcher infers that a participant has a particular conception, but the conception is not explicitly expressed by the participant. Similar notation can be used on the links between boxes. We used the convention that notation on links would only be added if it would be unclear otherwise.

Participant Child Maps

Participant child maps contain the details about how an individual participant conceives of a particular important feature. In addition to providing an in-depth view of an individual they also provide a direct link to the interview data. Figure 4 shows a simplified participant child map for the important feature of Some College Students. The numbers on each box and link refer to statements made during the interview. The statements are numbered sequentially, making it possible to easily determine which conceptions are expressed in two or more distinct parts of the interview. For example, the conception that "not caring is a characteristic that is detrimental to learning" is expressed once early in the interview

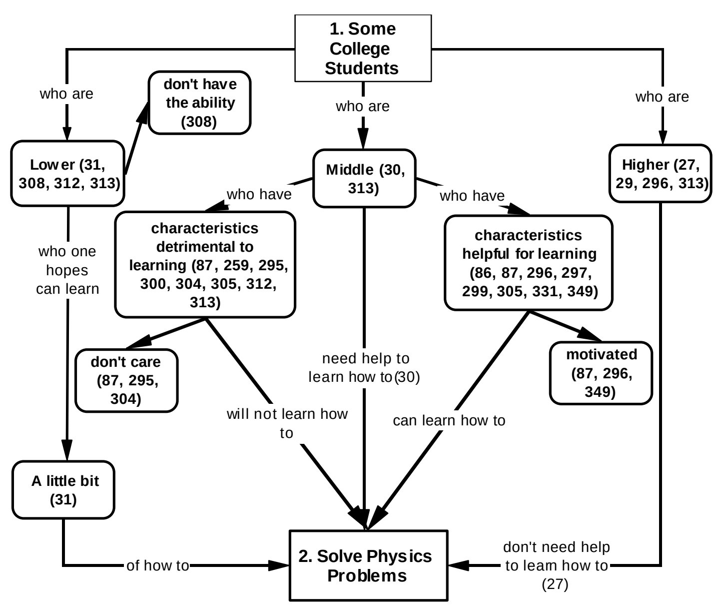

Figure 4: Example of a participant child map for the important feature of Some College Students. This one is from Instructor 6 (RU6).

(statement #87) and again later (statements #295 and #304). Similar to the composite child maps, we used the convention that notation on links would only be used if it would be unclear otherwise.

Participant Statements

Participant statements are the basic units of analysis. Each statement was constructed from the interview transcripts to capture a single idea expressed by the interviewee. [14] The words used by the participant were retained whenever possible. Each statement was designed to stand alone and was assigned a code to allow easy reference back to the original transcript. Parentheses were used when it was necessary to add context to a statement. Text in parentheses was not considered to be part of the statement. Figure 5 shows an example of a statement. Each of the 1½ to 2 hour long interviews used in our study yielded approximately 400 statements.

(Time is one factor that accounts for some students being more successful than others.) And of course there are some that just don't have the ability too.

Figure 5: An example of a participant statement. This one was statement #308 from Instructor 6.

III. Advantages of Using Multi-Layered Concept Maps

A. Multi-layered concept maps reflect, as much as possible, the interviewee worldview

Concept maps allow the researchers to identify new conceptions that are implicitly or explicitly expressed by the interviewees. Since the concept maps are built directly from interviewee statements, the new conceptions emerge from the interviewees' point of view. Often these conceptions could not have been explicitly stated by the interviewees or the researchers prior to the construction of the maps.

B. Multi-layered concept maps provide a powerful representation tool

Three advantages of this representation tool are described below.

Complex interrelations between conceptions can be represented.

A concept map can show complex relationships that would be difficult to describe in prose. In addition, concept maps clearly show where a relationship does not occur. For example, in our study, instructors believed that most students had poor problem solving abilities at the beginning of the course. One aspect of this was the instructors' conception that students used poor approaches to solving problems, such as tending to rely on looking up formulas rather than understanding physics. This poor problem solving ability, though, is not shown on the Some College Students composite child map. Thus, it is not seen by these instructors as a factor that limits students from learning how to solve physics problems.

Concept maps clearly show the similarities and differences between individual participants.

The composite concept maps show the range of participant conceptions as well as the overlap and distribution of these conceptions. For example, in our study, the composite child map for the important feature of Some College Students shows that all of the instructors have the same conception that only students with enough natural ability and characteristics beneficial to learning (such as motivation) will learn how to solve physics problems. Other composite child maps, however, show that the instructors do not have the same conceptions. For example, the composite child map for Solve Physics Problems shows that each of the instructors has one of three distinct conceptions about the process of solving physics problems.

The participant child maps can also provide useful information about similarities and differences between participants. For example, comparing the participant child map of Some College Students for Instructor 3 (see Figure 7) to that of other instructors (for example, Instructor 6 in Figure 6) shows that instructor 3 talked considerably more about the characteristics of very good students in his class than any of the other instructors. Instructor 3 also describes student characteristics of average students that are detrimental to learning, but not characteristics of average students that are beneficial to learning. This contrasts with other instructors who expressed detailed conceptions about characteristics of average students that were beneficial to learning.

Multiple layers make it possible to quickly "zoom" on an area of interest.

This representation allows the reader to use higher-order maps to navigate quickly to a particular area of interest at the desired level of detail.

<u>C. Researchers are forced to be explicit about interrelations in the data</u>

We found this to be one of the most difficult and most useful aspects of this analysis method. When constructing a concept map, the researcher is required to make an explicit link between two boxes and to name that link. One of the primary goals of constructing the concept maps was to combine similar conceptions in order to clarify the underlying thinking. This was done both within individual participants when constructing the participant maps and across participants when constructing the composite maps. This combination process forced us to clarify our interpretation of the conceptions and be explicit about why and how they were similar or different.

This could be done by a single researcher, but we found the different perspectives afforded by multiple researchers to be particularly important at this stage. As with any type of research, one of the problems that a lone researcher has is becoming aware of his/her implicit conceptions. These implicit conceptions can have a significant influence on the research results. For example, in our study, four researchers were involved in the creation of the concept maps. When developing the combined concept maps we would all, at times, use the term "feedback". Because of the connections made between feedback and other concepts on the map, it became apparent that we were all using this term to mean different things. Through discussion we were able to come to an agreement about what constituted feedback. This forced us to develop more accurate categorizations of instructor conceptions related to feedback. Instead of feedback, the final composite child maps contained more meaningful terms such as "real-time feedback", "delayed feedback", and "individualized response".

<u>D. There is a transparent link between the results and the raw data.</u>

This enhances the credibility of the analysis by showing the degree of support for each box and link. [4, 15] On the participant child maps it is possible to see how many interview statements support a particular box or link as well as where in the interview these statements came from. Similarly, on the composite child maps it is possible to see how many participants have conceptions consistent with a particular box or link. In addition, this provides a data trail that can be used by an external or internal researcher to audit the study and evaluate the results. [4]

IV. Procedures for Constructing Multi-Layered Concept Maps

The five basic stages in constructing multi-layered concept maps are shown in Appendix A (pp. 11-12). The table is meant to summarize the basic procedures used in our study. It is important to note, however, that the actual procedures we used were much more iterative than the relatively distinct stages presented in the table.

V. An Example from Our Study

This example will follow a piece of interview transcript from one participant, Instructor 6, as it gets broken into statements and then put onto a participant child map. Finally, it will show how this concept map for Instructor 6 and one from another instructor were combined to form a composite concept map.

Clarify Focus of Analysis

Hycner suggests that a researcher make all possible statements from an interview transcript and then decide which ones can inform the research interests and which can be discarded. [14] We found this impossible, however, since there is considerable interpretation in deciding what constitutes a single statement. In order to be transparent about this interpretation we created 7 broad questions to guide the creation of statements. These questions were based on a system view of teaching/learning, where the system of interest is the people, things, and activities related to an introductory physics course. From this perspective the instructor and students enter the system with some set of characteristics. The instructor and students interact within the system. There are also outside influences on the system. The instructor and students leave the system with some new set of characteristics. The 7 broad questions included "What are the instructor characteristics (e.g., beliefs about how physics should be taught) when he/she enters the teaching/learning system", "What are the possible interactions between participants in the teaching/learning system?", "What student outcomes does the instructor desire from the course? How do they compare to actual outcomes?".

Making Statements

After the interview, the audio portion of the interview was transcribed. Table 1 (next page) shows a portion of the Instructor 6's interview transcript and the resulting statements. This portion of the interview primarily informed the important feature of Some College Students (Map 1), which contains qualities of students that the instructor explicitly relates to success or failure in learning how to solve physics problems. The column labeled "Used?" indicates whether the statement was used in one of the participant child maps for Instructor 6 or whether it was excluded for being vague ("V"), not relevant ("NR"), or not understandable ("NU"). When the interview text was not understandable, the text was left "as is".

Creating a Participant Child Map

Figure 6 shows the complete participant concept map for the important feature of Some College Students for Instructor 6, which contains information from the statements from the example portion of the interview and other statements from other places in the interview. In each box on the concept map and on each link is the statement number that provides support for that particular idea.

Table 1: An example of statements made from a portion of the interview transcript.

Interviewer: *Ok. I want to talk about two different kinds of students. And looking at your chart [created earlier in the interview] there's students that come in knowing stuff, which is great. But there are also a lot of students who don't come in being able to handle these areas. And of those students that come in without being able to handle them, some of the students get better and some of the students don't. So I'm wondering what the difference between those two types of students is -- the students who improve during the class and the students that don't.*

<table>
<tr><th>Transcript</th><th>Stmt. #</th><th>Statement</th><th>Used?</th></tr>
<tr><td rowspan="11">Instructor 6: Well, I mean, there's certainly a lot of categories. First of all, there's the ones that just don't care, that aren't gonna get any better. And of course, there's the other extreme, the people that really have the intelligence and motivation to look into these things. I think problem solving in general is something that some people find fun, and some others don't. I mean, some people like going through, and I think probably most physicists are in it because they like doing it. And so I think the people that enjoy a challenge, that enjoy the idea of working these things out, and coming up with knowledge that they didn't have before. I mean, I think that's the sort of sense of wonder sort of thing. I think on the negative end of things there's a lot of people that just think all this stuff is just totally beyond them, they'll never be able to do it. And therefore they're not going to try. I think some people have a sort of feeling that if they're not going to be good at it, why worry about it. It's not going to be important for them. Here are these things about…there was a newspaper article that [name] used to have on his office a long, long time ago, which was some columnist saying, "why do we have to know algebra anyway? I never see any want ads for an algebra-doer!" or things like that. So some people, they have a tendency to disparage what they can't do. And so they won't care about it. I think that's the biggest problem with teaching these big general courses, is you get that bigger fraction that just don't care.</td><td>294</td><td>Well, I mean, there's certainly a lot of categories.</td><td>V</td></tr>
<tr><td>295</td><td>First of all, there's the students that just don't care, that aren't gonna get any better.</td><td>Map 1</td></tr>
<tr><td>296</td><td>And of course, there's the other extreme (as opposed to students who just don't care and aren't gonna get any better), the people that really have the intelligence and motivation to look into these things.</td><td>Map 1</td></tr>
<tr><td>297</td><td>I think problem solving in general is something that some people find fun, and some others don't. (This is a difference between students who improve and students who don't.).</td><td>Map 1</td></tr>
<tr><td>298</td><td>(I think problem solving in general is something that some people find fun, and some others don't.) I mean, some people like going through, and I think probably most physicists are in it because they like doing it.</td><td>NR
(this study is not concerned with why people go into physics)</td></tr>
<tr><td>299</td><td>(I think problem solving in general is something that some people find fun, and some others don't.) And so I think the people that enjoy a challenge, that enjoy the idea of working these things out, and coming up with knowledge that they didn't have before (will improve in the class). I mean, I think that's the sort of sense of wonder sort of thing.</td><td>Map 1</td></tr>
<tr><td>300</td><td>I think on the negative end of things there's a lot of students that just think all this stuff is just totally beyond them, they'll never be able to do it.</td><td>Map 1</td></tr>
<tr><td>301</td><td>(I think on the negative end of things there's a lot of people that just think all this stuff is just totally beyond them, they'll never be able to do it.) And therefore they're not going to try. I think some people have a sort of feeling that if they're not going to be good at it, why worry about it. It's not going to be important for them.</td><td>Map 1
Map 3</td></tr>
<tr><td>302</td><td>Here are these things about…</td><td>NU</td></tr>
<tr><td>303</td><td>There was a newspaper article that [name] used to have on his office a long, long time ago, which was some columnist saying, "why do we have to know algebra anyway? I never see any want ads for an algebra-doer!" or things like that.</td><td>NR
(it's not clear what this example relates to)</td></tr>
<tr><td>304</td><td>So some people, they have a tendency to disparage what they can't do. And so they won't care about it. I think that's the biggest problem with teaching these big general courses, is you get that bigger fraction that just don't care.</td><td>Map 1
Map 3</td></tr>
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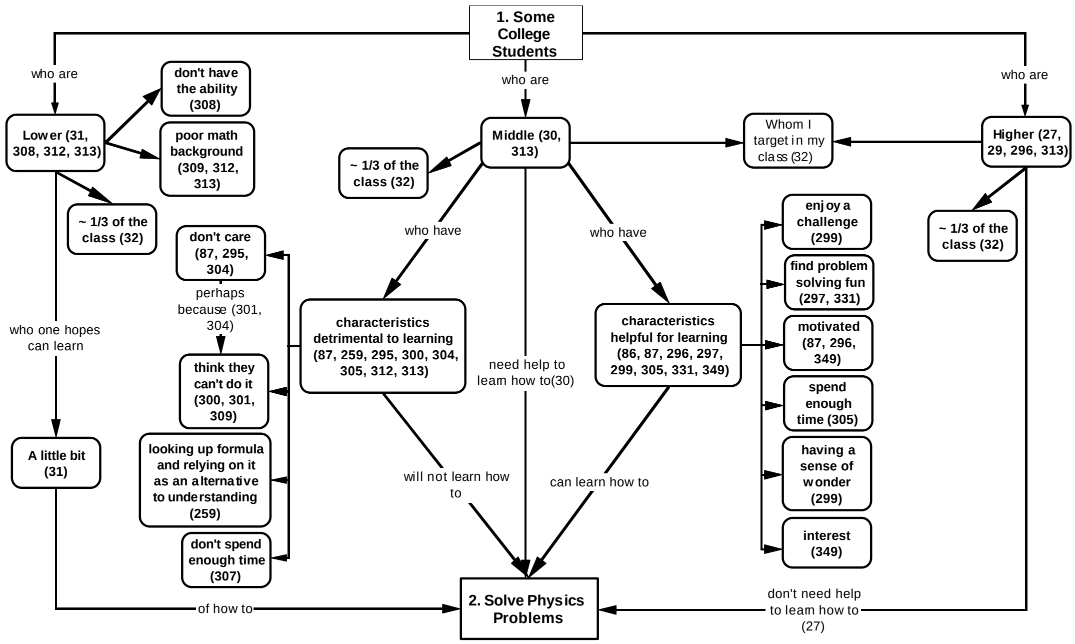

Figure 6: Instructor 6's participant child map for the relevant feature of "Some College Students".

Combining Concept Maps

In a similar way, participant child maps were constructed for all of the instructors. The participant child map for Instructor 3 is shown in Figure 7. These participant maps were combined to get the composite child map shown in Figure 8. Note that in combining the concept maps the goal was to combine individual instructor ideas when they seemed to have the same conception and to leave the ideas separate when they seemed to have different conceptions. That is, the composite maps should show the common core of conceptions as well as the range of the conceptions. The wording used on the composite concept maps is the wording that the research team believes can convey the instructor conceptions most accurately and most compactly.

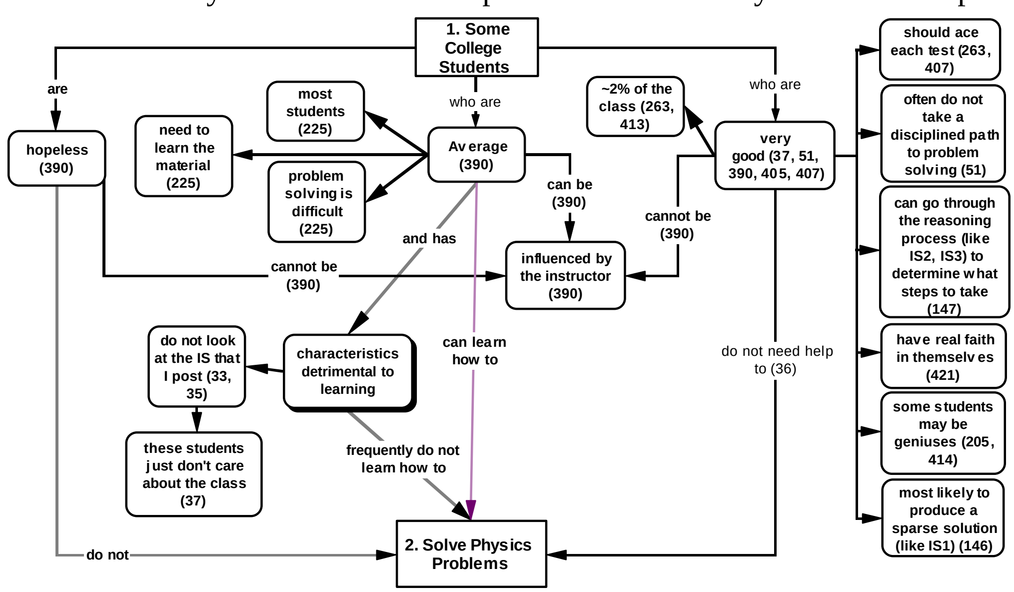

Figure 7: Instructor 3's participant child map for the relevant feature of "Some College Students".

As an example of this process, consider the path to the left of the Some College Students box on each of the participant concept maps. Instructor 6 (see Figure 6) describes a group of students that he calls “lower” who “don’t have the ability”, have “poor math background” and who he hopes can learn “a little bit” about how to solve physics problems. Instructor 3 (see Figure 7) describes a group of students that he calls “hopeless”, whom the instructor cannot influence. These two instructors seemed to be describing the same thing – that there is a group of students in their class who lack some sort of natural ability and who won’t learn how to solve physics problems. This, along with similar evidence from the other 4 instructors, led to the creation of the path to the left of the Some College Students box on the composite map (see Figure 8). Notice that in the “not enough natural ability” box on the composite map that Instructor 3 is shown as “unclear”. This is because on the individual map for Instructor 3 (see Figure 7), it is implied, but not explicitly stated that these students who are “hopeless” are hopeless because of a lack of natural ability rather than some other cause. Instructors 2, 4, and 6 explicitly identify the lack of natural ability as the reason that these students will not learn how to solve physics problems.

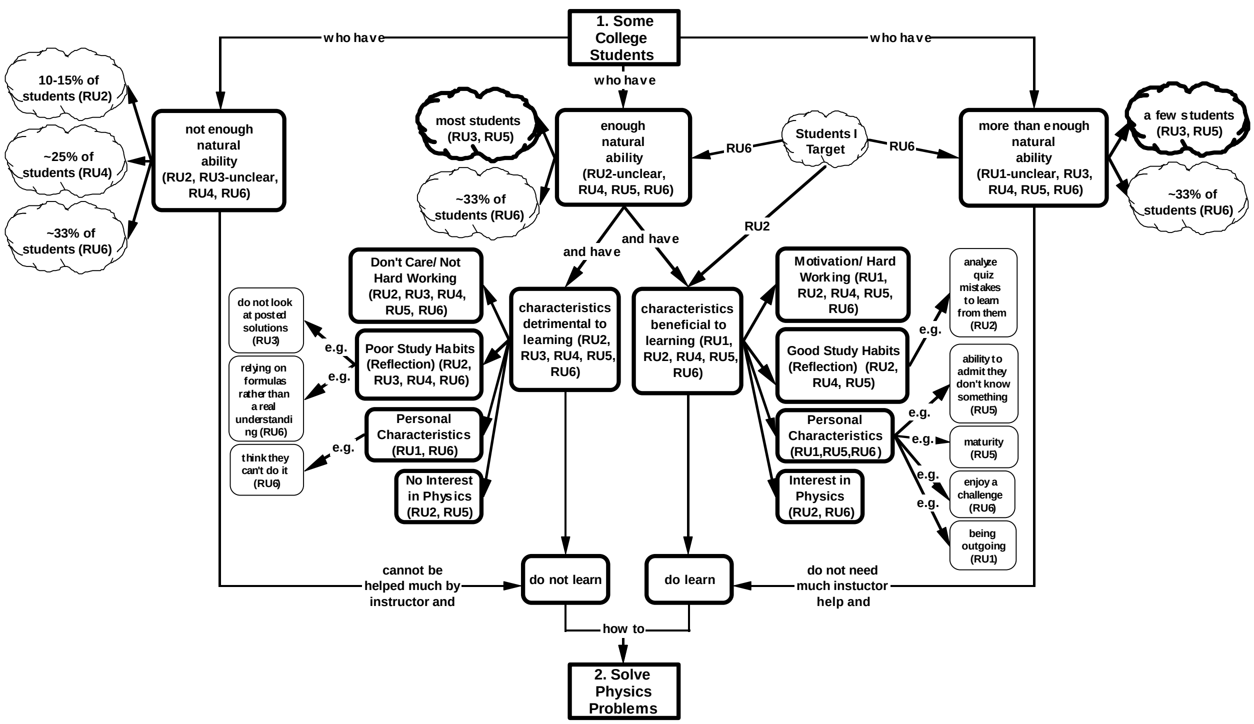

Figure 8: Composite child map for the relevant feature of “Some College Students”.

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Appendix A: Summary of procedures used to construct multi-layered concept maps

Analysis Stage	Goal	Basic Procedure	Details/Suggestions
1. Clarify Focus of Analysis	Sharpen focus of analysis and identify researcher bias. This is important since constructing statements is already an interpretive act.	Identify general questions that it is hoped can be answered using the interview data. (The analysis is open to other questions that may arise, but guided by these questions.)	In our study we had 7 broad open-ended questions based on our understanding of the context in which the interviewees worked (e.g. "What does the instructor think students are like?").
2. Construct Statements	Break the interview transcript into smaller units that can be used in constructing concept maps.	Rules for creating statements (also see Hycner [14]): • Statements should use participant's words and phrasing whenever possible – this minimizes the effect of researcher interpretation. • Each statement should represent a coherent idea. • Statements must be meaningful on their own. • Statements should be as brief as possible. • Keep statements that are not understandable or don't seem relevant – they may be important later.	Number statements sequentially from the beginning of the transcript. When writing statements use parentheses to identify information that adds necessary context, but that his not part of the statement. We wrote and organized statements in one column of an excel spreadsheet. This allowed us to use other columns for different categorization schemes and facilitated sorting. To develop skill in constructing statements and identify researcher biases we initially had two researchers make all statements. The resulting statements were compared and differences discussed. After two complete transcripts, the researchers were in agreement 93% of the time.
3. Construct Main Map	Develop tentative main map that will help to organize the data and focus further analysis. The main map should present a meaningful story about the way that the interview participants view the phenomenon.	Begin by identifying natural clusters of statements [14, 15] and possible relationships between clusters. These will form the basis for an initial "best guess" main concept map to use as a starting point. Each of these will eventually become an important feature and have its own child map. (e.g., the cluster of student characteristics that prevent them from learning became important feature of Some College Students)	This is more likely to be robust if it is based on the statements from more than one participant.

Analysis Stage	Goal	Basic Procedure	Details/Suggestions
4. Construct Participant Child Maps	Refine and validate main concept map. Create link between raw data and emerging concept map structure. Understand and represent similarities and differences among interview participants.	Take all of the statements from one participant and categorize each as belonging to one or more of the clusters. Start with one of the clusters. Try to arrange the statements into a concept map that shows how that participant spoke about that important feature and how that important feature is related to other important features. Keep the statement number with all statements. Do this for the other clusters. Select the participant who is most unlike the first participant and repeat this process. Revise main map and repeat. Repeat the process above for remaining participants, revising the main map and already completed participant child maps as necessary.	Two statements can be combined if the researcher believes that they mean the same thing. If there is any ambiguity it may be best to keep both wordings at this point. Statements can be shortened if there is no loss of information (they do not need to stand on their own since they are now linked to other statements in the context of an important feature). We used three types of researcher checking to diminish the effect of individual researcher interpretations on the final concept maps. 1) Two researchers independently create a map for a particular relevant feature for a particular participant. 2) After completing a concept map another researcher carefully scrutinizes it for aspects that are unclear or lack face validity. 3) After completing a concept map another researcher spot checks the connections between the map and the statements – going back to the transcript if necessary. We made the distinction between connections explicitly stated by the interviewee and those inferred by the researcher. The later were identified by dashed lines or dashed line boxes. Arrange all participant concept maps for a particular important feature so that similar ideas are in similar places. This prepares the maps for step 5 and can lead to the identification of discrepancies in the ways that different maps were created.
5. Construct Composite Child Maps	Identify the common core of conceptions that all participants have. Identify the range of conceptions (i.e., the outcome space) for conceptions that are not part of the common core.	Work with one important feature at a time. Construct a composite map that represents the similarities and differences on each of the participant maps. Language on the concept maps should express the underlying ideas as clearly and concisely as possible. It is not necessary to use participant's language, but should be done when possible. Use notation on each box or link to identify which interview participants expressed that idea.	We found that there were two basic types of composite maps. One type was where all of the participants basically thought about that relevant feature in the same way (e.g., the relevant feature of "some college students can learn"). The other type was where there were two or more qualitatively different ways that the participants viewed the relevant feature (e.g., the relevant feature of "solve physics problems"). We found that it was often necessary to go back to the original transcript to clarify the meaning.