Manual

Procedures for identifying the information content of student classroom experiences and predicting student learning.

(Revised for use in the Project on Learning)

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Introduction

The procedures described in this manual were developed for identifying the information that students experience during their participation in classroom activities. These procedures were originally developed in the early 1990s as part of our first studies of the learning of individual students in science and social studies classes. A brief report of those original procedures is given in an article in the *American Journal of Educational Research* (Predicting learning from student experience of teaching: A theory of student knowledge acquisition in classrooms. 1993, 30 (4), 799-840), and in a report to the Ministry of Education (*Student learning in the classroom: Understanding Learning and Teaching Project 3*. Wellington: Ministry of Education, June 1997). They were later revised and extended for the analysis of the data obtained in the six studies of student learning that were part of the *Project on Learning* funded by the Marsden Fund.

Purpose

The purpose of these procedures is to identify the curriculum relevant information that students encounter during their participation in classroom activities. It is presumed that as students participate in classroom activities, they automatically try to make sense of their experiences. This process of "making sense" means, among other things, that they identify the information that is relevant to the curriculum purposes of the activities. For example, if a teacher sets the students the task of finding out about the role of women in ancient Egyptian culture, as the students search for and read relevant books or web-sites, they encounter information relevant to answering teacher's the question. This information will come in a variety of forms that may be more or less complete or useful for answering the question. The purpose of the procedures in this manual is to identify what this information is, and in what form it is encountered.

The theory underlying these procedures is that what students learn from their classroom activities is dependent on the information they extract from their engagement in those activities. Predicting what students will or will not learn from classroom activities depends on identifying the information that they encounter. Individual student learning is a function of the sequence and timing of the information that the student encounters during their classroom activities.

The data needed for using these procedures

These procedures are designed to be used on recordings and observations of individual student experiences in classrooms. In our studies we have used a combination of individual videorecordings, individual audiorecordings, and live observations to obtain a continuous detailed record of the experiences of individual students throughout the course of a curriculum unit or topic. In order for the procedures to be useful, the data must be as complete as possible. Everything that a student does and experiences (from the time the student's prior knowledge is assessed to the time the student's learning is assessed) must, as far as possible, be included. This is not so difficult when the experiences occur within the classroom, it becomes more of a problem when the experiences occur outside the classroom. One way of partially overcoming this problem is to get the students to keep daily diaries of relevant out-of-class activities.

Preliminary data preparation.

The first part of the analysis involves dividing up all of the data on an individual student's experience into "item files". In the tests that we have used for assessing student learning, we have tried to write at least one item for every piece of knowledge (specific propositions, definitions, concepts, explanations, principles, generalisations, and procedures) that the teacher intended or hoped the students would learn, and that we thought they might learn from the resources and materials they would be using. This has meant that each item in the test has provided a focus for the analysis of the data. By dividing the data on individual student experience up into the data relevant to each individual test

item, these "item files" provide a complete record of all the student experience relevant to the learning of an individual proposition, concept, etc.

Procedures for coding the content of episodes

(Note that the examples used to illustrate procedures in this section are taken from a science class in which the students were studying the nature of light.)

Identifying types of learning outcomes

The first step in the coding procedures is to identify the type of knowledge being assessed in each of the outcome test items. This is because we have found that the experiences necessary for learning different kinds of knowledge vary slightly. The types of knowledge that we have identified are: 1. specific propositions, 2. definitions, 3. concepts, 4. explanations, 5. principles and generalisations, and 6. procedures.

The following are general definitions of these different kinds of knowledge.

1. Specific propositions: These included facts, names, and descriptions, e.g., During the peasant's revolt, the peasants were revolting against very low wages. The heart of New York is called Manhattan.
2. Definitions: These included definitions of technical or other significant words, e.g., Refraction means the bending of light. To be short-sighted means that you cannot see things clearly when they are a long way away.
3. Concepts: These involve the understanding of an idea or general concept and were often tested with more than one item, e.g., What did a scribe in ancient Egypt do? What happens when light is refracted?
4. Explanations: These involve identifying how something is or was caused, e.g., Why does a piece of white paper look white? Why were the ancient Egyptians almost never involved in wars with their neighbours?

5. Principles and generalizations: These involved propositions of a more general nature that could be deduced from examples, e.g., Medieval towns arose from the need of land owners to obtain goods their servants could not produce. In order to measure the air temperature correctly, a thermometer needs to be kept out of direct sunlight. Although there were female pharaohs, women were not considered as important as men in ancient Egypt.
6. Procedures: These items involved getting the students to carry out a procedure or describe how they would carry out a procedure, e.g., What is the temperature shown on this [picture of a] thermometer? What do you need to do to produce the colours of the spectrum on the wall of the classroom? What things did they use when they made a mummy in ancient Egypt?

Some items involve visual as well as semantic or textual content. For example, the students might be asked to locate the position of research bases on a blank map of Antarctica, to identify the correct diagram of the way light enables the eye to see objects, to name a sample of Egyptian hieroglyphic characters. In these items, the pictorial or visual content needs to be translated into propositional form, so that, for example, the visual representation of a hieroglyphic character was treated as the definition of the letter it represented, the location of a scientific base on a map of Antarctica was treated as a proposition about location. Examples contained in the last section of this manual illustrate how this is done.

Identifying the information needed to answer an item

The next step in content coding is to make explicit the information that is needed in order to know or understand the specific proposition, definition, concept, explanation, principle, generalisation, or procedure being assessed in the test item.

Where appropriate, this information can broken up into its key elements. For example, knowing the concept of ‘cumulus clouds’ involves knowing that the name ‘cumulus’ refers to clouds and knowing what cumulus clouds look like. Knowing why white paper appears to be white involves knowing that the appearance of objects depends on the light reflected off its surface and knowing that white paper reflects all

the colours of the spectrum off its surface. The purpose of doing this is to be able to identify when information that is partially or indirectly relevant to answering the question occurs.

Identifying relevant student experiences

The next step is to identify, within the transcripts of student experiences, the relevant informational content of those experiences. This involves (a) identifying the information that students are exposed to or can reasonably be expected to infer from their experiences that relates in any way to any concept assessed in the outcome test, and (b) identifying the boundaries of the episodes within which distinct pieces of information occur.

(a) Identifying relevant information

The informational content of students' experiences is identified in relation to the content of the test items and the specific propositions, definitions, concepts, explanations, principles, generalisations, or procedures that the items are about. This information comes in two forms.

(i) Information students experience. This is information that students hear, read, or see. It is information that is either made available to them through their exposure to spoken or printed verbal or visual materials, or it is information that is available to them though an activity they engage in, such as a science activity. In either case, there is an opportunity for students to identify and extract relevant information. The information is identified and coded provided there is a reasonable possibility that the students can understand what they are seeing, reading or hearing, or they know what they should be looking for during an activity or procedure.

(ii) Information that students express. This is information that students express through what they say, write, or draw. In this case, the act of saying, writing, or drawing the information is taken as a further occurrence of the information in the experience of the student. In the following example, Sonya explains to Kelly the reason for the results of their activity. This is taken as a further relevant experience for both Sonya and Kelly of the information that the colour of a filter determines the colour of the light it lets through.

Teacher: Which of these colours did the filters let through? What did the blue let through? Blue let through?

Sonya: Blue.

Teacher: Green let through?

Kelly: Green, lime green.

Teacher: Red let through?

Sonya and Kelly: Red.

Teacher: Yeah exactly. (85)

Kelly: Why?

Sonya (Kelly): Well if that there's red then of course it will let through the red, ‘cause it is red. If that there was green, of course it will let through the green, ‘cause it is green. If that there blue ..

Kelly: So what's the other thing?

Often these two categories are mixed together. For example, a student may be reading a source of information such as a text, or the work of a neighbouring student, as she/he writes a report. In the following example, Austin was looking at the work of Mary and Derek and reading an instruction sheet as he wrote out an explanation of the results of an experiment.

> Austin writes in his report book ‘why I think this happened’. He looks across at Mary’s and Derek’s reports. He continues writing ‘I think this happened because’ He mutters something to himself, looks around the classroom, taps his fingers on his desk, and reads the instruction sheet. He then turns back to previous pages in his book and reads what he has written there. He says to himself: ‘Ok. What happened’. He looks across at Derek’s work, and starts writing again: ‘blue cellophane only transmits blue light’ He then leans back in his seat with hands behind his head.

Austin is more or less simultaneously reading and writing that ‘blue cellophane only transmits blue light’.

The information that is identified is always identified in relation to a specific concept. Sometimes specific information is relevant to two or more different concepts. In this case it is coded separately for each of these different concepts.

We have found when carrying out this procedure that the coder needs to have a clear knowledge of the content of the entire test. This may mean learning the content of the test off by heart, so that as the record of an individual student's experiences are being read, anything relevant to any of the test items can be automatically identified. We have also found that going back through the records several times is necessary before everything relevant is identified and connected to the relevant test item.

(b) Defining relevant episodes.

An episode consists of a section of the transcript in which information relevant to a test item is discussed, read, seen, written, expressed, or is made available to a student through an activity. In general, an episode ends and a new one begins when a distinctly different kind of information (as defined by the content coding categories below) begins. Most episodes are larger than single statements or sentences in text. They consist of significant segments of discussion, the carrying out of an activity (or a significant part of an activity), or the sentences the student writes in answer to a question. The following are typical episodes.

Example 1. Teacher discusses with Sonya's group why water magnifies. The episode begins when the teacher asks Krista to repeat the original question and answer. Then the teacher asks the group to explain why. The significant information is 'why water magnifies'. The teacher suggests they refer to their previous experiences and leaves the group. Alice completes the explanation

Teacher: Sonya didn't hear the first one, go back to the first one.
Krista: Does your finger look bigger when it is in a jar of water? Yes.
Sonya (looking at Jerry's finger in the jar, to teacher): Yes.
Teacher: Why?
Krista: Why?
Jake: 'Cause um....

Krista: Because the water's like a magnifying glass and it makes it bigger. 48

Teacher: But why, what's that little ..

Krista: It's magnified.

Teacher: Yeah, but what's that - oh no - see if you can think of some of the things you've done before now that might tell you why, more - it does magnify but why does it magnify, why does make it look bigger? (leaves group)

Alice: Because the air through the water makes things looks um, bigger and closer up. And then it goes slowly and it makes all the things in the water look close up.

Jerry: Bigger.

Alice: Bigger. (50)

Example 2. Maurice, Patrick and Shaun are carrying out an experiment that involves looking at their finger in a jar of water. Between them, they agree that the water makes the finger look bigger. The focus is on the magnifying effect of looking at a finger through water.

Maurice (reading from instruction sheet): What does this say? Stick your finger in the small jar look to see how big it appears. Pour water in the jar. … Now go and get water in the glass, not full. Shaun about (Shaun shows Maurice how high he will fill the jar) No higher.

Shaun goes to sink and fills jar with water and returns to his desk.

Maurice: Now, I'll put my finger back in, how does it look?

Patrick: It's bigger.

Maurice: Wow, it's huge!

Shaun looks at Maurice's finger in the jar of water.

Maurice: Big finger.

Shaun puts his own finger in the jar of water.

Maurice: Whoa, that's one big finger.

In general, each episode contains one segment of relevant content that relates to one concept. However, there are occasions when the same episode contains information relevant to more than one concept. In the following example, Sonya is writing about

the way blue cellophane lets through only blue light (test item no. 30). In doing so she uses the word ‘translucent’ which is the focus of test item no. 35.

> Sonya is writing in her topic book ‘What happened to the colours. My blue cellophane was translucent’. She looked around at the poster on the back wall of the class, then continued writing: ‘so all the colours went through’. She poked her pencil at the blue cellophane on her card, and talking to herself, she continued writing: ‘so I had to double the colours. She crossed out the word ‘colours’ and wrote ‘cellophane so light blue didn't go through’ (160) ‘when I doubled the cellophane’.

Such episodes get coded twice. Once for each of the relevant items.

When the same information re-occurs in close proximity, it should be treated as one episode. The exception to this is when there is a distinct change in the nature of the activity. In the following example, Sonya reads and copies into her topic book that ‘No light is reflected and we see black’. The reading and the writing are taken together to constitute one episode. Then Sonya informs others (Kelly and Rowena) about what she has found out. The behaviour of telling the others typically counts as another episode although it contains the same information. As a consequence, this excerpt would be treated as two episodes (the blank line indicates the division between them).

> Sonya (reading information sheet): He we go, it says the black. It says here, it says here. ‘No light is reflected and we see black’.
>
> Rowena: No light reflected and we see black?
>
> Sonya: I've found the answer. Ok I'm going to write, ok. (185)
>
> She writes in her topic book: ‘if no light is reflected we see black.’.
>
> Sonya: Ok it says here ‘if an object absorbs all the rainbow colours in the, in light, no light is reflected and we see black’.
>
> Rowena: What's the actual sheet.
>
> Kelly: So there's no light reflected?
>
> Sonya (Kelly): Yeah if no light is reflected we see black.
>
> Kelly: That's what I write?

Sonya (Kelly): That's it, if no light is reflected we see black.

Kelly: I've done that. What are we doing now?

Sonya (Kelly): It's all finished.

Rowena: If no light is reflected. (190)

Sonya (Rowena): Yep no light is reflected we see black.

When the same episode contains both correct and incorrect information, it should be coded twice, once for each type of information. In the following example, two different definitions of black are provided – one by Shaun and one by Patrick. These should be coded as separate pieces of information, one coded as valid and the other coded as invalid.

Teacher: Blackness what causes blackness?

Shaun: All the colours that don't reflect. (160)

Teacher: Ok what, where did you see that Shaun?

Shaun: It says there, <u>if an object absorbs all the rainbow colours in light, no light is reflected and we see black</u>.

Teacher: Ok, so you put it in your own words.

Shaun (looking at the information sheet): Yeah I did.

Teacher: You tell me it in your own words now.

Shaun: Oh um… 162

Teacher: Patrick what causes blackness.

Patrick: Um <u>when there's no light</u>.

Teacher: Yeah ok that's a simple way of putting it isn't it?

Shaun: Yeah.

Once the information contained in student experiences has been identified along with the boundaries of the episodes in which the information occurred, each episode is classified according to the kind of information it contains, using the content coding categories listed below. Each episode is also classified according to the validity of the information that occurs in it. The validity categories are listed below the content categories.

The Information Content Coding and Validity Categories

Brief definitions of content categories

(Note: Extended definitions of each of the categories with examples of each category are contained in a later section, below)

In order to simplify the definitions of the content coding categories, the term 'concept' will be used as a generic term to refer to any of the specific propositions, definitions, concepts, explanations, principles, generalisations, or procedures that made up the intended outcomes of the units. Although some of these outcomes were measured using several different test items, the term 'item' will be used to refer generally to the test item or items that were used to assess each concept.

1. Explicit concept definition: The full information (including all key elements) needed to answer the item in words that a student can reasonably be expected to understand.
   1.1. Exact information: full information in the words or form (e.g. picture) used in the item
   1.2. Approximate information: Full information but in other words or form, e.g. paraphrase or different picture
   1.3. Wrong or misleading information: Information that appears to be a complete item answer but is wrong or misleading.

2. Implicit or partial information: Information which contains some of the key elements but not all required to answer the item, or information from which the answer to the item can be deduced or inferred.
   2.1. Information from which the item answer can be logically deduced.
   2.2. Information that contains some, but not all of the key elements needed to answer the item.

2.3. Corrections to incorrect information, or information about what the answer is not.

2.4. Implicit word meaning, in which the definition of a word is implicit in the way the word is used or occurs in a discussion or an activity.

2.5. Concept use. The concept is used as part of a description or explanation for another concept or principle in a way that implies the correct meaning for the concept.

3. Additional and background information, reasons and examples:

3.1. Definitions and descriptions of key elements or concepts that make up the information needed to answer the item

3.2 Reasons or explanations for the proposition, concept, principle, or generalisation being assessed by the item, or, use of the concept as the reason or explanation for another concept.

3.3. Analogies for key elements or concepts in the information needed to answer the item.

3.4. Descriptions or pictures of examples or instances of the concept, generalisation, or principle being assessed when the defining criteria are made explicit.

3.5. Descriptions or pictures of negative examples or non-instances of the concept, generalisation, or principle being assessed, with information that it is not an example or instance

3.6. Personal experiences of students that relate directly to the concept being assessed.

4. Preparatory or contextual information:

4.1. Information that provides relevant background, or is related closely to the information needed to answer the item.

4.2. Descriptions or pictures of examples or instances of the concept, generalisation, or principle being assessed when it is not clear why it is an example or instance

4.3. Information about the purpose and procedures of an activity intended to provide item relevant information.

4.4. Review of previously presented item-related information or relevant discussion.

4.5. Information about events leading up to, or the context of, activities or events, e.g., the historical context of an event.

4.6. Discussion or activities that are intended to prepare for, or lead up to the presentation of relevant information or the carrying out of an item-relevant activity.

4.7. Asking a question, or setting a problem that is designed to elicit or create item-relevant information.

5. Mention or reference to key words or concepts. These are references to the names of concepts or principles that do not contain any item-relevant information. They often involve creating links to other concepts or principles but do not add anything to what a student already knows.

6. Activities and procedures. These are activities or procedures that produce, create, or are intended to lead directly to concept-relevant information. This is more than just talking, reading or writing, and includes activities such as carrying out a science experiment or making a model of a key concept.

6.1. Activity or procedure in which the item-relevant information is explicit (obvious) and complete.

6.2. Activity or procedure in which the item relevant information is clearly explicit but is only part of the information needed to answer the item.

6.3. Activity or procedure intended to produce concept-relevant information, but the student needs to identify or infer the relevant information. The student may infer part or all of the relevant information.

7. Visual or object resources. These are resources in which relevant information is available but the resources are not the focus of attention, e.g., posters on the wall of the classroom that students look at from time to time. It is not possible to tell if the student has actually studied the information or not.

7.1. Visual or object resources that contain all of the information required to answer the item in an explicit form.

7.2. Visual or object resources that contain part of the information required to answer the item or contain information from which the answer could be inferred.

Validity Coding Categories

At the same time as the information in each episode is coded for type of content, it is also coded for validity. The basis of this coding is the relationship between the information contained in the episode and the information needed to answer the outcome test item.

1. Valid. The information is correct and relevant to the item
2. Ambiguous and mixed. The information contains both incorrect and correct information, or is ambiguous or confused.
3. Corrected. The information is incorrect but is corrected within the same episode. e.g., by the teacher.
4. Incorrect. The information is incorrect or clearly misleading.
5. Irrelevant: The information is about procedures or instructions and is not directly relevant to the content of the test item.

Learning prediction procedures

Once the information contained in each of the episodes has been coded for content and validity, it is possible to create a 'concept file' for each specific proposition, definition, concept, explanation, principle, generalisation, or procedure that is assessed in the outcome test. A concept file consists of all the episodes that have been identified as relevant to a specific concept. Where an episode is relevant to two or more different concepts, it is included in the concept-file for each of these concepts.

Once a concept file has been created for a specific concept, it is possible to predict, from an analysis of the content of that concept-file, whether the student will learn and remember that concept or not. This prediction procedure involves identifying the content, sequence and timing of the episodes that make up the concept-file.

Often, during the analysis of a concept-file, it is necessary to go back to the original transcripts in order to provide the context needed to interpret more fully how the student might have been experiencing and understanding the information contained in the concept-file.

Determining which episodes are relevant.

The first step in carrying out the prediction procedures is to look at the validity coding of each episode. Those episodes where the information has been coded as incorrect (code 4) or irrelevant (code 5) are omitted from the analysis. The second step is to ascertain whether or not the student was aware of the information contained in the episode. Where it is clear that the student was simultaneously attending to something else or could not have possibly seen or heard the information, the episode should be omitted from the analysis. It is rarely clear what students are actually attending to, and students are capable of attending to several things at once. Consequently, where there is any doubt, and episode should be included in the analysis.

Identifying the content of working memory.

The prediction procedures are based on the general assumption that learning results from the accumulated effects of a significant number of relevant experiences. For convenience, the effects of each relevant experience are said to be stored in a working memory (the theoretical reasons for using this concept are discussed in the later description of the learning process).

The first principle is that the effect of a specific experience only lasts for a maximum of two days. If the first relevant experience is not succeeded by a further relevant experience, then the first experience is discounted. It is treated as though it did not occur. Once two or more experiences have occurred, with no more than a space of two days between each of them, then their effect will last for significantly more than two days.

The second principle is that the combination of experiences that is critical for learning varies for the different kinds of learning outcomes. The specific combination of experiences that are required for each type of learning outcome are listed below. In general, when a student experiences new information, that information is stored in working memory where it interacts with prior knowledge and with any further related information that the student has experienced immediately before or after.

1. Specific propositions, concepts, and explanations:

For specific propositions, concepts, and explanations to be learned, working memory should contain representations of at least four relevant episodes, at least one of which should be an explicit concept definition (Code 1). The remaining three can be either further explicit concept definitions (Code 1), or a sufficient number of instances of implicit or partial information (Code 2), or relevant reasons, examples, or analogies (Code 3), or an explicit or partial activity or procedure (Codes 6.1, and 6.2). When working memory contains less than three instances of an explicit concept definition (Code 1), there needs to be an additional instance of either implicit or partial information (Code 2), or relevant reasons,

examples, or analogies (Code 3), or an explicit or partial activity or procedure (Codes 6.1, and 6.2)

Precisely If A = Code 1 information
And B = either Code 2, or code 3, or Code 6.1, or Code 6.2
Then working memory must contain either A + A + A + A
Or A + A + A + B
Or A + A+ B + B + B
Or A + B+ B + B +B

2. Principles and generalizations:

Working memory should contain representations of at least four relevant episodes, which can be either explicit concept definitions (Code 1), or instances of implicit or partial information (Code 2), or relevant reasons, examples, or analogies (Code 3), or an explicit or partial activity or procedure (Codes 6.1, and 6.2), except that when there are less than three instances of an explicit concept definition (Code 1), there needs to be an additional instance of either implicit or partial information (Code 2), or relevant reasons, examples, or analogies (Code 3), or an explicit or partial activity or procedure (Codes 6.1, and 6.2). When there is no Code 1 information in working memory, the content of the Code 2, 3, and 6 episodes needs to be checked to ascertain that there is no significant aspect of the principle or generalisation that is not contained in working memory.

Precisely If A = Code 1 information
And B = either Code 2, or code 3, or Code 6.1, or Code 6.2
Then working memory must contain either A + A + A + A
Or A + A + A + B
Or A + A+ B + B +B
Or A + B+ B + B + B
Or B + B+ B + B + B

3. Definitions:

Working memory should contain representations of at least four relevant episodes, at least one of which should be an explicit concept definition (Code 1). The remaining three should include one instance of Code 2.4 (use in which the meaning is implicit) and further instances of explicit concept definitions (Code 1), implicit or partial information (Code 2), or relevant reasons, examples, or analogies (Code 3).

Precisely If A = Code 1 information
And B = either Code 2, or code 3, or Code 6.1, or Code 6.2
And C = Code 2.4
Then working memory must contain either A + A + A + A
Or A + A + A + C
Or A + A+ C + B
Or A + C+ B + B

4. Procedures:

The precise combination of experiences necessary for learning procedures have not, at the time of writing this manual, been worked out. Relatively few examples of learning procedures have been identified in our data and until more are obtained, there is not enough information on which to write prediction rules.

Final Note: Although the rules for predicting student learning have been set out in a logically precise form, there needs to be an over-riding flexibility in how they are applied. Careful reading of an item-file is likely to show up other aspects of a student's experience that need to be taken into account. These include:

1. Misunderstandings: You need to be alert for any signs that the student is misunderstanding information in any way at all. Different understandings of what may seem obvious information can make apparently relevant episodes completely irrelevant in the learning process.

2. Additional learning experiences: Sometimes when a student does learn a concept without sufficient experience, or does not learn a concept with sufficient experience, it may be because the student is connecting apparently irrelevant experiences to relevant experiences. You need to be alert for the possibility that a student is making connections between information that do not appear logical or sensible to the researcher. As you examine the evidence and get closer to the student's thinking, you may discover the most unlikely connections have occurred.

In our experience, it almost always pays to go back through an item-file several times. Fragments of evidence that were not noticed on the first analysis, may become highly significant once the complete story of the student's experience is known. Repeated analysis leads to deeper and deeper understanding. Individual student learning is almost always surprising and fascinating, especially with more complex ideas and concepts.

Finally, be careful not to blame the teacher. We have found that, as we have got closer and closer to the classroom experiences of individual students, there is a tremendous amount going on in a classroom that the teacher is not aware of. Individuals are deprived of the information they need. Students are bullied, harrassed and put-down. Student behaviour is misunderstood and misinterpreted. Students are copying and creating ways of misleading and fooling the teacher. All of this is common in the best run classrooms. It is a function of the size of the classes and the common culture of our school system.

Expanded Definitions of Content and Validity Coding Categories, with Examples.

The Content Coding Categories.

In this section, the content coding categories are illustrated with examples from the transcripts of a science unit in an upper elementary school classroom. In each example, the number of the relevant test item is given first, with a brief description of its content. The name of the student who is the focus of the analysis is also given.

1. Explicit concept definition: The full information (including all key elements) needed to answer the item in words that a student can reasonably be expected to understand

1.1. Exact information: full information in the words or form (e.g. picture) used in the item

1.2. Approximate information: Full information but in other words or form, e.g. paraphrase or different picture

Q. 45. Austin (Black paper absorbs all the light that falls on it) In this example, the statements made by both Mary and Austin contain all the information needed to answer the item, but not in the exactly the same words as the item. Note that Mary's second statement is incorrect but since the focus is on Austin, and his is the final statement, the episode is coded as correct.

> Mary: So how shall we put this in a sentence about the black light. If an object absorbs all of the rainbow colours in light, no light is reflected and we see black.
> Derek: How do we put that in a sentence?
> Mary: Do we put something like um, if all rainbow colours are simply dark and light we only see black.
> Austin (reading from information sheet): If an object absorbs all the rainbow colours in light, no light is reflected and we see black. So...

Q 21. Sonya (Red coloured cellophane lets only red light through) In this example the teacher's question 'red let through?' and Sonya & Kelly's answer 'red' together make up the answer to the question, but leave the 'only' in the question implied.

Teacher: Which of these colours did the filters let through? … Red let through?
Sonya and Kelly: Red.
Teacher: Yeah exactly.
Kelly: Why?
Sonya (Kelly): Well if that there's red then of course it will let through the red, ‘cause it is red.

1.3. Wrong or misleading information: Information that appears to be a complete item answer but is wrong or misleading.

Q. 45. Austin (Black paper absorbs all the light that falls on it) In this example, Mary’s repeated statement that ‘all the light together’ make black is clearly a mistaken description of black resulting from all the colours being absorbed.

Teacher: What is blackness.
Mary: It's like all the light together.
Austin: Its um wait, it's. It's it's um.
Mary: All the lights together.
Austin: Oh I don't know. Black is black. (laughs)
Mary: All lights together that are bought in daylight make black.

Q.21. Austin (Red coloured cellophane lets only red light through) In this example, the students reach the conclusion that red cellophane may let all the colours through if you hold it in the right way. The idea that it depends on how you hold it seems to have come from Austin’s attempt to reconcile their different perceptions.

Mary: The red [cellophane] lets through everything.
Austin: Through the red? … Ok.
Mary: Something was able to get through the um. The (inaudible)
Derek: The blue, no another colour went through.
Austin: Yeah but all of the colours went through. Depends how you hold it aye.
Mary: Yeah all of the colours depending how you hold it, all of them went through.
Austin: So do you have to do what we did?
Derek: Yeah.

2. Implicit or partial information: Information which contains some of the key elements but not all required to answer the item, or information from which the answer to the item can be deduced or inferred.

2.1. Information from which the item answer can be logically deduced.

Q.16. Sonya (white paper looks white because it reflects all the colours of the spectrum). In this example, the statements are about white light being the result of all the colours of the spectrum being reflected. The question is about white paper, and, in order to answer the question, the students have to infer that the appearance of paper is the result of the colours that are reflected off it.

Rowena: Yeah white light is made out of all the colours mixed together.
Sonya: Ok. I've just about found the answer.
Rowena: We've got white light.
Sonya (reading from book): Ok she said 'the sun bounces off the prism to make white light'. That is white light.
Rowena (pointing to diagram of spectrum): We just put white light is made out of all the colours in the...
Sonya: Have you done white light.
Rowena: White light is made of all the colours mixed together.

Q. 27. Shaun. (refraction means the bending of light rays). In this example, Shaun hears Maurice say that when light goes through water, 'it slows down and bends'. Later he hears the teacher say about Maurice's statement that 'I thought you might have worked that out from refraction'. He could infer from the teacher's comment that refraction is about light bending.

Teacher (at Shaun's group): … what happens to the light when it goes through water? Who can remember?
Maurice: It slows down and bends.
Patrick: You read that out of the book.
Teacher: Yeah, I was just going to ask you that. You read it out of the book did you?
Maurice: Yeah.
Teacher: Where did you read that?
Maurice: When we were...
Teacher: You're right, but I was just wondering, I thought you might have worked that out from refraction, okay.

Q.s. 34, 35, 36, Whole class, Day 8. (Identifying pictures of transparent, translucent, opaque). In this example, the answers are given as definitions but the question requires that this information is translated into visual form. This translation from one medium to another is taken as a process of inferring.

Teacher: Who can tell me what translucent means. What does translucent meant Krista?
Krista: When some light comes in.
Teacher: Fantastic, some light. Who can tell me what transparent means, Rowena?
Rowena: When light passes through it.

Teacher: What about opaque please John?
John: When light does not pass through.
Teacher: Fantastic, okay.

2.2. Information that contains some, but not all of the key elements needed to answer the item.

Q. 32. Shaun (The sun needs to be at less than 45 degrees to make a rainbow). In this example, the teacher tells the students that the sun is too high at noon to cause a rainbow. This provides information that the angle of the sun is important, but not exactly what angle is critical.

Bettina: There, there. Oh you missed it [a rainbow] now.
Teacher: Can't see it because it's noon though. You won't get one will you?
Bettina: Yeah we saw one. 192
John: Can, go right on the sun.
Teacher: No apparently you can't get a rainbow at noon. No you can't get a rainbow at noon apparently.
Derek: Can we go out and have a look?

Q. 21. Austin (red coloured cellophane lets only red light through). In this example, Austin notes that red cellophane does not change red in a picture. This is part of the information he needs to know in order to reach the more general conclusion that red cellophane only lets red light through.

Austin (talking to self): Ok. Why I think this happened.
He writes in his book 'I think this happened because the red light [cellophane] doesn't change red but changes other colours.

2.3. Corrections to incorrect information, or information about what the answer is not.

2.4. Implicit word meaning, in which the definition of a word is implicit in the way the word is used or occurs in a discussion or an activity.

Q, 27. Sonya. (refraction means the bending of light rays). In this example, the word refraction occurs right next to the phrase 'the bending of light' although there is no actual reference to the meaning of 'refraction'.

Sonya (reading from instruction sheet to Kelly): What causes the bending of light (refraction) like you have seen in these activities. What would cause the bending of light? Water caused the bending of light.

Q. 34. Sonya. (meaning of 'translucent' -- identify the window that is translucent). In this example, Sonya uses the word 'translucent' in her written report in a way that indicates she knows believes she knows the meaning.

Sonya is writing in her topic book reporting what she did. She writes and says to herself 'My blue cellophane was translucent so all the colours went through so I had to double the cellophane so light blue didn't go through'.

2.5. Concept use. The concept is used as part of a description or explanation for another concept or principle in a way that implies the correct meaning for the concept.

Q. 4. Austin. (We see because of the light that is reflected off objects). In these examples, Austin and Shaun use the concept of reflection to explain how printing, when it is looked at through a mirror, looks upside down and back to front.

Austin writes 'Why I think this happened' in his topic book. He continues writing 'I think that this happened because it got'.
He glances around at the teacher who is talking to the class, and continues writing 'refelted and was turned upside-down'.

Q 4. Shaun (We see because of the light that is reflected off objects).

Shaun is writing in his report book, and talking to himself: 'Because it reflected and it went another way and turned around because of the brightness'

3. <u>Additional and background information, reasons and examples</u>:

3.1. Definitions and descriptions of key elements or concepts that make up the information needed to answer the item

3.2 Reasons or explanations for the proposition, concept, principle, or generalisation being assessed by the item, or, use of the concept as the reason or explanation for another concept.

Q. 24. Shaun (a green object seen through red cellophane looks brown). In this example, Shaun is trying to find an explanation for why, when you look at a green object through red cellophane, it looks brown. He gives an explanation, but it is a wrong explanation so the validity would be coded as 4).

Shaun is writing his explanation in his topic book. Talks to himself: Ok um. Why I think this happened.

He writes and talks to himself as he writes: It happened because there were different colours, different colours and (muttering) different coloured cellophane.

Q. 7. & Q. 8. Sonya. (a concave (convex) mirror makes you look bigger (smaller)). In this example, Sonya worked out an explanation for why, when she looked in a teaspoon the image of her face was changed in size and shape.

Sonya (to Kelly): Good, have you wrote why it happened?
Kelly: Yep.
Sonya: Why do you reckon it happened?
Sonya talks to herself and writes in her book 'I think it is because the mirror was curved inwards the picture was curved inwards'

Q.27. Sonya (refraction means the bending of light rays)

Teacher: Okay so how might bending of light help to make things bigger. You think about what happened when you looked at those coins this morning.
Kelly: When it bends, it makes it bigger. Yeah when it bends it makes things bigger. You have to write this down. Refraction is important to lenses.
Sonya (Kelly): What is it, because.?
Kelly: When it's like, its head's bent, it makes it bigger. That makes it...
Sonya (Kelly): So is that the answer, it makes things bigger?
Kelly: Cause that bit of pencil that's in water bigger.
Sonya (Kelly): Aye?
Kelly: It makes that bit of pencil bigger than that. (215)

3.3. Analogies for key elements or concepts in the information needed to answer the item.

Q. 5. Shaun (rainbows are formed by sunlight shining through raindrops). In this example, the way sunlight is refracted through raindrops is likened to the way sunlight is refracted through a prism ('they act like prisms'). Since the students have seen sunlight refracted through a prism, presumably it helps them understand how rainbows are created.

Patrick: How rainbows happen. When rainbows fall through sunlight.
Shaun (reading information sheet): No, when raindrops fall through sunlight they act as pris, prisms. (to self) Pris, prisms.

3.4. Descriptions or pictures of examples or instances of the concept, generalisation, or principle being assessed when the defining criteria are made explicit.

Q. 7. & Q8. Shaun (concave (convex) mirror makes you look bigger (smaller)). In this example, the students are trying to identify examples of concave and

convex mirrors. In some of the examples they also identify the reason why it is an example. It is clear from what the students are doing that they know the criteria ('its curved', 'they made you tall and thin and big') and are applying them.

Shaun (to Patrick): Where do we use curved mirrors? … Fashion shops, buses, boats, hospitals. Hospitals sometimes have them eh?
Patrick: What for?
Shaun: Well, if you like got a wheelchair and that they tell you, they look - and it's curved.
Shaun (talking to self as he writes): Um, fashion shops, hospitals. Mirror room.
Patrick: Mirror room?
Shaun: Mirror room. You know at carnivals and all that?
Patrick: Have you seen- have you been on a (inaudible) in that old farmers store, how they have those big mirrors and they made you tall and thin and big?
Patrick: That's about all isn't it?
Shaun: No, no, no, no. And going round um, going, going round steep corners. Going - round - some - corners.
Patrick: Oh yeah those big mirrors. 187
Shaun: Cause you know those corners sometimes, when you see them.
Patrick: Oh yeah, if you went up on the hill.

3.5. Descriptions or pictures of negative examples or non-instances of the concept, generalisation, or principle being assessed, with information that it is not an example or instance

3.6. Personal experiences of students that relate directly to the concept being assessed.

Q. 27. Austin (Refraction is the bending of light rays). In this example, Mary refers to her personal experience of mirages in the middle of reading about them.

Mary (reading from information sheet): 'You can bend light. On very hot day you can sometimes see what looks like a pool of water on the road although the road is completely dry. The light'. Oh, you know how you're going down the road and you see those big puddles.
Derek: Yeah.
Austin: It's like Mm ..
Mary: And it's not even there. (170)
Austin: It's like....
Mary: And they're not even there, eh.

4. <u>Preparatory or contextual information</u>:

4.1. Information that provides relevant background, or is related closely to the information needed to answer the item.

Q. 7. & Q.8. Austin (Concave (convex) mirror makes you look bigger (smaller)). In this example, Austin finds information that is relevant to the questions about how curved mirrors change the size and shape of images, but it is too general to be helpful in answering the questions.

> Austin (to Derek): Can I have that fact sheet there, beside you Derek?
> Austin reads the information sheet, nods his head and starts to write 'the mirrors'. He looks at the reflection of his finger in the spoon, and then finishes writing 'bend and curve you'.

Q. 40. Sonya (Light goes more slowly through water than through air). In this example, Sonya finds information about how light is refracted through hot air when the item is about light being refracted through water. It is related, but not directly relevant information.

> Sonya (reading from an information sheet to Kelly): There it is. Mirage, this is what people see. Okay, on a very hot day, you can sometimes see what looks like a pool of water on the road. Although the road is really completely dry. Light from the sky is bent (refracted) by the hot air near the road and the sky. You see it is actually refracted sunlight. This is why people see mirages in a desert. There you go.
> Kelly: Okay, so what is it? The sunlight.

4.2. Descriptions or pictures of examples or instances of the concept, generalisation, or principle being assessed when it is not clear why it is an example or instance

Q. 40. Shaun (light moves more slowly through water than air) In this example, Shaun watches and writes about an example of light bending as it passes through water (putting a thumb in water). There is nothing in the example to let him know that this is the case.

> Maurice: Now, I'll put my finger back in [in jar of water], how does it look?
> Patrick: It's bigger.
> Maurice: Wow, it's huge!
> Shaun looks at Maurice's finger in the jar of water.
> Maurice: Big finger.
> Shaun puts his finger in the jar of water
> Maurice: Yeah, that's what I did. Whoa, that's one big finger.
> Later Shaun writes (and talks to himself) 'We put our finger in some water and then we watched it magnify.

4.3. Information about the purpose and procedures of an activity intended to provide item relevant information.

Q. 7 & Q. 8. Whole class discussion. (concave (convex) mirror makes you look bigger (smaller)). In this example, the teacher talks about the way curved mirrors make you look quite different, but does not say in what way they make you different (e.g. that a concave mirror magnifies). Hence, this information is classified as introductory, alerting the students to what they ought to be looking for in their experiments.

> Teacher: Okay today we're looking at curved mirrors. (Holds up spoon) And I have a curved mirror here. Okay, I have a curved mirror here, too, and I look quite different if I look in different angles and different places, okay. Once again you have a sheet it tells you what to do. It has some questions which I would like you to talk about with your partner and with your group okay, so you - you do it -- you discuss the questions.

4.4. Review of previously presented item-related information or relevant discussion.

Q. 22. Whole class discussion. (Which of these colours do you find in a rainbow?). in this example, the teacher is getting the students to repeat what they learned the previous day. There is no discussion about the material, just a listing of what they learned.

> Teacher: … If I said I saw a colour spectrum this morning, who can tell me what colours I might have seen in my colour spectrum? Krista?
> Krista: Rainbow colours. (5)
> Teacher: Which colours are they Krista? Rowena?
> Rowena: Red, orange, yellow, blue, green, indigo, violet.
> Teacher: Ok, fantastic. Who can tell me the two colours I wouldn't have seen in my colour spectrum. Austin?
> Austin: Ultraviolet and red or something.
> Teacher: Infrared. Well done, okay excellent.

4.5. Information about events leading up to, or the context of, activities or events, e.g., the historical context of an event.

4.6. Discussion or activities that are intended to prepare for, or lead up to the presentation of relevant information or the carrying out of an item-relevant activity.

4.7. Asking a question, or setting a problem that is designed to elicit or create item-relevant information.

Q.5. Austin. (rainbows are caused by the sun shining through raindrops). In this example, Austin spends considerable time looking for the answer to the question about rainbows and keeps repeating the question. He never does get an answer that satisfies his interest in a 'scientific' answer.

Austin (reading the instruction sheet): What causes a rainbow? Ok, what causes a rainbow?
He moves across and reads the sheet on the colours of the spectrum on back wall of the classroom.
Austin (talking to self) What causes a rainbow?
Pupil: The spectrum.
Austin: Oh god! The spectrum.
Austin (talking to self) What causes a rainbow?
Teacher: What've you lost Austin?
Austin: No I'm looking for what causes a rainbow.
Teacher: What are you looking for?
Derek: What makes a rainbow? That's easy.
Austin (talking to self): It's easy when you think about it.
He picks up a book and turns the pages.
Derek: What are you looking for?
Austin: What causes a rainbow?

Q 2. Shaun. (light reflects off a solid board) In this example, the teacher poses the question and gets the children to provide answers but makes no comment at all about anyone of the answers. The students have no idea what the answer might be. Note there are, in fac t, two questions in this example.

Teacher: What happens to the light when it shines on that book? 160
Maurice: It stops.
Shaun: It stops.
Patrick: It just goes whiter.
Carly: It can't go through.
Verity: It's too thick.
Patrick: It just stays as it.
Shaun: Yeah, the book's too thick.
Teacher: So what's actually happening to the light when it gets there?
Shaun: It's stopping.
Patrick: It's spreading out.
Shaun: It's going smaller.
Patrick: It's going bigger, it widens 161
Patrick: 'cause now it's got nowhere to go through.
Teacher: Okay, those are the two questions you needed to discuss …

5. Mention or reference to key words or concepts. These are references to the names of concepts or principles that do not contain any item-relevant information. They often involve creating links to other concepts or principles but do not add anything to what a student already knows.

Q. 27. Sonya (Refraction means the bending of light). In this example, the key word refraction is used – it is said to be important – but there is no information about what it means.

Sonya (reading instruction sheet to Kelly): Refraction is important ...

Q.35. Austin (translucent means lets some of the light through). The name translucent comes up and Austin spells it, but nothing useful is said about the meaning of the word.

Derek: How do you write translucent? I writ mine wrong. 211
Austin: Transluc t-r-a-n-, a-n, s-l-u, s-l-u-, c-e-n-t. Okay?

6. Activities and procedures. These are activities or procedures that produce, create, or are intended to lead directly to concept-relevant information. This is more than just talking, reading or writing, and includes activities such as carrying out a science experiment or making a model of a key concept.

6.1. Activity or procedure in which the item-relevant information is explicit (obvious) and complete.

6.2. Activity or procedure in which the item relevant information is clearly explicit but is only part of the information needed to answer the item.

Q. 7. Shaun (a concave mirror makes you look bigger). In this example, Shaun is engaged in an experiment designed to show him that a concave mirror makes you look bigger. What the students see is that their thumb, reflected in the concave surface of a spoon is thinner and longer. This is an example of a general principle in which their conclusions are partially correct.

Maurice: Turn the spoon around so that you are looking into the back of the spoon. Now, back of the spoon now. Back of the spoon, you did it with the front first.
Shaun watches Maurice looking in the back of the spoon.
Maurice: You basically, you basically stretch taller.
Shaun (tries to take spoon off Maurice.): My turn.

Maurice: Oh man, and cause I know you're tall and (inaudible) and if you put your thumb on it, your thumb's completely thin.
Shaun takes the spoon off Maurice and looks at his reflection in the back of spoon.
Shaun: Very long.

Q. 30. Sonya (Blue coloured cellophane only lets through blue light). In this example, Sonya carries out an activity (looking at blue writing through blue cellophane) that indicates that blue writing is invisible through a blue filter. This is part of the information she needs to work out that blue cellophane only lets through blue light.

Sonya (to Jake): Could I please use it after her? Thank you. No I just need to try blue.
Picks out a blue felt from Jake's case and draws a small line on her card. She looks through the blue cellophane at the blue writing.
Student: Does that one work?
Sonya: Yeah this one works [is invisible].
Student: Could I use it after you please?
She holds her card up for the teacher to see, and then holds her card up for Jake to see.
Sonya (Jake): Look you can't see it. You can't see what I wrote. Ha! you can't see what I wrote. (59).

6.3. Activity or procedure intended to produce concept-relevant information, but the student needs to identify or infer the relevant information. The student may infer part or all of the relevant information.

Q. 24. Shaun. (a green object seen through red cellophane looks brown). In this example, Shaun is looking at several different colours through green cellophane. He appears to notice especially the brown effect produced by the green cellophane. It is not clear that he realises that this effect was produced by the red in the picture, and he does not articulate it.

Shaun picks up a green sheet of cellophane and looks at the picture through it.
Shaun (to Patrick): Look at that. … Pink, green, purple.
He moves a green sheet of cellophane around the picture.
Shaun: Yellow.
Patrick: And red.
Shaun: Yeah I had yellow. Orange. Brown, brown.
Patrick: Where's the brown?
Shaun: In there, that.
Patrick: What's colours are there?
Shaun: Round here, round all here's brown. (59)

7. Visual or object resources. These are resources in which relevant information is available but the resources are not the focus of attention, e.g., posters on the wall of the classroom that students look at from time to time. It is not possible to tell if the student has actually studied the information or not.

7.1. Visual or object resources that contain all of the information required to answer the item in an explicit form.

Q. 22. (Identifying whether green, red, yellow, brown, and blue, are colours in the spectrum.)

> Attached to the back wall of the classroom is a large coloured poster showing the visible colours of the spectrum emerging from a diagram of a prism.

Q. 10. Shaun. (Identify that the shape of a cross section of a magnifying glass). In this example, Shaun handles and looks through a magnifying glass for more than half the science period. It is not possible to tell whether he ever feels or looks at the shape of the lens.

> Maurice and Shaun look at each other through magnifying glasses. … Shaun goes to the bookshelf on back wall of the classroom, looking through his magnifying glass as he walks. … Shaun looks at his desk through his magnifying glass. … He looks at Maurice's work book through his magnifying glass. … He shows Patrick his magnifying glass.
> Shaun (to Patrick): Is yours bent like that? Is yours bent?

7.2. Visual or object resources that contain part of the information required to answer the item or contain information from which the answer could be inferred.

Validity Coding Categories

In addition to coding the informational content of the episodes, the validity of the content was also coded. The classification of the validity of the content was made in relation to the content of the test items, so that, for example, information that contradicted the information needed to answer a test item was coded as 'incorrect'.

1. Valid. The information is correct and relevant to the item

2. Ambiguous and mixed. The information contains both incorrect and correct information, or is ambiguous or confused.

Q. 16. Austin (White paper looks white because it reflects all the colours of the spectrum). In this example, two things are said about white light – that it is made of 'all the colours' and that it is made of 'heaps of colours'. It is not clear exactly what either of these means, although both could be the basis on which to answer the question.

Austin (to Mary): Have you done 'what is white light made up of'?
Mary: Yeah.
Derek: What is it? All colours.
Mary: Heaps of colours.
Austin (Derek): All the colours.
Mary: White light is made out of heaps of colours.
Teacher: Ok so what is white light?
Mary: Um, it's heaps of little, all the colours.
Austin: All the colours mixed together.

Q. 45. Shaun (Black paper absorbs all the light on it). In this example, Shaun provides an answer that is close to the information needed to answer the item, but the teacher accepts from Patrick a different answer that is also correct but not helpful for answering the item.

Teacher: Blackness what causes blackness?
Shaun: All the colours that don't reflect.
Teacher: Ok what, where did you see that Shaun?
Shaun: It says there, if an object absorbs all the rainbow colours in light, no light is reflected and we see black.
Teacher: Ok so you put it in your own words.
Shaun: Yeah I did.
Teacher: You tell me it in your own words now.
Shaun: Oh um ..
Teacher: Patrick, what causes blackness.
Patrick: Um, when there's no light.
Teacher: Yeah, ok, that's a simple way of putting it isn't it?
Shaun: Yeah.

3. Corrected. The information is incorrect but is corrected within the same episode. e.g., by the teacher.

4. Incorrect. The information is incorrect or clearly misleading.

5. Irrelevant: The information is about procedures or instructions and is not directly relevant to the content of the test item.