

# DEVELOPING RESEARCH-BASED TECHNOLOGY-ENHANCED CURRICULUM MATERIALS: AN EXAMPLE IN THE CONTEXT OF DECISION-MAKING SKILLS

Nicos Papadouris, Demerits Papademetriou, Theodora Kyratsi, Constantinos P. Constantinou

## ABSTRACT

This study describes the design of web-based learning materials for the development of decision-making skills in energy-based issues. First, we provide an overview of the curriculum development methodology we used and then we illustrate each of its stages in the context of the decision-making curriculum. In describing the curriculum development process, we seek to emphasize its research-based nature and the important role of certain tools, such as the capability analysis of available technological tools and the epistemological analysis of the learning objectives.

## KEYWORDS

Capability analysis, optimization, decision-making skills, epistemological analysis

## INTRODUCTION

This paper reports on a study targeted at designing and developing technology-enhanced learning materials for decision-making skills. In this section we provide an overview of the methodology we used in developing the learning materials (Figure 1. For a detailed account see Papadouris & Constantinou, in press).

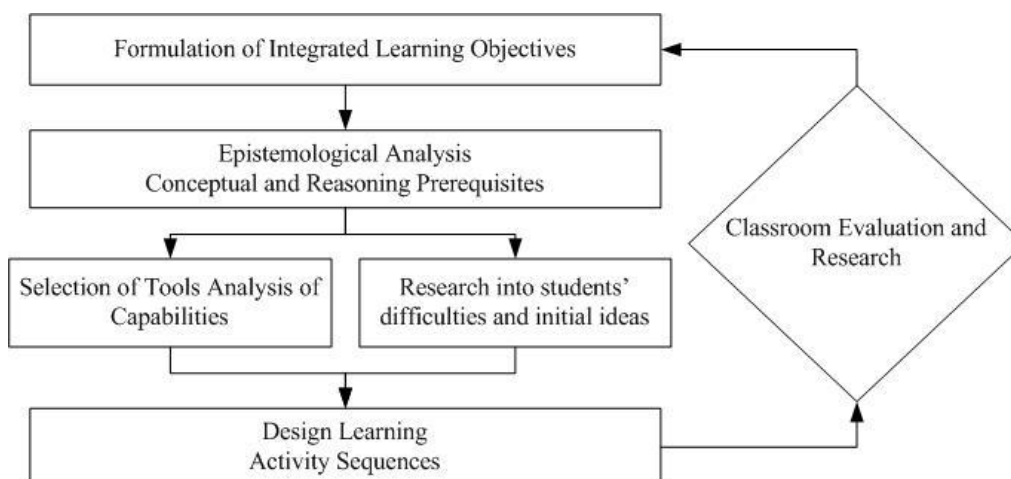


Figure 1. Curriculum development methodology

The first stage in this methodology includes the formulation of learning objectives. Two main issues seem essential at this stage. The first pertains to the need to formulate learning objectives that are developmentally consistent with students' abilities (Bransford et al., 1999). The second relates to the

need to establish consistency with the epistemology of learning in science. Learning in science can be analysed into a number of constituent components: the acquisition of *experiences* with natural phenomena provides the basis for the subsequent development of *concepts*; the mental representation of the structure and organization of scientific knowledge that is needed to avoid knowledge fragmentation and meaningless use of jargon comes with the development of *epistemological awareness*; *scientific and reasoning skills* provide the strategies and procedures for making operational use of one's conceptual understanding in order to analyse and understand everyday phenomena but also to undertake critical evaluation of evidence in decision-making situations. Finally, *positive attitudes* towards inquiry feed student motivation and safeguard sustainable engagement with the learning process. Effective instructional programs need to be targeted at integrated learning objectives that address all these components in unison (McDermott, 1991).

The second stage includes the epistemological analysis of the specified learning objectives. This type of analysis is undertaken for each of the learning objectives independently and it addresses the following question: Which competencies and skills should be possessed/developed by the students, in accordance with the epistemological structure of the domain, if they are to attain the corresponding learning objective? The result of the epistemological analysis includes a sequence of stages that reflect the prerequisite concepts and skills through which students could proceed towards attaining the learning objectives. In this attempt, special care is taken to ensure that the resulting sequence of stages is epistemologically appropriate, in that it is consistent with both the epistemological structure of the content relevant to the learning objective and the epistemology of science in general.

The next stage involves drawing on empirical research in order to identify students' initial ideas with respect to the content that is to be taught and also the relevant conceptual, reasoning, epistemological or other difficulties they seem to encounter. Results from empirical research can largely inform the design process in that they serve to reveal appropriate starting points.

The selection of technology tools that could be used to aid the attainment of the specified learning objectives presents an additional component of the development process. This is certainly not trivial and it is essential that special care be taken to ensure productive integration of computer technologies with curriculum materials in a manner that demonstrably enhances learning. This should emerge as a result of an analytic approach, rather than intuition, which includes a detailed and systematic analysis of the capabilities provided by the available computer-based tools. This type of capability analysis seeks to answer the following question: what are the capabilities that are provided by a particular tool and how could these capabilities enhance the learning process in science and contribute to the attainment of the learning objectives? Such analysis could serve to formulate a framework to guide the design and development of effective technology-rich curricula.

The next stage pertains to the actual development of activity sequences. This process relies on the results of the epistemological analysis of the learning objectives, the results from empirical research on students' initial ideas and the capabilities of available technological tools.

Finally, the last stage includes the exposition of the instructional materials to thorough evaluation through implementation in real classroom settings. Results from informal classroom observations or more systematic evaluations prior to, during and after teaching often lead the curriculum development process back to the drawing board where sequences of learning activities or even the entire curriculum might be revised to promote the learning objectives more effectively (McDermott & Shaffer, 1992).

In the next section we illustrate each of these stages through describing the process of developing learning materials for decision making skills. The paper concludes with a discussion of the ensuing implications.

## **THE PROCESS OF DEVELOPING WEB-BASED LEARNING MATERIALS FOR THE OPTIMIZATION STRATEGY IN DECISION-MAKING SITUATIONS**

In this section we describe the process we followed in developing web-based learning materials targeted at helping students in the age range 11-14 develop (a) conceptual understanding about energy, (b) epistemological awareness with respect to the relation between theory and observations and about the interconnections among science, society and technology, (c) appropriate attitudes towards energy management issues, and (d) decision-making skills. Due to space limitations, the discussion of the methodology will be constrained to the learning objective relevant to decision-making skills.

### **Formulation of learning objectives**

Decision-making skills are widely recognized as major components of scientific literacy and, hence, an important aim of science teaching (Ratcliffe & Grace, 2003; Kolsto, 2001). However, teaching and learning about decision-making skills has received scant attention in existing research.

Research shows that students tend to deal with decision-making situations in which no single solution is best in all criteria (which is often the case) through non-compensatory approaches (Hong & Chang, 2004). That is, they tend to rely on sole criteria and fail to recognize that balancing the strengths and weakness of alternative solutions would be a more appropriate approach (Baron, 2000). The optimization strategy, on the other hand, rests on the premise that all available information has to be taken into account through balancing trade-offs between alternative solutions (Birnbbaum, 1998; Baron, 2000).

This study focuses on a simplified form of the optimization strategy (Figure 2), which consists of the following stages: (a) converting raw data on a unique scale of measurement so as to render comparisons between the alternative solutions feasible, (b) adjusting for the variation in the relative importance of the various criteria through the assignment of weights, and (c) obtaining overall evaluations for each alternative solution. (The rationale underlying the optimization strategy is discussed in more detail in the next section.) This simplified form could be considered developmentally appropriate and could serve as an appropriate starting point for the subsequent development of more advanced decision-making skills.

### **Epistemological analysis**

The results of the epistemological analysis for the optimization strategy (Figure 3), consist of a series of skills, competencies and aspects of epistemological awareness that need to be present if one is to be able to develop this strategy in decision-making situations.

Three of the most fundamental prerequisite skills include students' ability to (i) recognize and describe the decision task under consideration, (ii) formulate criteria for acceptable solutions, and (iii) process available data and rank alternative solutions with respect to each criterion.

A relevant skill that is of higher sophistication pertains to the ability to perform comparisons between alternative solutions across criteria that are measured on different scales. This posits (a) awareness with respect to the need to simultaneously take into account the entirety of criteria, (b) appreciation of the advantages that emerge from employing such compensatory approaches, and (c) identification of the validity threats associated with comparisons across criteria measured on different scales (Baron, 2000).

<b><u>Which of the two alternative locations is the most appropriate for the new distillation station, provided that the project cost is considered more important by 25%?</u></b>			
		Area A	Area B
Number of people that will benefit from the presence of the station		110 000	105 000
Project Cost (pounds)		90 000	65 000
<b><u>Converting data on a unique common measurement scale (0-10)</u></b>			
		Area A	Area B
Number of people that will benefit from the presence of the station		10	8
Project Cost		7	10
<b><u>Assigning weights (on a scale from 1 to 10) to adjust for the relative importance of criteria</u></b>			
		Area A	Area B
	weight	score	score
Number of people that will benefit from the presence of the station	8	10	8
Project Cost	10	7	10
<b><u>Obtaining overall evaluation</u></b>			
		Area A	Area B
	weight	weighted score	<b>weighted score</b>
Number of people that will benefit from the presence of the station	8	10 X 8 = 80	<b>8 X 8 = 64</b>
Project Cost	10	7 X 10 = 70	<b>10 X 10 = 100</b>
Overall Evaluation		80 + 70 = 150	<b>64 + 100 = 164</b>

Figure 2. An example of the optimization strategy

Another reasoning skill that is vital in developing the optimization strategy relates to dealing with the possible variation in the relative importance of the criteria. This rests on three additional skills: the ability to (i) appreciate the possibility for criteria to vary in terms of their relative importance, (ii) recognize the need to take into account this variation, and (iii) identify mechanisms that could be used to correct for this variation (e.g., the assignment of relative weights).

The ability to develop competence in applying the optimization strategy in a valid and systematic manner also rests on certain metacognitive skills. First, students need to appreciate the essential role of criteria in rendering the exploration of the problem space systematic and consistent. Such awareness is needed for the development of understanding with respect to the rationale underlying optimization. Second, it is essential that students appreciate the subjective nature of collective decision-making, on the one hand, and the possibility for subjectivity to serve a potentially productive role, on the other. Third, students should be able to appreciate the important role of thorough information review regarding the parameters relevant to the task. Finally, students need to recognize the need for rigor in seeking consensus in collective decision-making, through careful linking of the evidence to the decision.

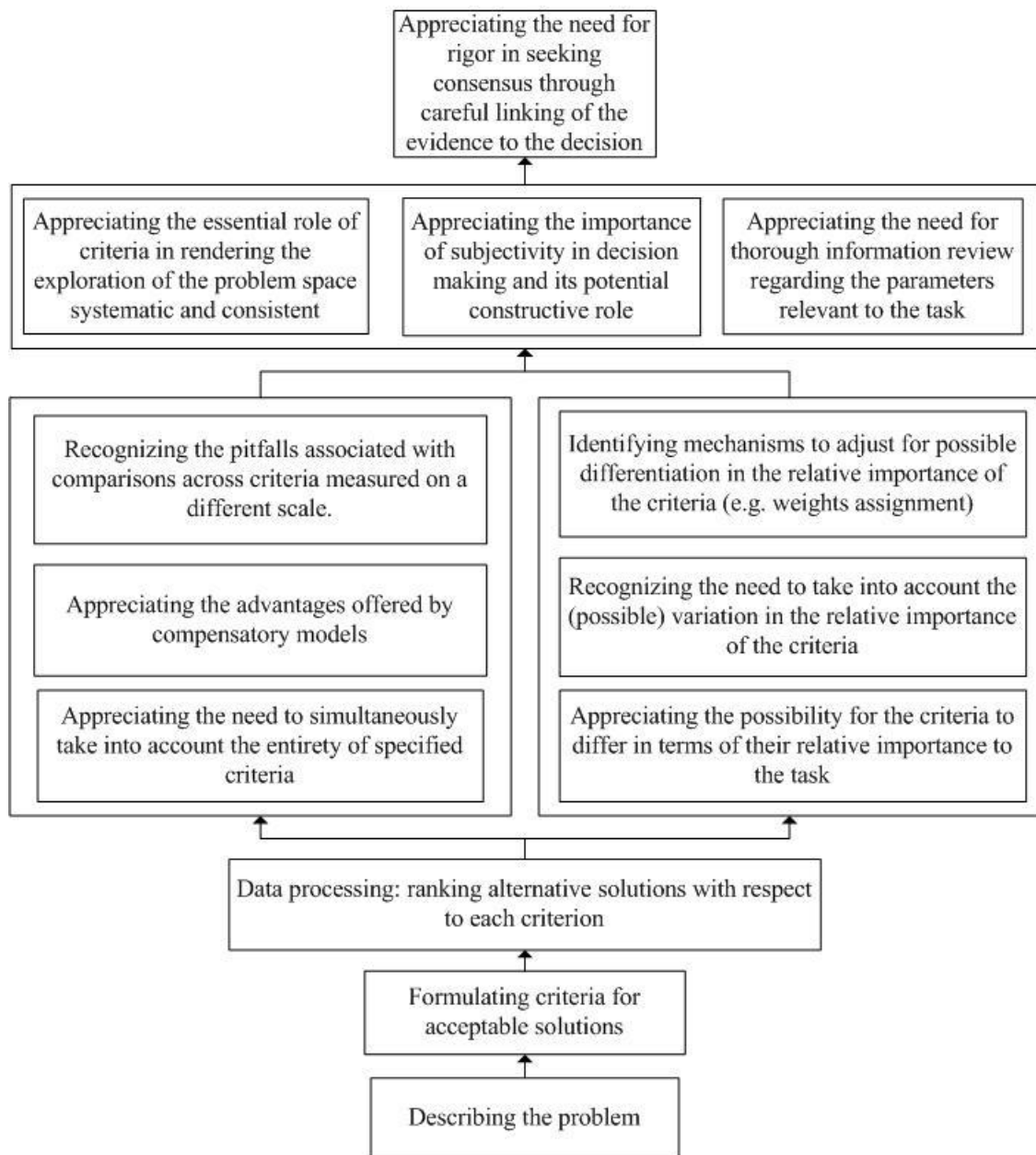


Figure 3. Epistemological analysis of the optimization strategy

**Research on students’ initial ideas and spontaneous approaches to decision-making situations.**

Once the learning objectives were specified the next stage included empirical research targeted at exploring students’ initial ideas. For this reason, we developed a decision-making task (Figure 4) and we conducted interviews with 27 students.

The analysis of the interview data helped us to identify the students’ spontaneous approaches to the decision-making task and also the reasoning difficulties they seemed to encounter (Table 1). It should be noted that most of these approaches are also reported in literature on behavioral decision-making (Birnbbaum, 1998; Baron, 2000).

<b>Which is the most appropriate location for the next power plant?</b>				
<p>There are three options and three criteria.</p> <p>Distance from sea is twice as important as the other two criteria</p> <p>Examine the available information for each option to identify the most appropriate site.</p>		Area A	Area B	Area C
	Distance from sea	4km	2km	3km
	Distance from inhabited areas	10km	2km	6km
	Cost	£9 000 000	£12 000 000	£11 800 000

Figure 4. Interview Task Example

Table 1. Students' approaches to the interview task

	<b>Approach</b>	<b>Typical student response</b>	<b>N</b>	<b>%</b>
1	Select the alternative solution that is superior in most of the criteria.	<i>"I would choose Area A because it is the best in two out of the three criteria"</i>	11	41
2	Select the alternative solution that is the best in the most important criterion.	<i>"I would choose area B which is the best in the most important criterion."</i>	9	33
3	Select the average alternative solution.	<i>"I would choose Area C because it is the average solution in each of the criteria."</i>	4	15
4	Note the complication of the task and state that no decision is possible	<i>"I can't decide. Some of the areas are better in some criteria but they are also inferior to others,"</i>	3	11

It is important noticing that none of the students was able to employ compensatory models and most of them tended to constrain themselves to only focusing on sole criteria. Also, a considerable percentage of students recognized the complication due to the lack of an apparent optimum solution (e.g., approach 4), though they were not able to deal with it.

The main reasoning difficulties evident in students' approaches include:

- Failure to rely on compensatory strategies that allow for trade-offs between the weaknesses and the strengths of the alternative solutions.
- Tendency to draw conclusions based on a limited portion of data and failure to appreciate how this could undermine the reliability of their decision.
- Failure to appreciate the possibility that an alternative solution, which is not the best in any of the criteria could be proven to be the most appropriate when possible trade-offs among weaknesses and strengths are taken into account.
- Failure to deal effectively with the variation in the relative importance of the criteria.
- Tendency to arbitrarily set cut-off values and to use them selectively and inconsistently to justify why they choose or eliminate specific alternative solutions.

The results from this empirical study served to induce appropriate starting points for the learning materials that are consistent with students' initial ideas and demonstrated the need for activities that are explicitly targeted at the various difficulties they encounter.

### **Selection of appropriate ICT tools**

The curriculum materials discussed in this study are based on the World Wide Web (WWW). Below, we summarize the various advantages that emerge from using WWW as a platform.

One of the most important capabilities relates to the enormous amount of information that can be accessed by students online. However, this should not be considered useful in itself since students are

liable to be distracted by irrelevant information. Therefore, special care should be taken to safeguard against this danger and establish that students engage in purposeful search (Jonassen, 2000).

Another capability relates to the fact that existing technologies allow for integrating web pages with computer-based cognitive tools. For example *Macromedia Flash* movies and *Java* applets can be easily embedded in web pages and thus acquaint students with visualization and simulation tools, in cases when it is assumed to enhance their understanding.

A further capability pertains to the possible shift from static and linear presentation of content to dynamically adjusted sequences of learning activities. The technology of *Active Server Pages* (ASP) allows for developing a dynamic sequence of learning activities, which can be tailored, in real time, to the needs of individual students or groups of students. For instance, it is possible to implement scripts that process students' inputs in real time and depending on pre-specified conditions determine the next activity.

Finally, using the WWW as a platform provides a number of procedural advantages which emerge as a result of the ability to link web pages with a database and to implement scripts that could process data in real time. This makes it possible to develop electronic worksheets and have students' responses collected and organized in the database in real time. In addition to this, it is possible to implement scripts that read the database and display their contents in pages which could be accessed by teachers to get information about students' progress in various formats. An additional advantage that emerges from this capability is that it becomes possible to devise activities that present students with their previous responses to certain probes and allow them to revise them as needed. This could provide students with the opportunity to reflect on the potential advancement of their understanding with respect to certain aspects. In addition to this, it could serve to collect data about the progression in students' ideas and this could enhance assessment while such data could also be of great value in addressing certain research questions.

### **Design of the initial version of the learning materials**

Taking into account (a) the results of the epistemological analysis undertaken for the optimization strategy, (b) information gathered through the analysis of interview data, and (c) the results of the capability analysis relevant to the WWW, we developed the first version of the sequence of the learning activities.

The curriculum materials are entirely web-based and they are organized in three webquests (Fisher, 2002). Webquests are inquiry oriented activities that are focused on the investigation of a certain issue and all (or most) of the available information is located on the Web. It is important noticing that most of the sources have been specifically designed for the purposes of the corresponding webquest.

The webquests are focused on energy-based issues. The first entails the selection of appropriate materials to be used for the construction of a house, based on their thermal insulation capabilities and their tolerance to earthquakes. The second concerns the selection of appropriate electric devices based on three criteria: cost, reliability and energy consumption. Finally, the third involves the selection of the most appropriate fossil fuel for the new power station, based on their price, efficiency, availability, and gas emissions.

All three webquests share the same structure. They begin with an introduction to the decision-making situation and the description of students' task. The next part contains links to on-line information directly relevant to the task and to a series of electronic worksheets that students have to fill at certain points. The worksheets are intended to help students explore the available information in a systematic manner and to confront them with certain reasoning difficulties. In each case, students' responses are automatically collected and stored in a database. Teachers can access the database online using a class code and obtain a summary of students' responses and statistics.

The sequence of the learning activities is designed in such a way so that certain worksheets appear more than once, completed with the responses provided by students earlier. Presenting students with their previous responses and providing them with the opportunity to revise them if needed, is assumed to help students reflect on the potential advancement in their understanding. Students' revisions and their underlying reasoning are automatically stored in the database.

### **Implementation of the learning materials**

One of the webquests was pilot tested in a sixth-grade class situated in an urban school. The school administration and the teacher of the class agreed to provide us with access to the students for three teaching sessions, each lasting 80 minutes. The main objectives of this pilot study was to (i) provide empirical feedback regarding the developmental appropriateness of the learning activities, (ii) convey a sense about how students seem to interact with the learning environment, and (iii) shed some light on potential practical issues. Based on this pilot implementation, the sequence of the learning activities and the webquests underwent minor amendments.

The revised version of the webquests was implemented in a computer/science club. Participants were 40 students in the age range 11-14 who volunteered to take part. Students met with the instructors twice a week for one and a half hours over a period of approximately 1,5 months.

The teaching method that was used during the intervention is based on the "Physics by Inquiry" pedagogy (McDermott et al., 1996). Students always worked in groups and there was no lecture. Certain worksheets were designed to serve as check-points. When students reached a check-point they had to discuss their responses and their reasoning, with a member of the teaching group. During these discussions instructors did not directly communicate any information to students or suggest appropriate responses. In contrast, they attempted to help students articulate their thoughts, identify inconsistencies in their reasoning, and negotiate epistemological, conceptual, practical and other difficulties they might have encountered.

The teaching group consisted of three elementary teachers. All of them were members of the Learning in Science Group and two of them were graduate students in science education. Instructors met once a week in order to prepare for the next sessions. During these meetings they also reviewed students' responses to previous worksheets in order to identify persisting difficulties and discussed possible revisions in the sequence of the learning activities.

### **Evaluation of the learning materials**

During the implementation of the learning materials we assessed students, through a number of open-ended tasks. These tasks were embedded in contexts other than those addressed during the teaching intervention.

The analysis of students' responses yielded promising results. In particular, after the teaching intervention a significant percentage of students (about 70%) selected to employ the optimization strategy in dealing with the tasks and most of them were able to do this in a valid manner. This becomes important in view of the fact that, prior to the intervention, the vast majority of students selected to employ non-compensatory approaches while none of them was able to synthesize information about the criteria in a consistent manner. A typical correct student response, drawn from one of the tests (Figure 5), is shown in Figure 6.



The Government has decided to construct a new distillation station and is looking for the most appropriate location. There are two alternative solutions (Area A and Area B). The decision will be based on two criteria: the cost and the number of people that will benefit in each case.

Based on the information in the table and provided that cost is considered twice as important criterion, which location would you choose and why?

	Area A	Area B
Number of people that will benefit from the presence of the station	110 000	105 000
Project cost	90 000 pounds	65 000 pounds

Figure 5. Task overview

	Area A	Area B
Number of people that will benefit from the presence of the station	110 000 <i>10</i>	105 000 <i>7</i>
Project cost	90 000 pounds <i>7 x 2 = 14</i>	65 000 pounds <i>10 x 2 = 20</i>
<i>Total</i>	<i>24</i>	<i>27</i>

*“Area B is the most appropriate location. We have scored each alternative with respect to both criteria on a scale from 0 to 10. The best alternative solution in each criterion was scored with 10 and we assigned a lower score to the other alternative solution. Then we multiplied the score relevant to the criterion “number of habitants that will benefit from the presence of the station” by 2, since it is twice as important as the project cost. The overall score for Area B and Area A were 27 and 24 respectively. Therefore Area B is the most appropriate location.”*

Note: Italics denote the students’ response and their notes over the table

Figure 6. A valid optimization approach

A common difficulty that often led students to invalid applications of the optimization strategy pertains to the process of weighing criteria according to its relative importance. In particular, students were liable to multiply raw data with the corresponding weights without making appropriate adjustments to convert data on a common scale of measurement (Figure 7).

	Area A	Area B
Number of people that will benefit from the presence of the station	110 000 <i>180 000 +</i> <i>290 000</i>	105 000 <i>130 000 +</i> <i>235 000</i>
Project cost	90 000 pounds <i>90 000 x 2 =</i> <i>180 000 pounds</i>	65 000 pounds <i>65 000 x 2 =</i> <i>130 000 pounds</i>

*“We should choose Area A. We multiplied the cost for each area by two (since is twice as important as the number of habitants that will benefit) and then we summed the product for each area with the number of habitants. The overall score for Area A was higher.”*

Note: Italics denote the students’ response and their notes over the table

Figure 7. An invalid optimization approach

### Revisions of the learning materials

Notwithstanding the promising results from data analysis, perhaps the most important point to pay attention to concerns the identification of possible revisions that could further increase the effectiveness of the learning materials. Two possible revisions are discussed below.

Data analysis showed that a considerable percentage of students have not acquired a sound understanding of the rationale underlying the optimization strategy. For example, in cases where the

strategy resulted to two or more alternative solutions having the same overall score, it was common for some students to arbitrarily increase the score assigned to one of these alternative solutions and, hence, force its overall score to rise. In an attempt to deal with this difficulty we identified two main issues that should be explicitly addressed by the curriculum materials. The first concerns incorporating learning activities to address the potentially productive role of subjectivity in collective decision-making. The contribution of multiple perspectives to the decision-making situation and the formation of informed opinions present examples of two useful aspects of subjectivity. The second is relevant to the important role of consensus. Determining the criteria that are to be used and their relative importance, and also scoring the alternative solutions with respect to each criterion, present largely subjective processes. Striving for consensus through careful linking of the evidence to the decision could serve to establish consistency and enhance reliability in tackling the task. Addressing these two issues through specifically designed learning activities is expected to assist the development of a functional understanding of the rationale underlying the optimization strategy.

The second revision relates to the design of additional activities to help students appreciate the need to adjust for the variability in the measurement scales in order to render comparisons valid and meaningful. Even though this difficulty was identified early in designing the learning materials and despite our explicit attempt to devise learning activities to specifically help students overcome this difficulty, it is the case that, to a large extent, it was proven resistant to instruction and it has influenced students' decision-making in ways that were not anticipated during the design phase.

## **DISCUSSION**

Three main implications seem to emerge from this study. The first pertains to the critical role of certain tools in rendering the design and development process more systematic and, hence, less intuitive. These tools include (a) the collection and analysis of data with respect to students' initial ideas and difficulties relevant to the learning objectives, (b) the epistemological analysis of the learning objectives so as to establish consistency with the structure of the skills or concepts to be taught, and (c) capability analysis of available ICT tools to establish appropriate integration with the learning environment so as to really support the implementation of the specified learning objectives. Relying on these tools makes it possible to design activity sequences that (a) foster multiple pathways for meaningful learning, which entails the construction of a coherent conceptual framework that enables one to reason through unfamiliar situations and make valid predictions; (b) include specific pedagogical strategies and appropriate activities for addressing certain difficulties, in order to nurture and sustain students' efforts to follow their pathway in a meaningful manner (McDermott & Shaffer, 1992) and (c) reflect the epistemological structure of the content to be taught.

The second implication is associated with the need to validate learning materials through research. Developing learning materials should be best conceived as a cyclical process involving research, development, implementation, evaluation and revision. Developing learning materials that can be reliably used to promote the learning objectives effectively could take a number of implementation-evaluation-revision cycles.

Finally, the last implication pertains to a discrepancy that characterizes the traditional practice in developing science curricula. In particular, while it is commonly accepted that science learning can be analyzed into a series of constituent components, such as conceptual understanding, scientific reasoning skills and epistemological awareness, traditional science curricula tend to solely focus on concepts. Results from this study suggest that reasoning skills and strategies could (and should) be directly addressed by instruction. Formulating integrated learning objectives that seek to promote the development of conceptual understanding, scientific reasoning and epistemological awareness in unison, could contribute towards resolving this discrepancy.

## REFERENCES

- Baron, J. (2000). *Thinking and Deciding*, 3<sup>rd</sup> edn. Cambridge University Press, New York, USA.
- Birnbaum, M. (1998). *Measurement, judgment and decision-making*. Academic Press, San Diego, USA.
- Bransford, J. D., Brown, A. L. and Cocking, R. R. (eds.) (1999). *How People Learn: Brain, Mind, Experience, and School*. National Academy Press, Washington, USA.
- Fisher, T. (2002). *Theory into practice: Webquests in Geography*, Geographical Association, Sheffield, UK.
- Hong, J. & Chang, N. (2004). Analysis of Korean high school students' decision-making processes in solving a problem involving biological knowledge. *Research in Science Education*, 34, 97–111.
- Jonassen, D. (2000). *Computers as mindtools for schools: engaging critical thinking*, 2<sup>nd</sup> edn. Prentice Hall, New Jersey, USA.
- Kolstø, S. D. (2001). 'To trust or not to trust, . . .?' - pupils' ways of judging information encountered in a socio-scientific issue. *International Journal of Science Education*, 23(9), 877-901.
- McDermott, L. C. (1991). What we teach and what is learned: Closing the gap. *American Journal of Physics*, 59(4), 301-315.
- McDermott, L. and Shaffer, P. (1992). Research as a guide for curriculum development: an example from introductory electricity. Part I: Investigation of students understanding. *American Journal of Physics*, 60(11), 994-1003.
- McDermott and the Physics Education Group at the University of Washington (1996). *Physics by Inquiry Volume II*. Wiley, New York, USA.
- Papadouris, N. and Constantinou, C. P. (accepted for publication). A Methodology for the integration of computer-based learning tools in science curricula. *Journal of Curriculum Studies*.
- Ratcliffe, M and Grace, M. (2003). *Science Education for Citizenship*. Open University Press, Buckingham, UK.

Nicos Papadouris  
Learning in Science Group  
Department of Educational Sciences  
University of Cyprus  
Email: npapa@ucy.ac.cy

Demetris Papademetriou  
Learning in Science Group  
Department of Educational Sciences  
University of Cyprus  
Email: demetris@netmail.com.cy

Theodora Kyratsi  
Lecturer  
Learning in Science Group  
Department of Mechanical and Manufacturing Engineering  
University of Cyprus  
Email: kyratsi@cy.ac.cy

C. P. Constantinou  
Associate Professor  
Learning in Science Group  
Department of Educational Sciences  
University of Cyprus  
Email: c.p.constantinou@ucy.ac.cy