

# Students' Perceptions of a Self-Diagnosis Task

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**Abstract.** What happens when students are required to engage in a self-diagnosis task; in other words get time and credit for identifying mistakes they made assisted by a sample solution? We examine this question using data collected on 180 high school students in the Arab sector in Israel. Students were able to find significant differences between their solutions and the sample solution. Yet many did not provide self-explanations indicating that they acknowledged a conflict between their mental models and the scientific model. Further, students also addressed non-significant differences. They apparently referred to the sample solution as an ultimate template and identified external deviations from it as flaws or weaknesses. Students reflected on their personal solution process, and the materials used in the task. The findings suggest allocating time for scaffolding "self-diagnosis".

**Keywords:** problem solving, sample solution, self-diagnosis, self-explanation, self-repair, learning from mistakes.

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## INTRODUCTION

How do students *self-diagnose* their problem solutions?

A common practice in physics classrooms involves providing students with sample solutions to problems they have solved. Instructors expect their students to engage in "*self diagnosis*"; namely, to compare their solution to the sample solution and learn from their mistakes. However many worry that only few of their students indeed engage in such an activity [1].

To encourage students to self-diagnose researchers have developed "*self diagnosis tasks*" [2,3,4] requiring them explicitly to identify where they went wrong and to explain the nature of their mistakes. A "*self diagnosis task*" differs from the typical practice in that students get time and/or credit to make certain that they will reflect on their solutions to learn from their mistakes.

Cognitive apprenticeship [5] is an instructional approach that commonly serves to develop reflective skills in problem solving. Scaffolding "self-diagnosis" as recommended in this approach implies that self-diagnosis should be explicitly modeled and students should get feedback on their performance. However, the typical practice rarely involves such support, self-diagnosis is seldom modeled, nor do students get feedback on their self-diagnosis.

In the present study we examined a situation similar to the common practice, using a self-diagnosis

task with minimal scaffolding (i.e. no modeling or individualized feedback was provided). However, in order to probe students' self-diagnosis performance we deliberately prompted students to self-diagnose by providing a sample solution, as well as time and credit to do so.

The sample solution conveys the accepted scientific model and the student solution conveys his/her mental model. To learn from the sample solution students needed a) to compare two textual artifacts, the sample solution and their solution and realize they differ in respects that are significant to finding the right solution, and b) to *self-repair* their mental model. Chi (2000) [6] suggests that students self-repair their mental models while reading solved examples by providing *self-explanations*. For self-repairing to occur, a student needs to recognize and acknowledge that a conflict between his/her flawed model and the scientific model exists.

We explored what kinds of divergences students recognized between the two solutions, and whether their related self-diagnosis statements reflected acknowledgement of the existence of a conflict between their mental model and the scientific model. More formally, we examined:

1. *To what extent do students identify significant vs. non-significant differences between their own solutions and the sample solution (by significant we mean differences that can instigate self-repairing mental models)?*

2. Do students produce "self-explanations" indicating they acknowledge a conflict between their mental models and the scientific model conveyed by the sample solution?

Students' perception of what they are required to do in the self-diagnosis task might affect their performance in such a task. Accordingly, we also analyzed students' statements which reveal their perception of the task to answer:

3. How do students perceive the self-diagnosis task?

## DATA COLLECTION

To study natural performance, the data for the study were made up of students' solutions and self-diagnosis statements in their first exposure to a self diagnosis task.

180 high school physics majors were administered the task. The students were in nine classes (three 10<sup>th</sup> grade classes and six 11<sup>th</sup> grade) from eight Arabic-speaking schools (five private schools and three public ones) in Israel. Their teachers had taken part in a year-long in-service professional development workshop for high school physics teachers from the Arab sector in Israel.

The students first solved a problem in kinematics, a topic all of the teachers had already covered, as part of a quiz (see figure 1). The problem was a "context rich" one [7], to challenge students in various aspects:

1. Representing a rich context in physics terms.
2. Constructing a solution plan; i.e. determining which intermediate variables are needed.
3. Tailoring carefully sub-problems; using the output of one sub-problem as an input in another.
4. Analyzing experimental data.

Students had only little experience with such problems. In the class session following the quiz, the teachers distributed a photocopy of the students' own solution and a sample solution (similar in all classes), and asked them to write a self-diagnosis in which they identified where they went wrong and explained the nature of their mistakes.

## ANALYSIS

Initially we adapted the generic structure of the self-diagnosis rubric presented in a previous study [8] to the problem used here. However, this rubric was not designed to distinguish between self diagnosis that can or cannot instigate students' self-repairing mental models. Thus we merged a bottom-up approach in which new categories emerged (see Findings).

The inter-rater reliability for this analysis technique was 75%. Any disagreements were discussed and resolved.

From a research station located on Mars a rocket is launched straight upward with a constant acceleration of 30m/Sec<sup>2</sup> by means of its booster engines. The goal of the mission is to collect data about the chemical composition of the atmosphere as a function of the distance from the ground by means of instrumentation located in the rocket. The fuel used to run the engines is depleted in 25 seconds. After that, the rocket travels without the engine power. As a student in NASA's "Young Scientist" project you are asked to find the maximum altitude the rocket can reach. The following data are provided to you:

- No significant change in the free falling acceleration until the rocket reaches the maximum altitude.
- A table of measurements produced by a robot to find the free falling acceleration close to the surface of Mars. The robot released a ball. From the time of release, which is defined as  $t=0$ , the robot measured (by means of its time and distance sensors) the distance of the ball relative to the release point in periods of 0.04 seconds. Data were gathered by the robot's computer and they are presented in the following table:

Time since the moment of release (Seconds)	Distance relative to the release point (Meters)
0.00	0.000
0.04	0.003
0.08	0.012
0.12	0.028
0.16	0.050
0.20	0.078

The problem solution should include:

1. Problem description: represent the problem in physics terms: draw a sketch, and list known and unknown quantities.
2. Solution construction: present the solution as a set of sub-problems, and in each sub-problem write down: The unknown quantity you are looking for, the physics principles you'll use to find it, and the process to extract the unknown.
3. Evaluation: Check whether or not your final answer is reasonable.

FIGURE 1. Problem used in the self-diagnosis task.

## FINDINGS

*The first question we address is: To what extent do students identify significant vs. non-significant differences between their own solutions and the sample solution?*

To answer this question we analyzed students' statements that pertained to the content of the solution. Table 1 describes the emergent categories, the students' distributions into these categories (those who provided a statement pertaining to each category at least once), and relevant quotations. Almost all the students (90%) realized there were significant differences (at least once), while 40% listed non-significant ones. In the latter case we defined the following categories: a) statements that only refer to vaguely defined deficiencies, b) statements focused on

the amount rather than the specific nature of details presented in the sample solution, and c) statements addressing differences in the order of sub-problems in the sample solution that do not affect the correctness of the solution.

*The second question we address is: Do students produce self-explanations indicating they acknowledge a conflict between their mental models and the scientific model conveyed by the sample solution?*

Table 1 shows that 45% of the students realized there were significant differences and provided self-explanations (at least once) conveying self-repair of their mental models. This result indicates that these students acknowledged the existence of a conflict between their mental models and the scientific model

conveyed by the sample solution. On the other hand, 70% did not provide such self-explanations. In this case, some students may have acknowledged a conflict implicitly but did not express this in writing. (Due to overlap between sub-categories (the same students provided statements in different subcategories) the percentage of students in a major category is not the sum of the percentages in the sub-categories.)

The quotations when no self-explanations were provided and when students identified non-significant differences help show how students view the sample solution as a resource for self-diagnosis. Students apparently referred to the sample solution as an ultimate template, mainly focusing on its surface and visually dominant elements. They identified external deviations from that template as flaws or weaknesses in their solutions.

**TABLE 1.** Students' distribution into the emergent categories - statements that pertain to the solution's content (N=180).

Major Categories	Sub-Categories		Sample Quotes
<b>Significant Differences (90%)</b>  1. With an explanation conveying self-repair of mental model. (45%)  2. Without an explanation conveying self-repair of mental model. (70%)	Presentation	Weaknesses in description ("1"=0%, "2"=40%)	1. None. 2. <i>The problem description is missing.</i>
		Weaknesses in evaluation ("1"=0%, "2"=30%)	1. None. 2. <i>I did not check the answer.</i>
		Weaknesses in plan ("1"=0%, "2"=20%)	1. None. 2. <i>Sub-problems d' and e' are missing (using the same labels as in the sample solution).</i>
	Application	Experimental data analysis ("1"=25%, "2"=20%)	1. <i>I made a mistake in calculating the acceleration due to the gravity on Mars. I used only 1 point from the table and this resulted in a larger inaccuracy. I should have plotted position vs. time, namely <math>y(t^2)</math>.</i> 2. <i>I did not plot a graph at all.</i>
		Tailoring ("1"=25%, "2"=0%)	1. <i>I made a mistake in calculating the displacement in the first stage of the motion. I substituted 3.9 instead of 30 for the acceleration. In other words I substituted the value of the acceleration of gravity instead of the actual acceleration.</i> 2. None.
<b>Non Significant Differences (that cannot instigate self-repair of mental model) (40%)</b>	Vaguely defined (20%)		<i>All the answers were wrong. I just knew the value of gravity.</i>
	Focused on amount of detail (10%)		<i>I did not provide a detailed verbal description throughout the solution.</i>
	Differences in the solution order/arrangement (30%)		<i>I only found the final velocity of the first stage in a later step (in contrast to the sample solution).</i>

*The third question we address is: How do students perceive the self-diagnosis task?*

To answer this question we analyzed students' statements that were indicative of their perception of the task. Table 2 shows the emergent categories, the students' distributions into these categories (those who provided a statement pertaining to each category at least once), and sample quotations. First, we found that a frequent object of diagnosis was the problem solving process rather than its product (the solution): 45% of

the students reflected on their problem solving process - where they got stuck, time management difficulties, etc. Another object of diagnosis was the artifacts used in the task: 20% of the students made comments on the materials used in the task, namely the "context rich" problem and detailed solution that differed from problems and solutions they were accustomed to. These students thought part of the task was to reflect on these issues along with realizing there were significant and/or non-significant differences between their solutions and the sample solution.

**TABLE 2.** Students' distribution into the emergent categories - statements related to their perceptions of the task (N=180).

Major Categories	Sub-Categories	Sample Quotes
Reflection on Solution Process (45%)	What did I do (30%)	<i>It became clear to me that my solution up to the stage I got to was right. However, I couldn't continue the test.</i>
	Time management (20%)	<i>I spent a lot of time describing the problem.</i>
	Things I did not know (15%)	<i>I did not know how to draw the graph correctly.</i>
	Interaction with teacher (10%)	<i>Concerning the unfortunate graph that I drew, it was just to provide a graph as the teacher emphasized the need for a graph. The teacher should not be in the room because his presence disturbs students' performance.</i>
Reflection on Artifacts (20%)	Problem characteristics: wording, requirements, breaking down into parts, etc (20%)	<i>The problem is not broken down into parts. This means you have to understand a lot of things at once. Also, we are not familiar with this kind of problems.</i>
	Sample solution (10%)	<i>The sample solution is very complicated, and I did not understand it.</i>

In Vygotsky's terms, this characterized the students' alternative situation definitions of the task [9]. Table 3 presents the instructors' and the students' situation definitions.

**TABLE 3.** Alternative situation definitions.

Instructors' perception of Self Diagnosis task	Students' perception of Self Diagnosis task
An opportunity to identify weaknesses in students' solutions, understand their nature and correct them.	<ul style="list-style-type: none"> <li>• Realizing there are non-significant differences between the two solutions.</li> <li>• Reflecting on the solution process.</li> <li>• Reflection on materials.</li> </ul>

## DISCUSSION

We examined students' self-diagnosis performance in a self-diagnosis task that differs slightly from the common practice. We found that students were able to realize there were significant differences between their solutions and the sample solution. However, less than half of them provided self-explanations indicating that they acknowledged a conflict between their mental models and the scientific model conveyed by the sample solution. Almost half of the students also addressed non-significant differences. They used the sample solution as an ultimate template and identified the weaknesses in their solutions as a function of this template. Harper (2004) also reported that novices focus on surface features of solutions whereas experts look more closely at the deep structure [10]. Moreover, we found that students' situation definitions of the task differed from that of the instructors. These results suggest that the first stage in the self-diagnosis process indeed takes place - students are aware of significant differences between their own solution and the sample solution. However, there is need to provide appropriate scaffolding to make sure that students' situation definitions of the task are concordant with the

instructors' definition, and to enhance their self-diagnosis performance.

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