

# The Development of Optimisation Decision-making Skills Within the Area of Technology Education Through a Technology Fair

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## Abstract

The ability to make effective choices and decisions is one of the most important competencies that students need to be successful in life. This paper suggests the idea of using the technology fair as a means for promoting students' decision-making skills. The purpose of the study was to investigate the influence of a procedure of working with primary school children to complete and present a technology fair project, on the decision-making skills of undergraduate primary education students. Pre-tests, mid-test and post-tests were administered to undergraduate students before, during and after the preparation of the technology fair, respectively. Data were also collected from reflective diaries kept by the university students during the preparation of the technology fair. A number of students were selected and interviewed after the completion of the technology fair. The analysis of the results indicates that the technology fair has an influence on improving students' decision-making strategies within the domain of design and technology.

## Key words

decision-making, design and technology, problem-solving, technology fair, optimisation

## Introduction

Recent education trends have been calling for science and design and technology teaching that supports meaningful learning and helps in the development of thinking, problem-solving and decision-making skills (AAAS, 1993; Fisher, 1990; Wehmeyer, 2002).

Within the literature there are some studies investigating students' understanding of the importance of decision-making skills. Most of the studies are coming out of science education and are related with socio-scientific issues (Kolstø, 2001; Patronis, Potari & Spiliotopoulou, 1999). In the area of design and technology there are

limited research reports addressing decision-making (Kennett & Stedwill, 1996). This paper will focus on optimisation decision-making strategies used by pre-service teachers as part of their design and technology activities when working with pupils.

## Theoretical background

Many of the research papers concerning decision-making come from the area of cognitive development (Sternberg 1996; Birnbaum 1998; Baron 2000) or operational research, economics and management (Bazerman 2005; Gibson, Fichman & Plaut, 1997). In the field of educational research, decision-making strategies have recently gained attention, with most of the studies related to science education (Patronis, Potari & Spiliotopoulou, 1999; Kennett & Stedwill, 1996; Kolstø, 2001). In design and technology education there are only few studies concerning decision-making (Davies, 2004; Coles & Norman, 2005).

Design and technology provides an important opportunity to students' to develop awareness and understanding in making informed choices that contribute to the development of the society in which they live. Such awareness enhances students' thinking in being more critical and making informed decisions as designers, makers or citizens (Patronis, Potari & Spiliotopoulou, 1999; Kennett & Stedwill, 1996). At the same time society will influence students' design decisions, and therefore this is a two-way process from an early age.

Standards for technological literacy suggest two goals on the issue of decision-making. The first is that at the end of their education in technology, students should understand notions of risk and how they depend on psychological and social factors. The second goal is related to the kind of questions that are important to ask in introducing new technologies. Therefore, understanding the factors in making decisions about technology requires students to develop ideas about

cost and benefits, side-effects, and how people perceive technology (AAAS 2001).

Therefore a vital characteristic of a design and technology teacher is to empower students' to make their own decisions. A decision could be taken almost at every step of designing; either while evaluating the alternative solutions or while deciding on the appropriate materials to be used (Davies, 2004). It is important that students' decisions are made with awareness of the different factors that influence the outcome.

According to Barlex and Rutland (2004) an important step in design decision-making is to audit a variety of design decisions that are likely to be made by pupils tackling a design and make activity. Barlex and Rutland (2004) identified five key areas of design decisions:

- conceptual (overall purpose of the design, the sort of product that it will be);
- technical (how the design will work);
- aesthetic (what the design will look like);
- constructional (how the design will be put together);
- marketing (who the design is for, where it will be used, how it will be sold).

Decision-making in the context of design and technology involves the evaluation of a discrete set of alternatives while considering conflicting objectives. Even though it is essential to use techniques that include these multiple and conflicting objectives, decision-making is often performed with single-objective decision-making methodologies such as benefit cost analysis.

Throughout the design of a solution various decisions should be made in order to end up with a proper and functional design. When the problem is 'ill-defined' the decisions are usually more complicated because of the lack of specific information and constraints (Norman, 1998). As the problems transform to 'well-defined' the decisions are more specific and mathematical models could be used to improve the quality of the decision (Norman, 1998). This paper illustrates how a multi-criteria decision-making technique can be used to make decisions regarding the selection of an optimum solution to a technological problem.

The current research aims to improve the understanding about the different decision-making process used by students when using an optimisation technique. In this paper, the term optimisation refers to the decision-making process that is logically expected to lead to the optimal result. Optimisation is an activity that aims at developing the best (i.e. optimal) solution to a problem. For optimisation to be meaningful there must be alternative solutions available in various steps of designing to be optimised and more than one feasible solution must exist, i.e. solution, which do not violate the constraints (Birnbbaum 1998; Garnham and Oakhill 1994).

Optimisation can be used in decision-making situations with multiple constraints and criteria that should be fulfilled. Constraints could have different weight value and therefore comparisons between different solutions are based on each criterion separately since solutions are coming in different scales. In order to choose the optimum solution, the conversion of a unified scale that takes into account all the criteria and their weight factor is needed (optimization). Different researchers specify a number of steps which typically are applied in order to decide for an optimum solution (Bazerman, 2005; Hammond, Keeney and Raiffa, 1999, Birnbbaum 1998; Garnham and Oakhill 1994). A typical example of decision-making process using an optimisation technique is shown in Appendix 1.

### **The technology fair**

The technology fair was organised as part of the compulsory subject (for university students studying educational sciences) of design and technology education. The subject aims to prepare university students (pre-service teachers) to teach the subject of design and technology in local primary schools. The technology fair required students to prepare teaching materials, and teach a primary education pupil to solve a simple technological problem (i.e. design a model of a renewable energy house). The technology fair was implemented with an emphasis on decision-making.

During the technology fair, university students act as teachers and guide pupils to design an appropriate solution to a technological problem given to them. Feedback and guidance was given to university students throughout the technology fair. University students

(pre-service teachers) work with primary school students in a single technological project. Within the collaboration of pupils and students there are various decisions that should be made for their design and the construction work in order to end up with an optimum solution. A sample of the decisions that had to be made during technology fair includes among others:

- decide about the appropriate materials for the design of the solution;
- choose the "best" solution among a number of alternatives;
- decide upon the appropriate type of mechanism or electrical circuit that should be used.

University students and pupils worked together as a team for approximately a period of four weeks. Once their work reaches a level where specific products are available, the school organizes a public event which is called "the technology fair". In the technology fair each team (student and pupil) displays a poster describing the design process with emphasis to their design decisions. They also display the constructed artifact which is a solution to the initial technological problem. In addition, students and pupils develop interactive activities which are implemented with a view to engage the visitors in the learning process and enhance the educational value of the fair (Mettas and Constantinou, 2005).

## **Purpose of the research and research questions**

The aim of the study is to explore the ability of university students (pre-service teachers) to use optimisation technique in order to make their choices, while engaging with the teaching of primary school pupils for the organization of the technology fair.

Specifically, the research questions of this study are the following:

- (a) What strategies do pre-service teachers follow in order to make their design choices through an optimisation technique?
- (b) What are the difficulties that pre-service teachers face in their efforts to make correct decision in their designs?

- (c) What is the influence of the technology fair in undergraduate primary education students' decision-making skills using optimisation techniques?

## **Research Design, Methods and Sample**

The study used both quantitative and qualitative research methods in order to collect and analyze data in relation to optimisation decision-making strategies.

A single task was designed and given to university students as pre-test, mid-test and post-test. The task was administered to students at the beginning of the subject, before and after the preparation of the technology fair, respectively (25/10/2004, 8/11/2004 and 29/11/2004).

In addition to the decision-making task, each student teacher was asked to keep a detailed reflective diary after every meeting with the child. In the diary each pre-service teacher recorded all the information about their design decisions for their project. The diaries were completed after each meeting with the primary school students. After the completion of the technology fair 12 pre-service teachers were selected and interviewed about their decision-making strategies while working for the fair. Figure 1 shows graphically the design of the research.

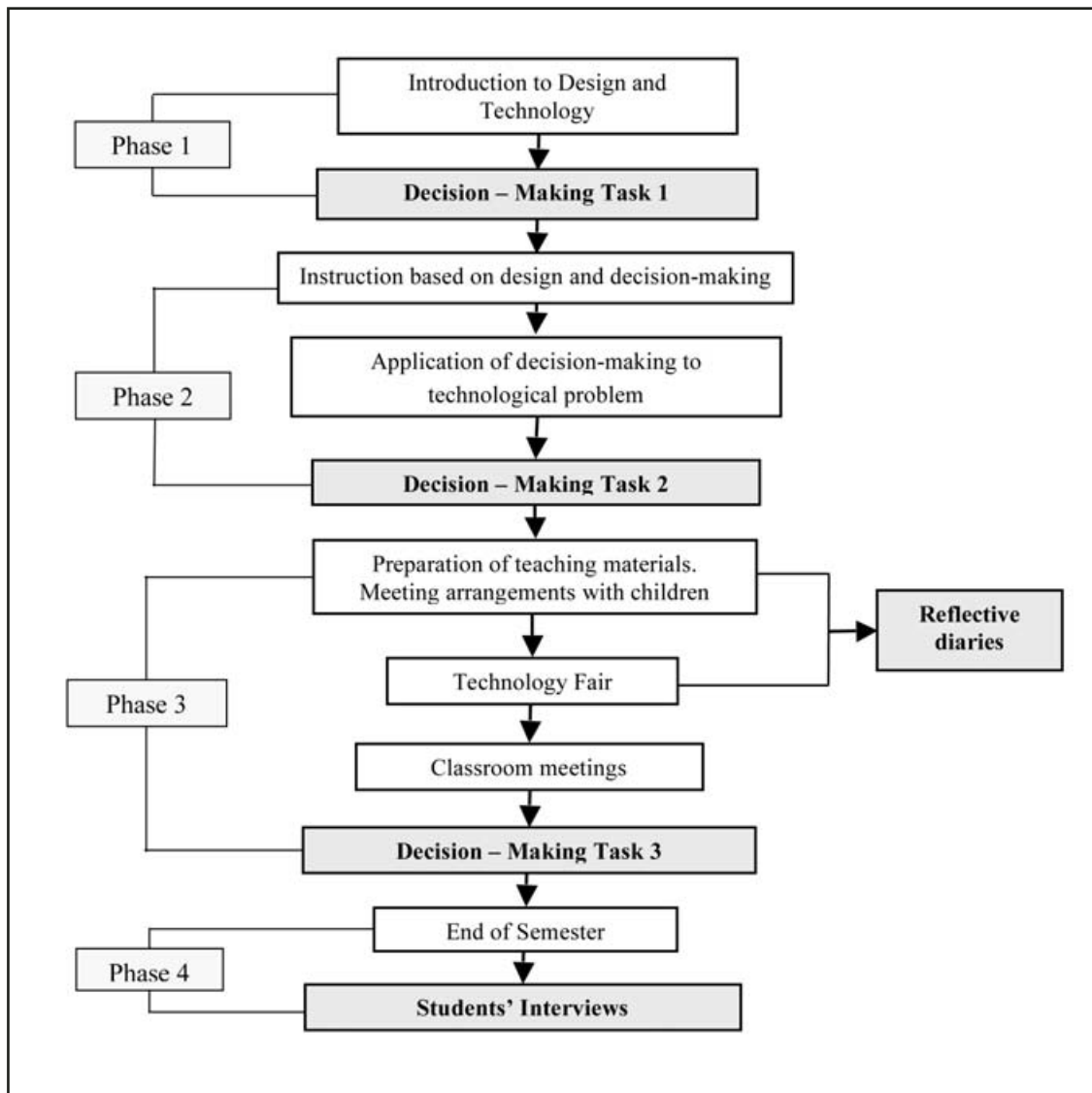


Figure 1: The research design

**Sample**

The technology fair was held with the co-operation of a local primary school in November 2004. The sample of the research consists of 82 pre-service teachers at the Department of Educational Sciences, University of Cyprus. All pre-service teachers enrolled in a compulsory course on Design and Technology Education.

**Purpose of the decision-making task included to the test**

The task given to students requires from them to choose the optimum solution using the information given in Table 1. The same task was presented in all phases of the research (pre-test, mid-test, post-test). In a table given to students all solutions were evaluated according to the most important criteria/specifications of the product. The criteria/specifications between them could have different weights in the overall design and therefore could be of different importance.

<b>Decision-making Task</b>					
Please choose one of the solutions given to the table using the information below. Explain the reasons of your decision.					
<b>Solution Value</b>					
Absolutely Satisfied    4    3    2    1    0    Not Satisfied					
<b>Criterion Weight</b>					
Very Important    5    4    3    2    1    Not Important					
<b>Criterion</b>	<b>Criterion Weight</b>	<b>Idea 1</b>	<b>Idea 2</b>	<b>Idea 3</b>	<b>Idea 4</b>
Functionality	5	4	3	2	0
Time Limit	2	2	2	4	4
Aesthetics	3	3	4	3	4
Ergonomic	2	2	2	3	4
Safety	4	2	3	3	4

Table 1: Selection of optimum solution

**Reflective diaries and interviews**

Reflective diaries and interviews formed an additional source of data in relation to the use of optimisation decision-making techniques. In the reflective diary each student recorded information about decision-making difficulties they encountered while working with pupils. The purpose of reflective diaries was to collect information and data about students’ understanding of decision-making strategies used while collaborating with elementary school pupils in designing a solution to a simple technological problem.

The purpose of the student interviews was to investigate their understanding of decision-making techniques after their experience with the technology fair. The interview questions were open-ended and based on students’ design decisions while working for the technology fair.

**Research limitations and weaknesses**

The main weakness of the research is that the tests (pre-test, mid-test and post-test) based on a single task with an emphasis to optimisation techniques. As a result is difficult to envisage a valid measurement of such a complex area like decision-making skills from a single task.

However, the results of the test gave interesting information of the use of optimisation techniques within design and technology activities. In addition, the results of the study will be considered for further research in the domain of design and technology education.

**Phenomenographic analysis**

Students had to decide which of the alternative solutions were considered to be the optimum though an optimisation process. Responses to the task during the different phases of the research were analysed using the phenomenographic approach developed by Marton (1981). The following categories identified from students responses and presented in order, from the optimum (category 1) to the worst (category 4) classified category. The percentages for each category of task 6 for pre-test, mid-test and post-test are shown in Figure 2.

**Category 1:** Solution 2, their decision considered both the solution score and the criterion weight (optimisation).

**Category 2:** Solution 3, their decision considered only the solution score and not the criterion weight.

**Category 3:** Solution 1, their decision was based only upon the best score in the most important criterion.

**Category 4:** Solution 4, their decision does not take into account that one of the criteria is not satisfied.

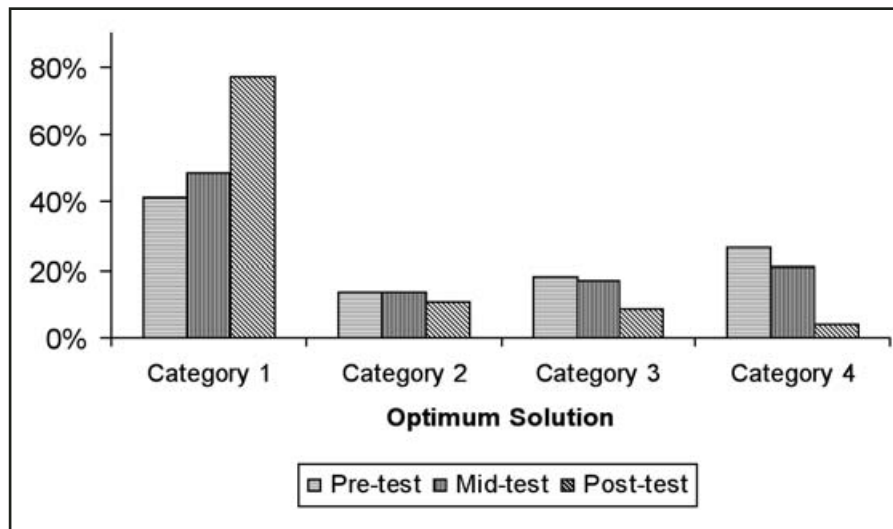


Figure 2: Students' responses percentages

Processing the information given in Table 2, the optimum solution in this task is considered to be the idea 2 (category 1), which is taking into account all criteria and their weight factor (Optimisation). The number of students selected idea 2 increases from 42% in pre-test to 49% in mid-test and 77% in post test. The 27% of students in pre-test and 21% in mid-test selected idea 4, which is not taken into account that at least one of the criteria is not satisfied (functionality is scored with 0, which is not satisfied, category 4) and therefore this idea should be eliminated. Only 4% of pre-service teachers selected idea 4 to be the optimum solution in the post-test. The 13% both in pre-test and mid-test and 11% in post-test selected idea 3 (category 2), which is not taking into account the relative weight of the criteria and is taking into account only the values of each

criterion separately. Students that selected idea 1 (category 3) considered only the most important criterion; idea 1 has the highest value in functionality, which is the most important criterion. The 18% in pre-test, 17% in mid-test and 9% in post-test selected idea 1 to be the best option for the task.

### Statistical Analysis

The statistical analysis is executed using the non-parametric Wilcoxon test (Table 2) because the data are on an ordinal scale. This statistical tool is appropriate for non-parametric data and compares the values of two tests in order to determine whether the differences between them are statistically significant or not.

	Mid Test – Pre Test	Post Test – Mid Test	Post Test – Pre Test
Z	-1,502(a)	-4,310(a)	-4,978(a)
Asymp. Sig. (2-tailed)	,133	,001	,001

Table 2: Wilcoxon test comparing Pre-test, Mid-test and Post-test

a Based on negative ranks

b Wilcoxon Signed Ranks Test

Table 2 shows the results of the Wilcoxon test in pre-test, mid-test and post-test. From the comparison between pre-test and mid-test, i.e. the period from the introduction to the subject until the teaching and the implementation of the technological problem solving and decision-making process, it can be seen that the differences are not statistically significant ( $p=0.133$ ). However, for the comparison between mid-test and post-test, i.e. the period from the preparation of the technology fair until the presentation of technology fair, there are statistically significant differences ( $Z(82)=-4,31$ ,  $p<0.01$ ). Statistically significant differences can be observed between pre-test and post-test as well ( $Z(82)=-4,978$ ,  $p<0.01$ ), i.e. the period from the introduction to the subject up to the completion of the technology fair.

From the results it can be seen that there is an improvement of pre-service teachers' ability to make optimum decisions through optimisation technique as a result of the implement with the technology fair.

### Indications from students' reflective diaries and interviews

Students express the belief that the technology fair gave them the opportunity to enhance their decision-making skills, e.g. a student said during his interview: *"the technology fair helped me to set more effective criteria in relation to the product design. The weight of each criterion was crucial to the decision made."* Some of the examples that students mentioned during the interview as assessment criteria were the product safety, environmental issues, cost and materials availability.

Throughout the day that the technology fair was held a significant number of different ideas were presented as solutions to various technological problems. Pre-service teachers expressed the belief that it was interesting and helpful to see the optimisation concept used for different decisions made for various projects, e.g. a student said during his interview: *"during the designing part of our projects we tried to consider the best possible solutions. In the technology fair we saw that other people made different decisions for the same project, which we didn't even think about. This part was very important in understanding the importance of decisions in designing"*.

In reflective diaries a considerable number of students (86%) stated that the procedure of working with primary school pupils helped them to understand students' difficulties during decision-making process, e.g. a student stated in his reflective diary: *"my co-operation with the primary school pupil was very important. I found that I had a better understanding of possible difficulties that pupils may face during their design decision-making"*.

One of the main difficulties that university students faced while working with pupils was the weakness of students in identifying multiple assessment criteria in order to evaluate the possible solutions and choose the best between them. The majority of students could only mention attractiveness as the only criterion, e.g. a student stated in his reflective diary: *"I realized that it's difficult to consider different criteria further than attractiveness. As a result there is a possibility to develop a solution that may not be the optimum"*.

Some of the students (19%) did not follow any kind of optimisation technique as a strategy to make their decisions. They mentioned rules of thumbs or trial and error methods as a medium to make their decisions, e.g. a student mentioned during the interview: *"I found optimisation difficult and time consuming as a technique for decision-making. I mainly made a number of trials in order to decide the appropriate materials or available shapes that are suitable to implement"*.

### Conclusions

The purpose of the present study was to examine the influence of the technology fair in developing undergraduate students' decision-making skills through an optimisation technique. The analysis of the results indicates that the technology fair has an influence on improving students' understanding and application of decision-making optimisation strategies within the area of design and technology.

The research identified some difficulties faced by university students and primary education pupils in relation to decision-making during the designing of a technology project. The main difficulty identified from the study is the weakness of some students to consider a number of different assessment criteria in order to

evaluate their alternative solutions. Those findings should be considered for possible redesign of the technology fair.

Although the results of the study indicates that the involvement of pre-service teachers with the technology fair, and their autonomous collaboration with primary education students is helpful to the enhancement of decision-making skills, a number of critical issues need to be reexamined in order to obtain more clear ideas. Therefore in-depth research is needed to examine the optimisation steps that pre-service teachers are following while implementing the technology fair.

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## Appendix 1 A typical decision-making process using an optimisation technique

- 1. Define the problem.** Accurate judgment is required to identify and define the problem. Common mistakes that might be occurred at this step are: (a) defining the problem in terms of a proposed solution, (b) missing a bigger problem, or (c) diagnosing the problem in terms of its symptoms. Our goal should be to solve the problem, not just eliminate its temporary symptoms. For example the decision-making task presented in Table 1 requires deciding for the optimum solution in a certain technological problem.
- 2. Identify the criteria.** Most decisions require the decision maker to accomplish more than one objective. The rational decision maker will identify all relevant criteria in the decision-making process. For the example shown in Table 1, the criteria that should be satisfied by the product in order to assess all available alternatives are: product should function appropriate, be safe while operating, be aesthetically nice, be ergonomically designed and be completed within the time limitations.
- 3. Weight the criteria.** Different criteria will be of varying importance to a decision maker. Rational decision makers will know the relative value they place on each of the criteria identified. For example the relative importance of functionality is scored with 5, which is consider to be very important while the relative importance of aesthetics is scored with 3, which is less important than functionality but more important than time limitations which is scored with 2.
- 4. Generate alternatives.** The fourth step in the decision-making process requires identification of possible solutions. For the purpose of the current example solutions 1 to 4 are consider to be the alternative solutions to the problem (see Table 1).
- 5. Rate each alternative on each criterion.** How well will each of the alterna–tive solutions achieve each of the defined criteria? This step typically requires the decision maker to forecast future events. The decision maker will be able to carefully assess the potential consequences of selecting any of the alternative solutions on each of the identified criteria. For example in Table 3 solution 2 is rated with 2 in functionality and with 3 in safety.

<b>Solution Value:</b> <i>Absolutely Satisfied</i>		4	3	2	1	0	<i>Not Satisfied</i>
<b>Criterion Weight:</b> <i>Very Important</i>		5	4	3	2	1	<i>Not Important</i>
<b>Criterion</b>	<b>Criterion Weight</b>	<b>Solution 1</b>	<b>Solution 2</b>	<b>Solution 3</b>	<b>Solution 4</b>		
Functionality	5	4	2	3	1		
Safety	4	2	3	3	2		
Aesthetics	3	3	3	4	3		
Ergonomic	2	2	3	2	4		
Time Limitations	2	2	4	2	2		

Table 3: Optimisation technique

6. **Compute the optimal decision.** Ideally, after all of the first five steps have been completed, the process of computing the optimal decision consists of: (1) multiplying the ratings in step 5 by the weight of each criterion, (2) adding up the weighted ratings across all of the criteria for each alternative, and (3) choosing the solution with the highest sum of the weighted ratings. Table 2 shows the new values obtained after calculations in a unified scale.

Criterion	Solution 1	Solution 2	Solution 3	Solution 4
Functionality	(4x5) <b>20</b>	(2x5) <b>10</b>	(3x5) <b>15</b>	(1x5) <b>5</b>
Safety	(4x2) <b>8</b>	(3x4) <b>12</b>	(3x4) <b>12</b>	(2x4) <b>8</b>
Aesthetics	(3x3) <b>9</b>	(3x3) <b>9</b>	(4x3) <b>12</b>	(3x3) <b>9</b>
Ergonomic	(2x2) <b>4</b>	(3x2) <b>6</b>	(2x2) <b>4</b>	(4x2) <b>8</b>
Time Limitations	(2x2) <b>4</b>	(4x2) <b>8</b>	(2x2) <b>4</b>	(2x2) <b>4</b>
<b>Total Score</b>	<b>45</b>	<b>45</b>	<b>47</b>	<b>34</b>

Table 4: Optimisation unified scale

For example, the score for solution 1 in functionality criterion is 4 and this number should be multiplied with the equivalent score of the criterion weight which is 5 and as a result the new score is (4x5) 20 (Table 4). After calculating all the new scores the next step is to add all the new scores, to get the total score. From Table 4, solution 3 has the higher score and seems to be the optimum solution and therefore is the one that should be chosen to be developed.