Analysing the enacted object of learning in lab assignments in programming education

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***Abstract*—In this paper we propose a way to analyse *the enacted object of learning* in written instructions for lab assignments in programming. Moreover, we apply the proposed kind of analysis to empirical data. The data stem from a small pilot study where we studied instruction material for one specific lab session, concerning non-void methods in Java. The larger framework for the results presented here is a research project aimed at better understanding the relation between how novice students learn theory and how they learn practice in the computer lab.**

Keywords—computer programming lab; self-documenting lab instruction;s phenomenography; variation theory; enacted object of learning

I. INTRODUCTION

What opportunities for learning can written lab instructions open to students in the computer lab? Previous research shows that lab sessions often offer complex learning environments where students might learn new things – but not necessarily what was the teacher's intention [1].

In this paper we present results from a pilot study that prepared for a larger research project [2]. The research project focuses on programming students' learning process and particularly on the relation between how students learn theory and how they learn practice in the computer lab. In the larger project, we need a way to analyse written instructions for lab assignments, with the objective to understand what opportunities for learning the instructions offer. In other words, the aim is to analyse the instructions with regard to the enacted object of learning (see Section IIA for explanation). In the pilot study reported here, we developed a way to carry out such analysis. Here, we will present this way of analysis and illustrate it by applying it to data from the pilot study.

II. BACKGROUND

A. The theoretical background

1) The object of learning.

The methodology in the main project builds on phenomenography and variation theory [3][4]. In the project we will study and compare the intended, the enacted, and the lived object of learning. In the present work we focus on the enacted object of learning.

Learning is to learn about *something*, the object of learning. Marton and Pang [5] explain that the object of learning does not only refer to the goal or aim of the learning, but also "to the conditions and outcome of learning" [5, p. 195]. There are thus different objects of learning that are relevant to study. *The intended object of learning* relates to what the teacher intends the students to learn in a certain learning situation, where *the lived object of learning* is the object of learning as experienced by the students in the same learning situation. *The enacted object of learning* on the other hand is, briefly explained, a researcher's description, from a particular theoretical perspective, of what the possibilities are for seeing a certain object of learning in a certain learning situation. Runesson writes: "Analyzing the enacted object of learning means revealing the constraints and possibilities for developing a certain capability." [6, p. 70] She further explains: "the description of the enacted object of learning reveals the space of variation and invariance that is possible for the learner to experience". [6, p. 85]

2) The phenomenographic view on learning

According to phenomenography and variation theory, to learn something about an object of learning is to discern a new aspect of this object, in the sense that this aspect comes into the learner's focal awareness and is experienced as being significant. In other words, the learner comes to "see" this aspect as important or "critical" for the understanding of the object of learning.

Variation theory [4] says that learning is to come to "see" some phenomenon (the object of learning) in a new way. In order for a student to "see" the phenomenon in a new and more complete way, it is necessary for the student to become aware of an additional aspect or of some relation between aspects that the student had not discerned before. In variation theory, it is said that each aspect of a phenomenon is related to a *dimension of variation*. This means, simply, that the aspect can take different "values" for different instances of the phenomenon. A very concrete example is the aspect

"diameter" of the phenomenon "circle". Different circles can have different sizes of diameter, so in that sense there is a "diameter" dimension, along which circles vary.

A key assumption in variation theory is that for a learner to come to see a new dimension, or a new relation between dimensions, it is necessary for the learner to be exposed to some variation or invariance along those dimensions. The rationale for this assumption is straightforward: if all examples of circles have the same diameter, then it is unlikely that "diameter" will come to the fore as a significant aspect of circles. Only when exposed to circles of different diameters will it be possible for the learner to discern "diameter" as a critical aspect of "circle". On the other hand, when exposed to different examples of circles of different diameter, the learner may observe that the shape of the object is invariant between these examples, and thus come to see this particular shape as a characteristic aspect of "circle". In this way, variation and invariance play significant roles in opening possibilities for learning. Marton and Pang write: "What varies and what is invariant both constrains learning and makes it possible." [5, p. 195] Learning presupposes discernment, and discernment presupposes variation. In order to distinguish what is critical in a learning situation, some variation and invariance is necessary.

B. *Related work*

The enacted object of learning has previously been discussed and studied, particularly in learning studies, [5]. In their article Marton and Pang report results from a learning study with five teachers teaching economics at the secondary level, giving the same lesson. The object of learning was enacted in this lesson. All five teachers' lessons are described and analysed in terms of the pattern of variation and invariance that occurred. The authors discuss how the "necessary pattern of variation and invariance (the enacted object of learning) was brought about, which yielded striking differences in outcome (the lived object of learning)" in the five groups of students (p. 216-217).

Holmquist, Gustavsson, and Wernberg [7] summarised results from three learning studies with 4th grade school children. The learning studies were performed in three subject areas, viz., English as a second language, Swedish as a first language, and Mathematics. The authors write: "The connection between the students' experience of the learning object and the complexity of the critical aspects in the contrasted cases of the enacted object of learning indicates where learning should be expected to occur." [7, p. 187]

Runesson [6] discusses how the enacted object of learning can be used to analyse learning in Mathematics education. By re-analysing data previously analysed from a constructivist and a sociocultural perspective, Runesson concludes: "describing the enacted object of learning implies describing a space of dimensions of variation that is opened in the classroom interaction. This space of opened dimensions of variation is a space of learning and as such constitutes both constraints and possibilities to learn." [6, p. 84-85].

In the learning study literature referred to above, the main focus is on the object of learning as enacted through classroom interaction. In our case, we apply similar analysis to understand the object of learning that is enacted via written instructions for lab assignments.

C. *The pilot study*

The pilot study reported here was conducted during the fall 2011 at Uppsala University. The students who participated were in the first year of a five-year degree programme towards a Master of Science in Engineering Physics. We collected data during their first programming course. The programming language used in the course was Java. During non-compulsory lab sessions the students worked with self-documenting on-line material consisting in written instructions, including explanations and exercises on different topics. The students were encouraged to work in pairs and were allowed to ask questions during the lab.

Two student pairs volunteered to participate in the study. One of the groups was video filmed during a lab session and was subsequently interviewed. The topic of this particular lab session was non-void methods in Java. The data analysed in the case study below is the self-documenting on-line material that the students were using during the lab session when they were video filmed.

In the pilot study, we used the collected data to also analyse the lived object of learning. An interview with the teacher gave additional data, for the analysis of the intended object of learning. These results will be reported elsewhere.

III. RESULTS

A. *The way of analysis, illustrated by a case study*

The analysis of the enacted object of learning is grounded in the learning theories discussed above, that variation and invariance are keys to students' discernment of new critical aspects, or relations between critical aspects, of an object of learning. The lab material we studied was completely self-documenting. It consisted of short theoretical explanations and a few examples, followed by some exercises.

In order to explain our proposed way of analysis of the enacted object of learning we first show a case study of how to apply the analysis. In the case study, we analyse the object of learning enacted through the written lab instructions for the specific lab session mentioned above, concerning non-void methods in Java.

The analysis of the enacted object of learning has three components: (i) we identify what dimensions of variation the lab material addressed; (ii) we analyse how different patterns of variation are used in the lab material; and (iii) we use the results of (i) and (ii) to make claims, from a variation theoretical point of view, about what possibilities the lab instructions open for students to "see" various aspects of the

object of learning. The result of the analysis is an argument about what aspects of the object of learning it would be theoretically possible for students to see when working according to these lab instructions. In other words: the result of the analysis is an argument about what is the enacted object of learning in this case.

In the case discussed here, our variation theoretical analysis is based on dimensions of variation identified in two previous phenomenographic studies, one concerning students' conceptions of "computer programming" [8], the other about students' conceptions of "object" and "class" in object-oriented programming [9]. In relation to "computer programming" five dimensions of variation emerged from the empirical data (interviews with students who had recently taken a novice programming course). These were the textual representation of a program, the action of a program, the application addressed by a program, the problem to which the program is a solution, and the various contexts in which programming skills can be an empowering resource. In relation to "object" and "class" three dimensions of variation emerged: text and action as above, and the modelling of real world phenomena.

We have analysed the entire document containing the written lab instructions for this case study. The complete document can be subdivided into eight different sections. Here, we will present the analysis of *one* of these sections, as a paradigmatic example. The textbook for the course was [10]. In the lab session, the students were expected to work with classes `Turtle` and `World` that are introduced in the book. In the particular section that we analyse here, the students are told to open the code for the `Turtle` class in an editor and to read the code for the method `getDistance`. That code, partly in Swedish in original, is also included in the lab instruction, as shown below.

```
/**
 * Get the distance from the passed x and y location
 * @param x the x location
 * @param y the y location
 */
public double getDistance(int x, int y) {

 // Calculate the distance between the given x-
 // coordinate and the currently executing turtle's
 // (this) x-coordinate
 int xDiff = x - this.getXPos();

 // Calculate the distance between the given y-
 // coordinate and the currently executing turtle's
 // (this) y-coordinate
 int yDiff = y - this.getYPos();

// Calculate the distance
 double d = Math.sqrt((xDiff*xDiff) + (yDiff*yDiff));

// Return the distance
 return d
}
```

This code as a whole is a "value" in the text dimension. For the purpose of our analysis we note that the "text" dimension that emerged from the empirical data in our interviews with students could be analytically subdivided into further dimensions, to increase the level of granularity in the analysis. The particular lab exercise focuses on methods in Java. Consequently, "method header" and "method body" are two relevant aspects of "text" in this lab. Methods differ with respect to both header and body, so these two aspects correspond to dimensions of variation that are sub dimensions of "text" in this context. Moreover, there are sub dimensions of "method header", notably "return type" and "input parameters". The "method body" has sub dimensions such as "declaration statements", "algorithmic statements" and "return statement". All of these are important aspects of the "text" dimension in this lab and all of them correspond to dimensions of variation for methods in Java. Another sub dimension of "text" of relevance for the section we are currently analysing is "method call". From a more abstract perspective, "structure" is an aspect of "text" that corresponds to an additional sub dimension of variation of relevance here.

In the lab instructions above, the words in bold face point the students' attention to particular aspects of the text. The word "double" is a value in the "return type" sub dimension of variation. In previous sessions of the same course, the students had been exposed to methods of type "void", so by now showing an example with type "double" the lab instruction in principle opens a possibility to "see" the "return type" dimension as significant. In the first section of the present lab instruction, examples of method calls had been shown. Thus, the two "this" statements in bold face in the present section exhibit further variation in the "method call" dimension. Finally, the return statement is in bold face. This points the students' attention to the return statement, but there is no variation.

By highlighting certain parts of the text in bold face, the lab instruction exhibits a variation in the "structure" dimension. The words in bold face get a "figure" position (using the "figure"-"background" dichotomy from gestalt psychology). This opens the possibility that these particular words come into the student's focal awareness. The potential effect of this is that the student becomes aware of the words "double" and "return" as having some significance in the example.

However, the *relation* between the "return type" dimension ("double", in the method header), the "declaration statement" dimension ("double d", the declaration of the return value) and the "return statement" dimension ("return d") is *not* highlighted by the bold face emphases in the code example. The fact that *both* text elements connected to this relation *and* examples of calls to the method `getXpos` are in bold face means that two different and unrelated parts of the "structure" dimension of the text are highlighted simultaneously. This reduces the possibility of seeing the significant relation between method header, declaration of return value and the actual return statement. Moreover, one of these text elements, the declaration of the return value, is *not*

in bold face, which further reduces the possibility to discern the relation through this example.

B. *The proposed way of analysis in summary*

In summary, our way of analysing the enacted object of learning in this case consisted in carrying out a variation theoretical analysis of the written instructions, based on dimensions of variation identified in two previously published phenomenographic outcome spaces. The empirical data for those previous phenomenographic studies were interviews with students having recently taken a novice programming course. In the present analysis of the lab material we used the previously identified dimensions of variation. We further observed a need to describe more fine-grained dimensions of variation than those previously identified, and thus added sub-dimensions to them.

The analysis allowed us to see what dimensions of variation the lab material addressed. The analysis also revealed how different kinds of variation, used in the lab material, opened possibilities for students to become aware of some of these dimensions, while other dimensions and relations between dimensions were more or less obscured, either by lack of relevant variation, or by the structure of how the content was presented.

The three components of the analysis, as described above for the particular case study, can be generalized to the study of any learning material and learning session. A video recording of a learning session can reveal additional variation that took place during the session although it was not present in the learning material. For example, discussions between students or additional learning material brought in by the teacher may provide further variation.

In general, the three components of the proposed analysis are: (i) identify what dimensions of variation the material and session address; (ii) analyse how different patterns of variation are used in the material and come into play in the session; and (iii) use the results of (i) and (ii) to make claims, from a variation theoretical point of view, about what possibilities the material and session open for students to "see" various aspects—and relations between aspects—of the object of learning. The aspects and relations between aspects that are possible to see according to this analysis constitute the enacted object of learning.

IV. CONCLUSIONS AND DISCUSSION

We conclude that the proposed way of analysis can be useful to investigate what opportunities a particular self-documenting written lab instruction open for students' learning. In the analysis, this is achieved by identifying what aspects of the object of learning are addressed in the written instructions and by analysing whether variation and invariance exhibited in the presentation have a potential to make it possible for students to see corresponding dimensions of variation and/or relations between such dimensions.

Self-documenting written lab instructions are important learning material in today's international online world of informal and formal learning as well as in student-centred lab sessions on campus. Computer programming is an area where students use—and are expected to use—e.g., available Internet resources. These resources are often written, self-documenting, and with no additional support given. The new trend of MOOC, Massive Online Open Courses [11] is an example of the importance of constructing online material that enhances students learning. In such learning contexts there might be no oral instructions to direct the students' activities during the lab session. Instead, the teachers' attempt to guide the students and direct their attention to important aspects during the lab session is "encoded" into the written instructions. For this reason, we argue that it is essential to understand what object of learning is actually enacted by the instructions. Relating the enacted object of learning to the object of learning that the teacher intended to make visible can be a useful tool for teachers when designing and improving lab instructions.

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