Learning Outcomes Report

EAC/49/2010

Lifelong Learning Programme

Project type:	Action ERASMUS Multi-Lateral Projects
Start date of project:	1st October 2012
Duration:	24 months

Authors: Slavi Stoyanov, Howard Spoelstra, Louise Burgoyne, Colm O'Tuathaigh

Contributors: Anca Croitor, Bill Wright, Catherine Sweeney, Deirdre Bennett, Diarmuid Cahalane, George Shorten, John McSweeney, Padraig Cantillon-Murphy, Sabine Van Huffel, Siun O'Flynn, d.kelliher@ucc.ie, e.popovici@ucc.ie, takacs@palyazat-sote.hu, V.Pakrashi@ucc.ie

Learning Outcomes Report

Action submission date: March 2013

Version 1.0

Summary

Aim of the study

The learning outcomes study, conducted as part of WP3 of the BioApp project, has as objectives: (a) generating a comprehensive list of the learning outcomes; (b) reaching an agreement on the scope and priority of the learning outcomes, and (c) making suggestions for the further development of the Biomedical Design module.

Method

To address the objectives of the study, the group concept mapping approach was applied. Group Concept Mapping (GCM) is a systematic approach that objectively identifies an expert group's shared vision on a particular issue, in our case the Biomedical Design module learning outcomes. The method involved the participants in activities that most professionals are used to: idea generation, sorting of ideas into groups and rating the ideas on some values (e.g., importance and difficulty to achieve). The analysis applied multi-dimensional scaling and cluster analysis to visually depict the experts' shared representations on the learning outcomes as thematic groups. One of the distinguishing characteristics of GCM is the visualisation of the results from the analysis. Visualisation allows the emerging data structures and their interrelationships to be grasped. This facilitates decision making. Group Concept Mapping produces three main types of visualisations: conceptual maps, pattern matches and go-zones.

Results

The following thematic groups (clusters) of learning outcomes emerged from the data: *'Attention to the end user'*, *'New approaches to design'*, *'Design process'*, *'Regulation and Ethics'*, *'Commercialisation'*, *'Knowledge integration'*, *'Communication'*, *'Collaboration', 'Higher order skills'*, *'Problem solving process'*, *'Connecting domains'*, and *'Learning goals'*. Five more global areas of interest could be identified after conceptually related clusters were combined: *'Design'* (including 'Design process', 'New approaches', and 'Attention to end user'); *'Marketing'* (containing 'Commercialization' and 'Regulation and Ethics'); *'Interdisciplinary group dynamics'* (comprised of 'Communication' and 'Collaboration'); *'Learning objectives'* (consisting of 'Learning goals', 'Higher order skills' and 'Problem solving process') and *'Creative combination'* (which includes 'Knowledge integration' and 'Connecting domains'). Furthermore, the learning outcomes could be classified into two major categories: a) *technical skills* (new advancements in design process with special attention to users, also commercialisation and standardisation), and b) *transversal skills*, which include working effectively in teams ('communication' and 'collaboration') and creative problem solving ('problem solving process').

The rating results indicate that the most important groups of learning outcomes are 'Higher order skills' and 'Communication'. At the same time, however, these outcomes are deemed to be the most difficult to achieve. Other difficult to achieve learning outcomes are 'Learning goals', 'Problem solving process' and 'Connecting domains'. The least important group of learning outcomes is 'Commercialization' and the easiest to achieve is 'Regulation and Ethics'. The framework of learning outcomes consists of not only learning outcomes related to traditional topics such as 'Design process' and 'Creative problem solving', but also themes not very popular in curriculums on design such as 'Commercialisation', 'Standardisation', 'Regulations', and 'Ethics'. The results also show there is a

moderate correlation between the two values of importance and difficulty to achieve on the cluster level. The clusters ‘Problem solving process’, ‘Connecting domains’ and ‘Commercialization’ score lower on importance but higher on difficulty to achieve. In contrast, ‘Regulation and Ethics’ scores higher on importance but relatively lower on difficulty to achieve.

Conclusions

This study provided not only an empirical basis for identifying the main learning outcomes areas for an educational module on Biomedical Design, but also suggested how to operationally define them (through the statements in each cluster). The study emphasizes the need for addressing the highest level of learning taxonomy (analysis, synthesis, problem solving, creativity) when defining learning outcomes. It further reveals the need to teach students to integrate knowledge from different professional domains.

However, the overall conclusion must be that the study not only identified learning outcomes for the Biomedical Design module when considered in isolation from the encompassing curriculum, but that the identified learning outcomes can only be effectively achieved when further integration of the module in the curriculum is allowed.

Table of Content

Introduction

The purpose of the BioApp project work package 3 as described in description of work is twofold: (a) based on the preliminary report of WP2, and in collaboration with the other partners, to conduct a requirement analysis that matches the survey analysis, and apply findings from the WP2 report to the generation of the Biomedical Design module learning outcomes and (b) to generate a consensus on the module' learning outcomes.

These objectives are to be achieved through consultations with partners via e-meetings and a review of the WP2 findings on the BioApp needs assessment.

There are, however, two major issues with online expert consultations: (a) generating a *comprehensive* set of learning outcomes, and (b) reaching *agreement* on them. During the preparation of a list of learning outcomes, participants might be focused on the current practice of a course already running. This could narrow the scope of the learning outcomes to be defined. An agreement on learning outcomes might even be more difficult to achieve: the partners represent different professional domains, and individually they might have rather different thinking styles. The participants might also not agree on how much emphasis should be put on each learning outcome. Additionally, during live meetings there is always the phenomenon of 'group think', or 'peer-pressure', (the negative effect of the group on the opinions of the individual members).

Methods for expert consultation, such as *Focus groups*, *Affinity diagram* and the *Delphi*-method are some of the most used structured approaches aimed at achieving consensus. However, applying these methods can reveal undesired side-effects. The analysis of focus group data imposes pre-determined classification schemas, which can be either non-exhaustive or impose biases. In affinity diagram sessions, participants typically would suggest different clustering solutions, both in terms of number of clusters and the content of the clusters, which makes it difficult for researchers to come up with a unified vision on how best to structure the information. The Delphi method requires several iterative rounds before claiming consensus in the group. The consensus is more or less forced and the subjective approach is always there.

Our solution to the issues just mentioned is to use Group Concept Mapping (GCM) (Trochim, 1989; Trochim & Kane & Trochim, 2007) to determine the desired learning outcomes and to achieve consensus on them. This research methodology, while building on the strengths of Focus groups, Affinity diagrams and the Delphi-method, mitigates some of their weaknesses. In contrast to the Delphi method, in GCM, there is only one round of data-structuring as the participants work independently and anonymously of each other to limit the possibility of 'groupthink' or 'peer-pressure'. Unlike interviews and focus groups, GCM does not rely on pre-determined classification schemas. The method does not need inter-coder discussion to come up with an agreement. When sorting the statements into groups, the participants, in fact, 'code' the text themselves. Then multivariate statistical analysis aggregates the individual coding schemas across the participants. Consensus is not forced, but emerges from the data. Group Concept Mapping supports the researcher in dealing with diverse information, structured in various ways, which is a problem in Affinity diagram sessions.

Group Concept Mapping (GCM) is a structured, mixed approach applying both quantitative and qualitative measures to objectively identify an expert group's common understanding about a particular issue, in our case the Biomedical Design module learning outcomes. The method involves participants in activities that most professionals are used to: *idea generation*, *sorting of ideas into groups* and *rating the ideas* on some contrasting dimensions, such as *importance to achieve* and *difficulty to achieve*. The participants work individually but it is the advanced statistical techniques of multidimensional scaling and hierarchical cluster analysis that quantitatively aggregates individual inputs of the participants to reveal objective patterns in the data. One of the distinguishing characteristics of GCM is visualisation, which is a substantial part of the analysis. Visualisation allows the emerging data structures to be grasped together with their interrelationships, and their interpretation to support decision making. Group Concept Mapping produces three main types of visualisations: conceptual maps, pattern matches and go-zones.

The main research question the BioApp learning outcomes study aims to answer is: *How can we support partners to arrive at an agreed set of the Biomedical Design module learning outcomes*?

The report is structured as follows: In the method section, we introduce the design of the study using the Group Concept Mapping methodology. In the results section we present participant demographics and the results from the Group Concept Mapping on clustering and rating of aggregated learning outcome statements. The discussion section critically reflects on the outcomes. Finally, the conclusions and suggestions section presents recommendations for further development of the BIODESIGN educational module.

Method

The GCM procedure consisted of five phases: (1) idea generation (brainstorm) and idea pruning, (2) sorting of ideas into groups, (3) rating on two values (importance and difficulty to achieve), (4) analysis of the data and (5) interpretation of the results. All project members were invited to participate in the learning outcomes study through the project's online management system. They were fully informed about the purpose, the procedure, and the time needed for completing the activities. The participants were provided with a link to the brainstorming page of a web-based tool for data collection and analysis (Concept System Global, 2012). They could visit the web site as many times as they needed, using their own username and password. The participants were asked to generate ideas completing the following trigger statement: "One specific learning outcome of the Biomedical Design module is…". Participants were instructed that the ideas generated should take the form of short phrases or statements, expressing one thought. We purposely did not ask the participants to follow standard formats for defining learning outcomes. Introducing such a format would be counterproductive, as it would restrict the free flow of ideas. The participants had two weeks to complete the idea generation task.

After the idea generation phase finishes, the procedure normally requires data cleaning to remove or restate duplicate or vague ideas, and to split statements which contain more than one idea. In this study, all ideas were unique, so the researchers needed only to split statements consisting of more than one idea. The final list was then made available to the participants, firstly for the sorting of ideas into groups (based on similarity in meaning), giving names to the groups, and secondly for the rating of the ideas on two values – *importance to achieve* and *difficulty to achieve*. (Please see Appendix A for the detailed instructions given for sorting and rating). The participants were allowed three weeks to completing both sorting and rating. A reminder was sent after two weeks. As the return rate was still low we prolonged the time for completing the second phase (sorting and rating) by two weeks. As in the brainstorming phase, the participants could save their work and return later to continue.

The analysis included multidimensional scaling and hierarchical cluster analysis for the sorting of the data, and means, standard deviations, and correlations for the rating data.

Results

Demographics

Nineteen experts from the BioApp consortium responded positively to the invitation to participate in the study. They registered to a system for online data collection, supporting the GCM approach, (Concept System Global, 2012) creating a username and password. All participants gave their informed consent. 16 participants contributed to the idea generation phase, 9 to the sorting phase, and 7 to the rating phase. Three demographic questions were included (on educational background, professional experience and gender), but despite the assurance in the letter of informed consent that their data would be treated confidentially and would be used for research purposes only, half of the participants were reluctant to share this information. Tables 1a and 1b provide the demographic information we gathered about the participants.

Table 1a. Demographic information.

Participant Question	Option	Frequency	%
Gender	Female	3	15.79
	Male	7	36.84
	did not respond	9	47.37
TOTAL		19	100.00
Educational Background	Engineering & Computer Sciences	3	15.79
	Medicine & Healthcare	2	10.53
	Social Sciences	3	15.79
	Math & Science	1	5.26
	Business & Management	0	0.00
	Other	0	0.00
	did not respond	10	52.63
TOTAL		19	100.00

Table 1b: Demographic information (continued).

Participant Question	Option	Frequency	%
Experience	Less than 5 years	0	0.00
	6-10 years	2	10.53
	More than 10 years	7	36.84
	did not respond	10	52.63
TOTAL		19	100.00

More male than female participants signed up for the study. The participants represented three professional domains involved in the development of the BioApp educational module: Engineering & Computer Science, Medicine & Healthcare, and Social Sciences. Most of the participants have more than 6 years of professional experience.

Clustering results

The first step in analysis the data is called clustering. Clustering uses multidimensional scaling to position the learning outcome statements. Figure 1 shows the outcome of the multidimensional scaling – a point map.

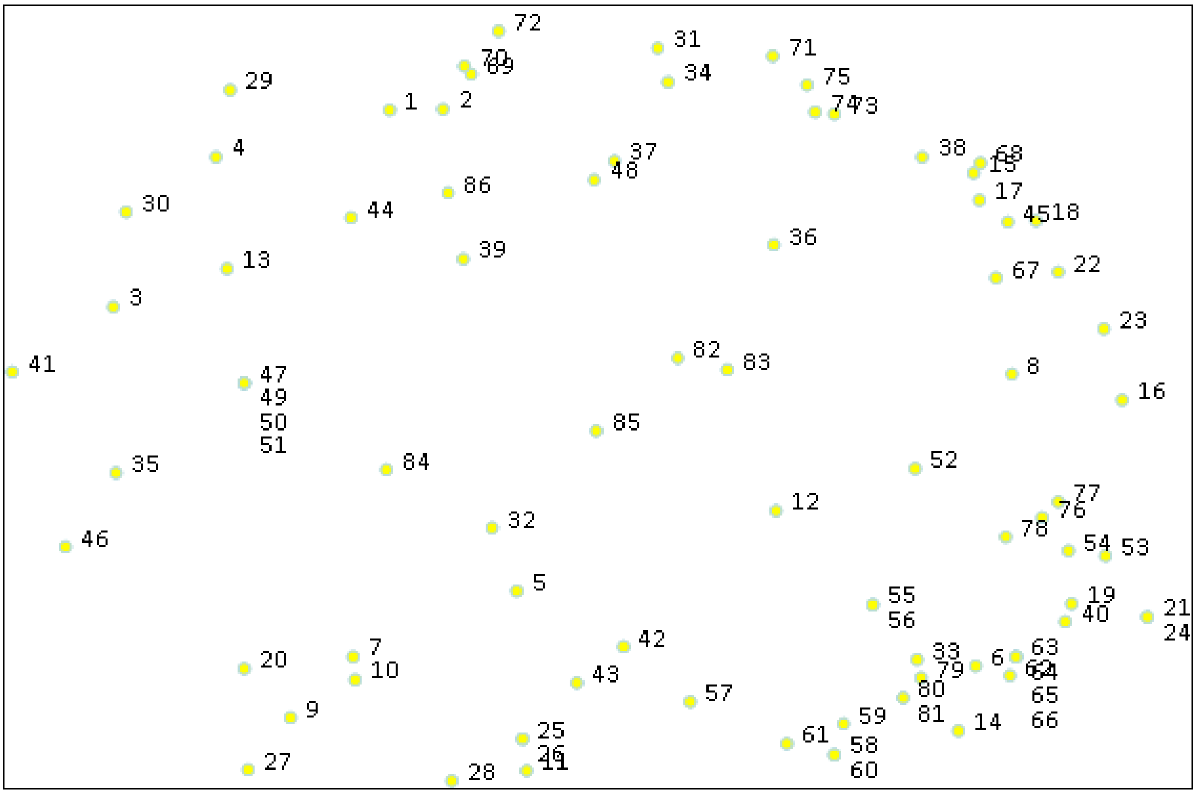


Figure 1. Point map showing the position of all statements after multidimensional scaling.

Explanation of Figure 1: The closer the points (representing learning outcomes) are to each other, the closer in meaning they are. This is a result of more people clustering them together. Multidimensional scaling (MDS) assigns each statement a bridging value, which is between 0 and 1. A low bridging value means that a statement has been grouped together with statements around it, as is the case with the statements 33, 79, 80 and 81. A higher bridging value means that the statement has been grouped together with some statements further apart from the either side, which is the case with e.g., the statements 13 or 84. Some clustering groups of learning outcomes can already be detected by a simple visual inspection, but to make the process more efficient, the hierarchical cluster analysis (HCA) was applied to the results. Several clustering solutions were checked, applying the practical heuristic ’20-to-5’. This means we started from a 20-cluster solution with the goal to arrive at a 5-cluster solution. At each iteration we checked whether the merging of clusters made sense (for an example of an intermediate map see Figure 2).

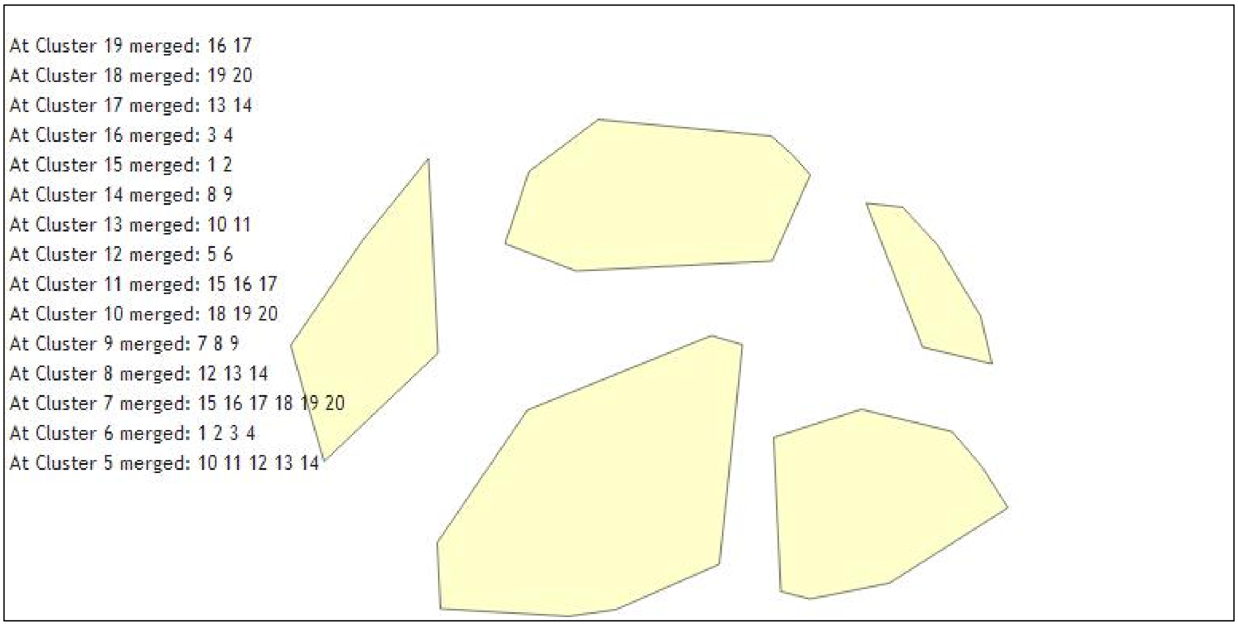


Figure 2. Intermediate map for decision on the number of clusters.

We determined that a twelve-cluster solution seemed to represent the data best, serving the purpose of the study (see Figure 3).

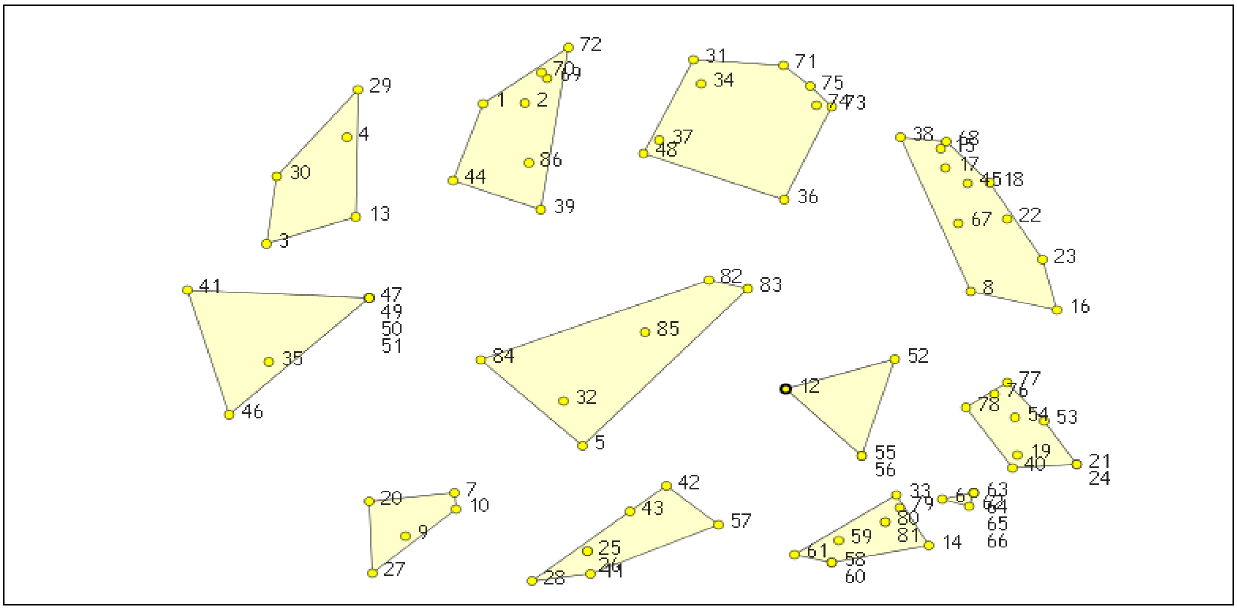


Figure 3. Twelve-cluster solution.

The next step in making sense of the data was to attach meaningful labels to the clusters. There are three methods available for labelling. The first method is to check what the system suggests. The system suggest a label for a group of statements, based on the label given by a participant, whose centroid is the closest to the centroid of the cluster formed by the aggregation of the data from all the participants. The second method is to look at the bridging values of the statements composing the cluster. The statements with lower bridging values better represent a cluster. The third method is to read through all the statements in a cluster and to define in a label what is the story behind the learning outcome statements (what is it that the cluster wants to tell us). To define the cluster labels (e.g., collective theme of the statements, or category) we combined all three methods. The following clusters were identified: (1) Attention to end user, (2) New approaches to design, (3) Design process, (4) Regulation and Ethics, (5) Commercialization, (6) Knowledge integration, (7) Communication, (8) Collaboration, (9) Higher order skills, (10) Problem solving process, (11) Connecting domains, and finally (12) Learning goals (see Figure 4).

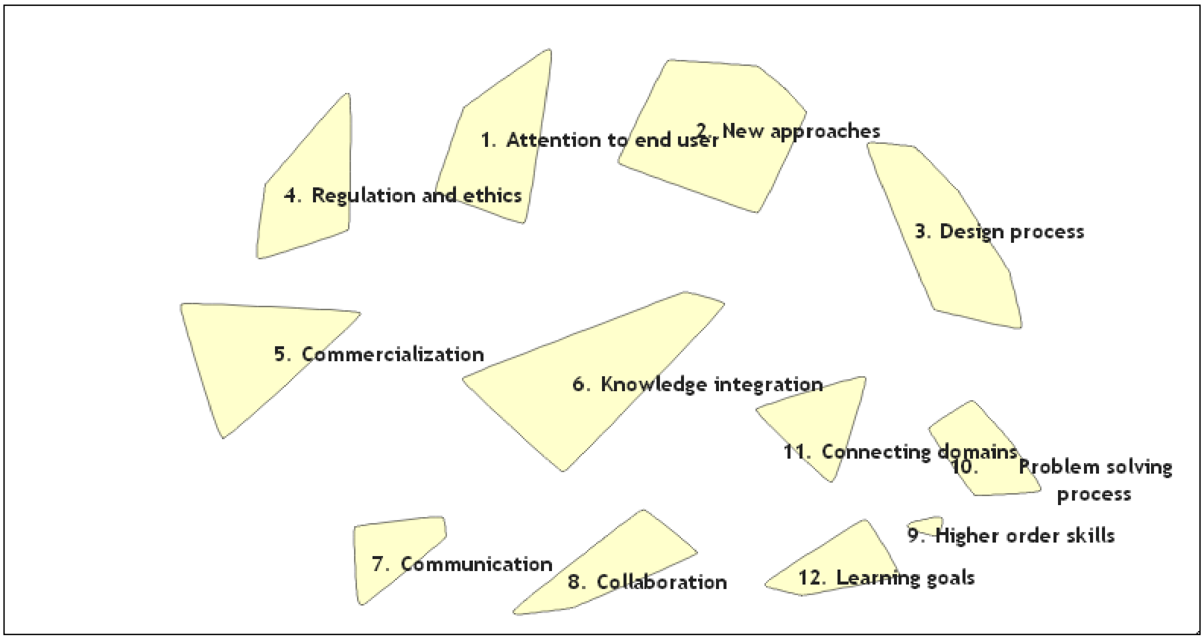


Figure 4. Map with clusters of learning outcomes and their labels.

The average bridging value among the clusters is 0.37. High coherence inside a cluster (with the lowest bridging values) means that the most people agreed on the learning outcomes in it. This applies to the clusters 'Higher order skills' (0.03), followed by 'Learning goals' (0.10), 'Problem solving process' (0.18) and Connecting domains (0.20). The clusters with the highest bridging value are 'Regulation and ethics' (0.71) and 'Commercialization' (0.70). (Please see Appendix B for the statistics regarding the sorting of the data.)

Below, we describe the general theme of the learning outcomes in the clusters. The cluster:

(1) *'Attention to end user'* is about the need to take the characteristics of end users into account. Designing BIOAPP applications is to solve real problems. Representative statements for this cluster are: "The ability to take the medical constraints into account"; "The ability to take the potential of the user of the end product into account (doctor, nurse, patient)"; and "The ability to take the limitations of the user of the end product into account (doctor, nurse, patient)".

(2) *'New approaches'* emphasizes the need to look for new design methodologies, include results from design research and implement original ideas in designing medical devices. Representative statements are: "To apply new insights to design new medical-technological products", "The ability to take the technological constraints into account", "To apply new results to design new medical-technological products".

(3) *'Design process'* refers to knowledge and skills related to conducting high quality design activities from need assessment to developing and testing working prototypes. Examples of ideas included in this cluster are as follows: "Learn a design based approach to developing healthcare technology", "To build a working prototype", "The ability to satisfy the design specifications".

(4) *'Regulation and Ethics'* focuses on the need to be aware about regulations, standards, quality controls and ethical norms when designing medical devices. Some ideas included in this clusters are: "A clear understanding of the regulatory landscape for medical technologies in the European Union", "Increased awareness of clinical constraints during design of biomedical devices", "An understanding of the importance of relating potential benefits to patient health to potential risks".

(5) *'Commercialization'* suggests considering possibilities for entering the market and related knowledge and skills for making the product commercially attractive. Statements included in this cluster are: "Ability to present outcomes in a commercially compelling way", "Ability to write a business plan", "Ability to recognise commercial opportunities".

(6) *'Knowledge Integration'* highlights the need for combining knowledge and research from different professional domains. Ideas that represent this cluster are as follows: "Be able to integrate knowledge from the technological-scientific field", "Be able to integrate knowledge from the medical-scientific field", and "To promote student integration of knowledge across disciplines and thereby create rich and complex knowledge structure".

(7) *'Communication'*, as the name suggest, is about skills to communicate effectively with representatives of other professional domains. Examples of ideas included in this cluster are: "To learn to communicate understandings of your own discipline to those from other disciplines", "To learn to negotiate common ground and understandings with team members from different disciplines", and "Learn to work in a team with individuals from other disciplines".

(8) *'Collaboration'* includes a range of ideas from specific issues of creative team dynamics such as "Understand differences in the way people solve problems", "Understand that everybody is creative but in different way", to informal network learning ("Create a network from which students would benefit in their future carrier").

(9) *'Higher order skills'* suggests focusing on the highest level of learning taxonomy: creative problem solving, experimentation, analysis and synthesis. Examples of statements in this groups are: "To promote high level thinking processes (synthesis)", "To promote high level thinking processes (analysis)", and "To promote high level thinking processes (problem solving)".

(10) *'Problem solving process'* is about skills in conducting effective and efficient problem solving (analysis of problem situation, idea generation, applying new problem solving methodologies, and awareness of own and the others problem solving styles). Examples are: "Develop the hand on solving problem abilities in students", "Being able to identify different creative problem solving styles" and "Ability to deconstruct a real life problem".

(11) *'Connecting domains'* is about recognising and evaluating connections to different concepts, fields and contexts. Some examples are: "To develop the ability to recognize connections among disparate concepts, fields, or contexts", "To develop the ability to evaluate connections among disparate concepts, fields, or contexts", and "Introducing clinical/medical students to problem solving strategies employed in other domains which may lead to more creative clinical problem solving".

(12) *'Learning goals'* lists a number of learning goals and some more specific learning objectives. Statements representative for the cluster are as follows: "To broaden the students' synthetic thinking power", "Can critically reflect on his/her own way of creative problem solving thinking", and "To raise awareness in university educated students that problem solving/critical thinking is the primary goal of their chosen degree program".

Rating results

The system can visualise rating results, depicting high rating results as a high number of layers in the cluster presentation. Figure 5 shows the layers representing the rating category outcome

“Importance to achieve”. In it, the clusters ‘Higher order skills’ and ‘Communication’ score highest with five layers each. ‘Commercialization’ gets the lowest score (one layer).

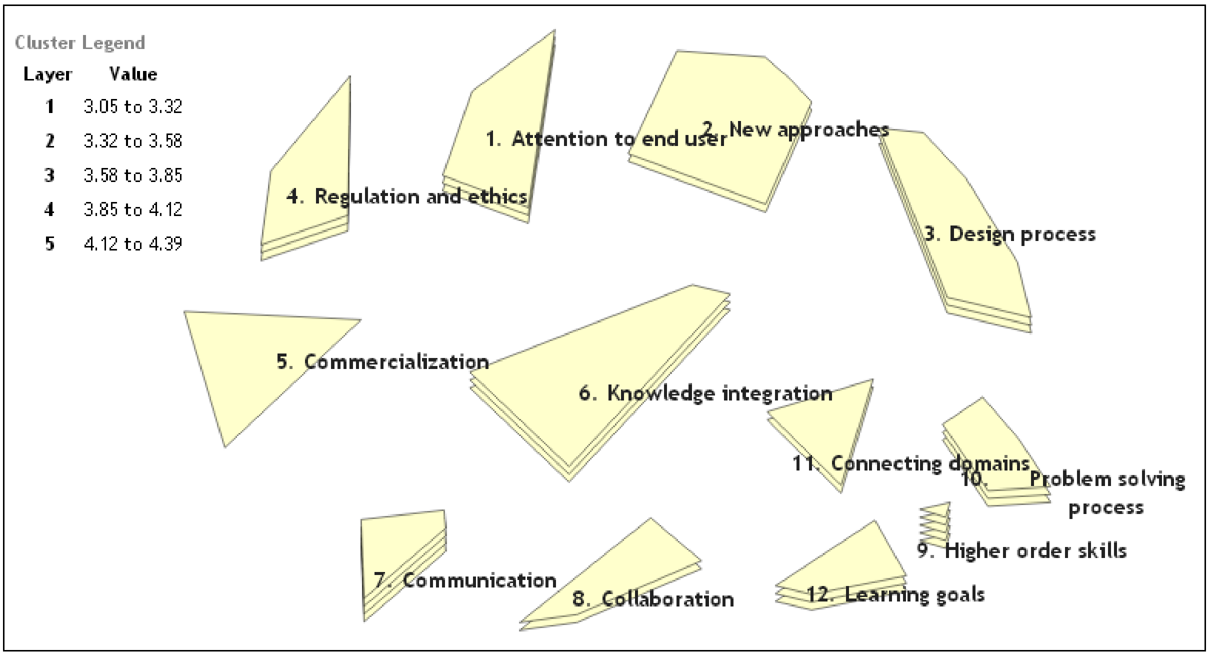


Figure 5. Cluster map depicting cluster importance on the rating category “Importance to achieve”.

In Figure 6, the clusters are depicted rated according to the category “Difficulty to achieve”. In it, ‘Higher order skills’ and ‘Communication’ again score the highest ratings (five layers). The clusters ‘Learning goals’, ‘Problem solving process’ and ‘Connecting domains’ also gets five layers on this rating category (see Figure 6).

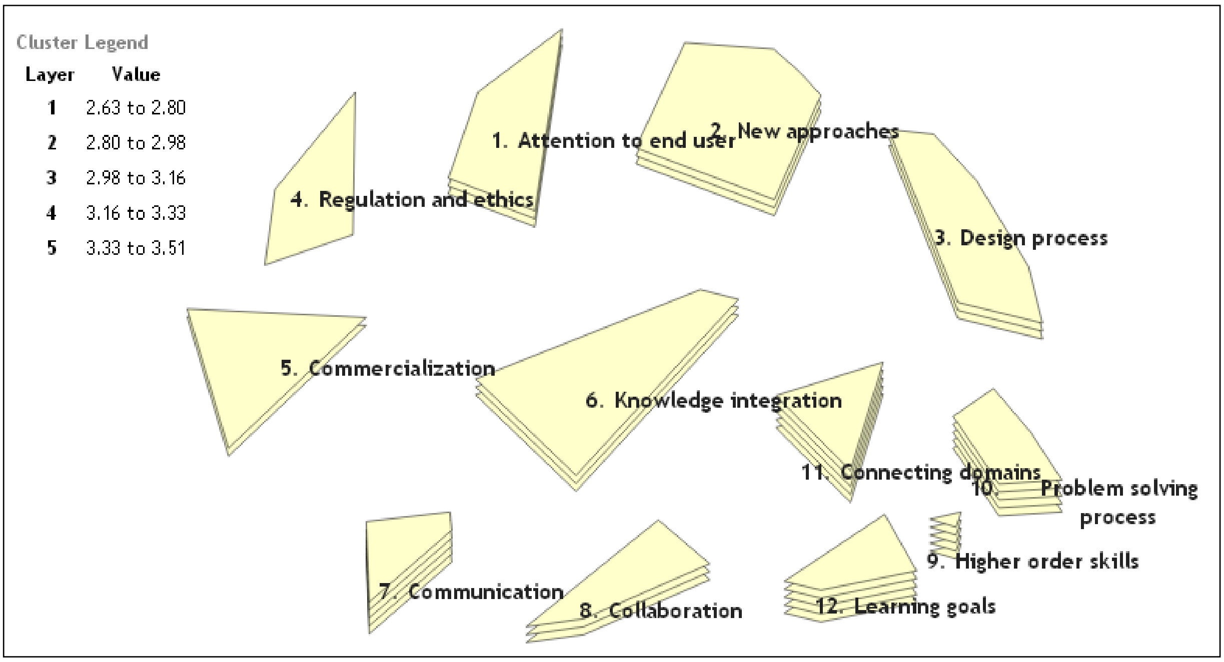


Figure 6. Cluster map depicting cluster importance on the rating category “difficulty to achieve”.

According to the participants, the easiest to implement are the learning outcomes in the cluster ‘Regulation and ethics’ (one layer). (Please refer to Appendix C for the ratings on importance and Appendix D for the rating on difficulty of all statements in the clusters.)

The ladder graph depicted in Figure 7, called a "pattern match", compares the clusters on their *importance to achieve* and *difficulty to achieve* ratings. The lines between the cluster labels show how pairs of clusters are related according to their ratings' values. A Pearson product-moment correlation coefficient shows how strong the connection is between the two patterns of data on importance to achieve and difficulty to achieve.

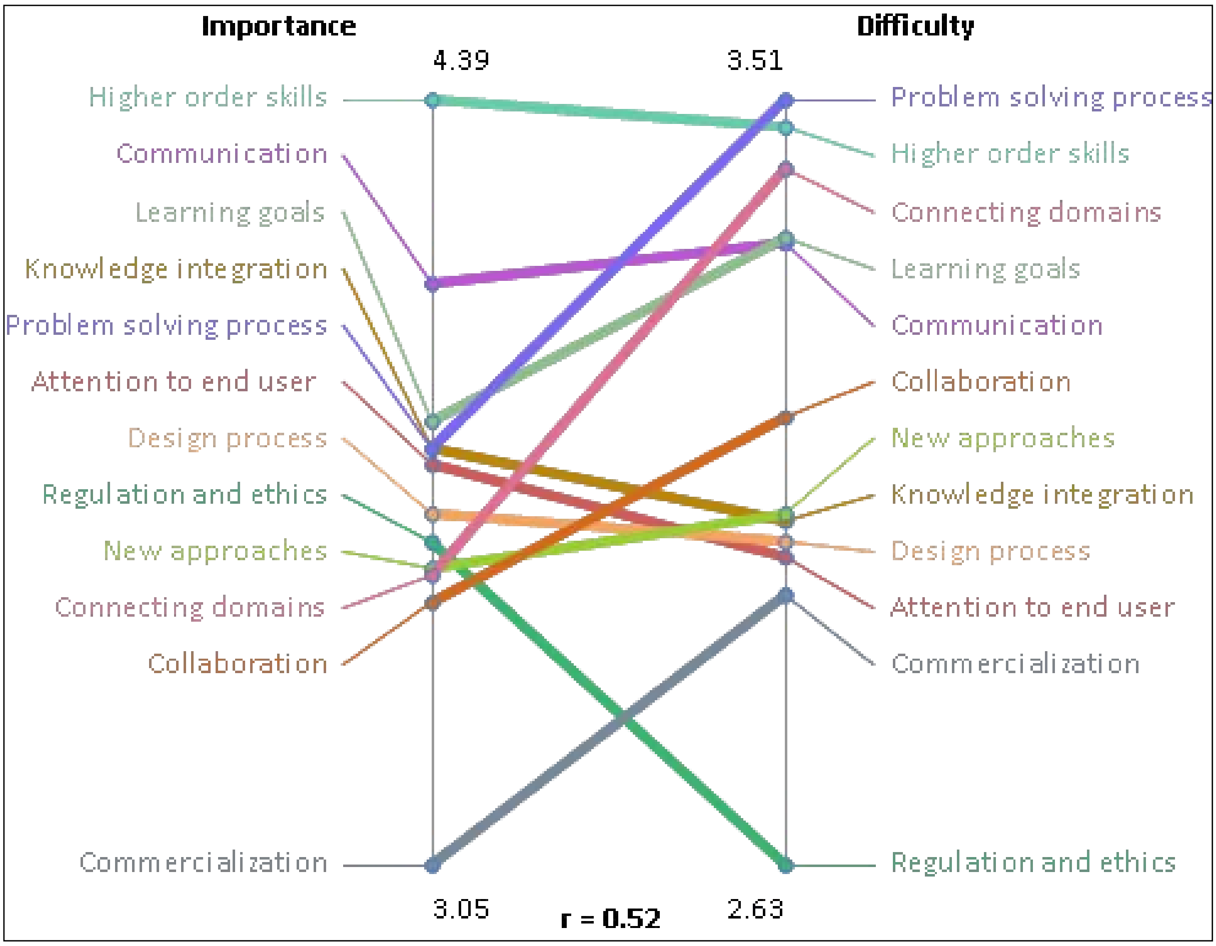


Figure 7. Pattern match with respect to "Importance to achieve" versus "Difficulty to achieve".

There is a moderate correlation between the two values (r = 0.52). The pattern map helps to easily detect differences between the two ratings in some clusters. The clusters 'Problem solving process', 'Connecting domains' and 'Commercialization' score lower on importance but higher on difficulty. In contrast, 'Regulation and Ethics' scores higher on importance than on difficulty.

For a deeper exploration of the statements in a particular cluster, bivariate graphs, called "go-zones", were used. Go-zones are divided into four quadrants based on the mean values of importance and difficulty. When looking for short term solutions, we should focus on implementing the ideas in the lower-right quadrant – these are very important to achieve *and* easy to achieve (e.g., "To learn to negotiate common ground and understandings with team members from different disciplines (learning outcome 9)" and "Learn to work in a team with individuals from other disciplines (learning outcome 27)". However, for long term solutions we should look at the upper-right quadrant – very important to achieve *but also* very difficult to achieve (e.g., "To learn to communicate understandings of your own discipline to those from other disciplines (learning outcome 10)". (See Figure 8 for an example of a go-zone map.) (Please see Appendix E for an overview of the go-zones of all clusters.)

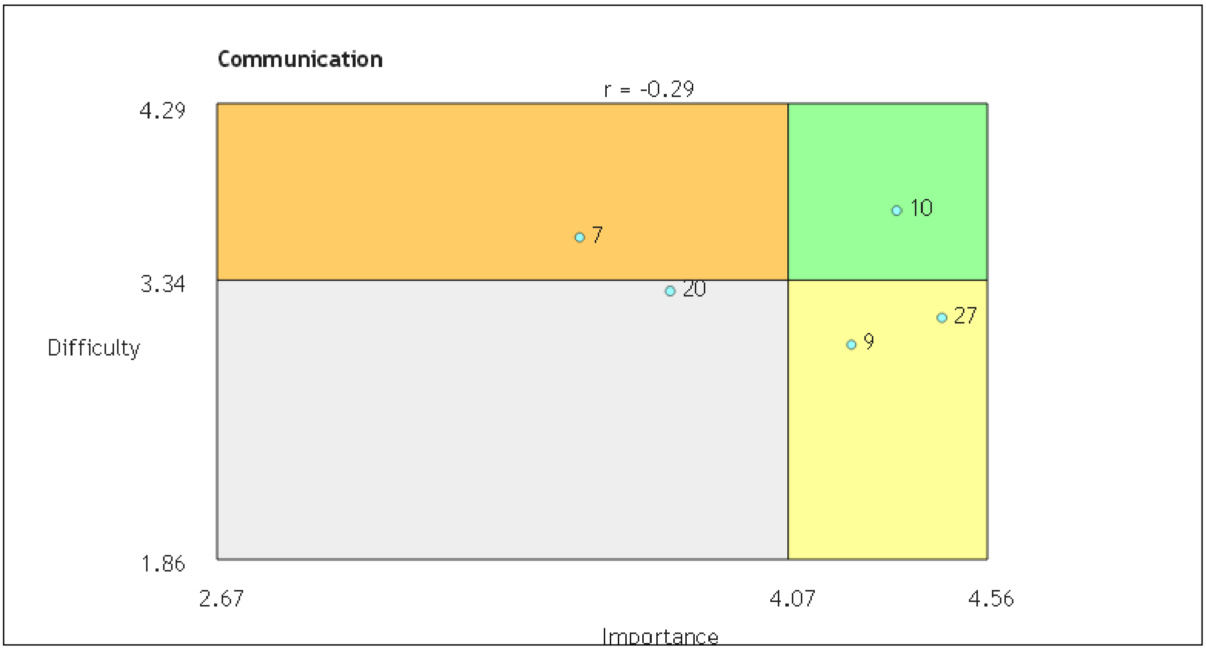


Figure 8. An example of a go-zone map.

Discussion

The learning outcomes of the BioApp project can be defined within a framework of learning outcome clusters, consisting of the following categories of outcomes: ‘Attention to end user’, ‘New approaches to design’, ‘Design process’, ‘Regulation and ethics’, ‘Commercialization’, ‘Knowledge integration’, ‘Communication’ , ‘Collaboration’, ‘Higher order skills’, ‘Problem solving process’, ‘Connecting domains’, and ‘Learning goals’.

The most important clusters of learning outcomes are ‘Higher order skills’ and ‘Communication’. However, these outcomes will also need the most effort before they can be achieved. The clusters ‘Learning goals’, ‘Problem solving process’ and ‘Connecting domains’ are also difficult to achieve. The least important group of learning outcomes is ‘Commercialization’ and the easiest to achieve is ‘Regulation and Ethics’.

This framework reveals not only learning outcomes related to traditional topics such as ‘design process’ and ‘creative problem solving’, but also draws attention to educational outcome themes such as ‘commercialisation’, ‘standardisation’, ‘regulations’, and ‘ethics’.

The results suggest emphasising elements of the highest levels in learning taxonomies by defining learning outcomes such as ‘analysis’, ‘synthesis’, ‘problem solving’ and ‘combining knowledge from different professional domains’ for either informing the design process (e.g., implementing recent development in the software design to the BioApp process) or stimulating creativity (e.g. creative strategies of ‘looking in other worlds’, ‘making novel combination’ and ‘connecting the unconnected’). The scope of some learning outcomes discovered in the current study clearly suggests that they cannot be achieved by reviewing the Biomedical Design educational module in isolation from the curriculum in which it is embedded. These learning outcomes need to be addressed on a BioApp curriculum level.

The clusters of learning outcomes, and how they are operationalised through the statements which they contain, provide an empirical basis for further defining learning outcomes for the Biomedical

Design module, by applying a standard for defining learning outcomes. One example learning outcome statement could be: 'After finishing the Biomedical design module the student should be able to conduct a contextual inquiry interview for a needs analyses.'

The principle that the distances between individual ideas in Group Concept Mapping matter applies to the distances between the clusters as well. The closer the clusters are to each other, the closer they are conceptually. Based on the combination of clusters, five more global areas of interest could be identified: (1) 'Design' (including 'Design process', 'New approaches', and 'Attention to end user'); (2) Marketing (containing 'Commercialization' and 'Regulation and Ethics'); (3) Interdisciplinary group dynamics (comprised of 'Communication' and 'Collaboration'); (4) 'Learning objectives' (consisting of 'Learning goals', 'Higher order skills' and 'Problem solving process');, and (5) Creative combinations (including 'Knowledge integration' and 'Connecting domains'). Furthermore, the learning outcomes could be classified into two major categories: *technical* skills (new advancements in design process with special attention to users, also commercialization and standardization) and *transversal* skills including working effectively in teams ('communication' and 'collaboration'), and creative problem solving (problem solving process). Both types of learning outcomes are equally important.

Specific knowledge and skills are defined with regard to the design process, such as 'conducting needs analysis', 'addressing usability issues', 'testing prototypes' (related to the cluster 'Design process'). A suggestion is made for the inclusion of the latest developments in the domain of design, based on research and practice in different professional fields (related to the cluster 'New approaches'). Examples of such new approaches could be *scenario-based design*, *design based research*, *contextual design*, *user-centred design*, *participative design*, *rational unified process*, or *extreme programming* (Holtzblatt, Wendell & Wood, 2007; Kuniavsky, 2003). While the specific details of these methodologies vary, they share the basic idea of a progressive, spiral refinement through a cyclical prototype development process. All these design methodologies put the user in the centre of the design, development, evaluation and implementation activities (related to the cluster 'Attention to end user'). Before discussing functional specifications and interface issues ('build the product right'), they make sure that the real problem people have is addressed ('build the right product'). There are many cases when design ends up with a nice product from interface point of view but it is not useful, as it does not address people's problems.

Making products commercially attractive ('Commercialisation') should take regulations and ethical rules ('Regulation and Ethics') into account. Identifying commercialisation and regulation as distinctive clusters is an important result of this study. Commercialisation and regulations currently are underestimated issues in developing curriculums on design.

The statements in the clusters 'Communication' and 'Collaboration' are about working effectively in interdisciplinary groups. If 'Design process', 'New approaches' and 'Attention to end user' put emphasis on users in the design process, 'Communication' and 'Collaboration' focus on teams of designers. Issues may arise either because of differences in educational background and professional orientation, or because of differences in thinking styles. Research indicates that the more diversity in a team, the greater the potential for problem solving but the more difficult it is to manage (Kirton, 2003). This makes knowledge and skills about managing diversity in teams essential. The participants in this study did *not* recognize a strong relationship between *users* (an issue emerged in the clusters 'Design process' and especially 'Attention to end user') and *designers* ('Communication' and 'Collaboration'). The distance between these clusters is large. This is not to suggest that designers and users do not need to communicate. Identifying users' needs and testing prototypes with users are substantial parts of the design process, but it is not reasonable to ask users to design. There are specific issues in the design teams and users are not involved in it.

While 'Learning goals' define the targets of interdisciplinary learning in designing medical devices in more general terms, 'Higher order skills' is about specific learning objectives. In addition, 'Higher order skills' identify the cross-cluster issue of reaching the highest levels of learning taxonomy: analysis, synthesis, problem solving and creativity. The 'Problem solving process' includes knowledge and skills on how to make problem solving more effective in terms of the analysis of problem situations, idea generation, the selection of ideas and their implementation into practice. The results suggest a connection between the 'Problem solving process' and the 'Design process'. The terms 'problem solving' and 'design' have been used interchangeably in the literature about educational design, engineering design and management consulting (Block, 2000; Dabbagh, Jonassen, Yueh & Samouilova, 2000; Hutchinson & Karsnitz, 1994; Shein, 1999; Schön, 1996). The idea is that any kind of design should be considered as a problem solving process. Creativity is another common issue traditionally related to both problem solving and design. Most of the problem solving methodologies and design approaches include methods and techniques for breaking down the dominant thinking pattern and coming up with non-traditional solutions. The 'Problem solving process' is directly related to 'Higher order skills', and indirectly to 'Learning goals'. The capability of solving real-life problems is the primary goal of higher education. The statements in the cluster operationally define problem solving as a learning goal.

'Knowledge integration' and 'Connecting domains' play "bridging" roles between the other clusters. They also provide a context to the other clusters, which all are about learning and design at the cross section of engineering and medicine. In addition, the two clusters suggest making use of creativity techniques that force the relationships between different concepts and professional domains. (Michalko, 1998).

Limitations of the study

The number of participants (almost all of which were teachers) in the sorting and rating activities was rather low. We hoped to get at least the number that contributed to the idea generation. However, a recent meta-analytical study on 69 GCM projects conducted over the last 10 years found that 20–30 sorters produce the optimal goodness-of-fit between the aggregated similarity matrix and its representation as a conceptual map. Usability studies (Turner, Lewis & Nielsen, 2006) claim that there is 0.75 correlation between the results from 5 participants and ultimate results. Nielsen suggests 15 participants for sorting to get a correlation of 0.90 (Nielsen, 2013). In previous research (Stoyanov et al, 2012), the sorting analysis using the data from 10, 12, 15, 17 and 21 participants was checked at different stages of the study, and no substantial differences were found between the group sizes. We therefore believe that multidimensional scaling using the sorting data from 9 people, produced a relatively correct picture.

Sorting might have been influenced by the fact that after splitting some of the statements, the list was not randomised before sending it for sorting.

Although rating is of secondary relevance with respect to sorting in the GCM method, the number of participants for rating was very low.

Conclusions and suggestions

The group concept mapping study identified the following content areas of the biomedical design module learning outcomes: 'design process', 'new approaches for design', 'attention to the end user', 'commercialisation', 'regulations and ethics', 'communication', 'collaboration', and 'problem solving process'. These areas can be grouped into two main categories: technical skills (new advancements in design process with special attention to users, commercialization and standardization) and transversal skills such as working effectively in teams and creative problem solving.

This study provided not only an empirical basis for depicting the main learning outcomes areas, but also suggested how to operationally define them (through the statements in each cluster). The study emphasizes the need of addressing the highest level of learning taxonomy (analysis, synthesis, problem solving, creativity) when defining learning outcomes. Teaching students to integrate knowledge from different professional domains is another important finding.

The overall conclusion is that the study suggests learning outcomes not only for the Biomedical Design module , but for a Biomedical Design curriculum.

References

Block, P. (2000). *Flawless consulting. A guide to getting your expertise used*. San Diego: University Associates.

Concept Systems Global [Computer Software]. Concept Systems, Inc. Ithaca, N.Y; 2012.

Dabbagh, N. H., Jonassen, D., Yueh, H-P., & Samouilova (2000). Assessing a problem-based learning approach to an introductory instructional design course: A case study. *Performance Improvement Quarterly*, 13 (3), 60-83.

Holtzblatt, K., Wendell, J., & Wood, S. (2005). *Rapid contextual design*. San Francisco: Morgan Kaufmann.

Hutchinson, J., & Karznitz, R. (1994). *Design and problem solving in technology*. New York: Delmar publishers.

Nielsen, J. (2013). *Card sorting: how many users to test*. Retrieved from http://www.nngroup.com/articles/card-sorting-how-many-users-to-test/

Kane, M & Trochim W.(2007). *Concept mapping for planning and evaluation*. Thousand Oaks: Sage Publishing.

Kirton, M. (2003). *Adaption—Innovation in the context of diversity and change. London*: Routledge

Kuniavsky, M.(2003). *Observing user experience. A practitioner's guide to user research*. San Francisco, CA: Morgan Kaufmann.

Michalko, M. (1998). *Cracking creativity*. Berkeley, CA: Ten Speed Press.)

Rosas, S.R., Kane, M. (2012). Quality and rigor of the concept mapping methodology: a pooled study analysis. *Evaluation and Program Planning*, 2 (35), 36–245.

Schein, E. (1999). *Process consultation revisited. Building and helping relationship*. Reading, Massachusetts ± Addisson-Wesley.

Schön, D. (1996). *The reflective practitioner. How professionals think in action*. London: Arena.

Stoyanov, S., Boshuizen, H., Groene, O., van der Klink. M, Kicken, W., Drachsler, H., & Barach, P. (2012). Mapping and assessing clinical handover training interventions. *British Medical Journal Quality & Safety*, 21, i50-i57. doi:10.1136/bmjqs-2012-001169.

Trochim, W (1989). An introduction to concept mapping for planning and evaluation. *Evaluation and Program Planning*, 12, 1–16.

Turner, C.W., Lewis, J.R, Nielsen, J. (2006). Determining usability test sample size. In: W. Karwowski (Ed.). *International Encyclopedia of Ergonomics and Human Factors*. Boca Raton, FL: CRC Press, 3084–3088.

Appendices

Appendix A: Instructions for brainstorming, rating and sorting

Brainstorming

Please generate as many ideas as possible in the text box below about expected learning outcomes of the BIOAPP module, completing the following statement: "One specific learning outcome of the BIOAPP module is…" What are knowledge, skills, attitudes, and values…that are important for and would have an impact on the future professional life of students? You may add as many statements as you wish. They can be either ideas that immediately pop up to your mind or you may take some time to consult written resources (reports, books, articles). Please keep each statement brief, just one thought but it should be understandable for other experts taking part in the study.

Select "add this statement" after each statement or idea. Your statement will then be saved and added to the list of collected statements at the bottom of the page. When you finish with the brainstorming, you can click on 'Done Brainstorming' but you still be able to add new statements if you need to do so at a later stage.

Sorting

INSTRUCTIONS: In this activity, you will categorize the statements, according to your view of their meaning or theme. To do this, you will sort each statement into a category in a way that makes sense to you.

First, read through the statements in the Unsorted Statements column on the left.

Next, sort each statement into a category you create. Click on the items to drag them onto the empty area in the middle of the screen. Group the statements for how similar in meaning or theme they are to one another. Give each category a name that describes its theme or contents.

There is no right or wrong way to group the statements. You will probably find that you could group the statements in several sensible ways. Pick the arrangement that feels best to you. Some statements may sound almost identical to you. Do not worry about that. They should go then in one group.

The task may seem overwhelming at first glance, but while you are reading the statements you will get an idea about some of the possible categories. You can always create new categories, delete categories, or move statements from one category to another. You can save your work at any time and return later to continue.

Please,

Do NOT create categories according to priority, or value, such as 'Important', or 'Hard To Do.'

Do NOT create categories such as 'Miscellaneous' or "Other" that group together dissimilar statements. Put a statement alone in its own category if it is unrelated to all the other statements.

Do NOT put one statement into two groups at the same time. Each statement must be put into only one group.

Do NOT leave any statements in the Unsorted Statements column.

People vary in how many categories they create. Usually 5 to 20 categories works well to organize this number of statements.

The Help provides some useful tips for how to use the environment (e.g., naming a pile, switching the mode of sorting). You can look at it at any time you need to do so. The Help also gives you the opportunity to ask specific questions to the administrator. Question marks ("?") attached to some fields also provide some contextual hints. Do not forget to save your work. Click the button 'Save' frequently.

Rating

Importance

How important are the learning outcomes listed below? Please rate each statement on a 1-to-5 scale where: 1 = not at all important; 2 = somewhat important; 3 = neither important nor unimportant; 4 = moderately important; 5 = very important. Try to use the full range of ratings values (e.g. 1 to 5) judging the relative importance of the statements compared to each other.

Difficulty

How difficult is it to achieve the learning outcomes listed below? Please rate each outcome on a 1-to-5 scale where: 1 = not difficult; 2 = somewhat difficult; 3 = neither difficult nor easy; 4 = moderately difficult; 5 = very difficult. Please try to use the full range of ratings values (e.g. 1 to 5).

Appendix B: Clusters, statements and bridging values

	Cluster /Statement	Bridging
	1. Attention to end user	**0.41**
72.	The ability to take the medical constraints into account	0.33
70.	The ability to take the potential of the user of the end product into account (doctor, nurse, patient)	0.35
69.	The ability to take the limitations of the user of the end product into account (doctor, nurse, patient)	0.36
86.	Ability to translate technical concepts to their medical partners (for engineers)	0.40
2.	An awareness of the importance of data and record integrity particularly when such data and records can be used to demonstrate efficacy from a medical perspective	0.40
39.	Solve real-life problems using simple concepts make a bridge between two languages/vocabularies (medicine and engineering)	0.42
1.	Understand how to provide documentary evidence (electronic or paper records) that innovative medical technologies will consistently produce results meeting predetermined design specifications	0.49
44.	Raise the interest for using latest technology in medical students	0.51

Count	Std. Dev.	Variance	Min	Max	Average	Median
8	0.06	0.00	0.33	0.51	0.41	0.40

	Cluster /Statement	Bridging
	2. New approaches	**0.37**
75.	To apply new insights to design new medical-technological products	0.31
71.	The ability to take the technological constraints into account	0.32
73.	To apply new results to design new medical-technological products	0.33
74.	To apply new methodologies to design new medical-technological products	0.33
37.	Extending course modules (say, structural engineering) to fresh and contemporary applications	0.38

31.	Development of user-oriented engineering design solutions	0.39
48.	Ability to engage in an engineering approach (for medical students)	0.39
34.	Make engineers aware of the technological needs of healthcare	0.41
36.	Addressing biological/biomedical problems in a quantitative fashion	0.47

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.05	0.00	0.31	0.47	0.37	0.38

	Cluster /Statement	Bridging
	3. Design process	**0.39**
38.	Learn a design based approach to developing healthcare technology	0.34
45.	To build a working prototype	0.36
18.	Skilful in applying methods for testing prototypes.	0.36
22.	Being able to conduct needs analysis.	0.37
67.	The ability to satisfy the design specifications	0.37
17.	Include different evaluation activities through the whole design cycle.	0.38
68.	The ability to apply design methodologies in real-life situations, resulting into a functional product (device, software, procedure)	0.40
8.	To learn to deconstruct authentic clinical problems	0.42
23.	Skilful in applying different methods for evaluating the ideas generated.	0.43
15.	Can address usability issues.	0.43
16.	Being able to conduct task analysis.	0.46

Count	Std. Dev.	Variance	Min	Max	Average	Median
11	0.04	0.00	0.34	0.46	0.39	0.38

	Cluster /Statement	Bridging
	4. Regulation and ethics	**0.71**

4.	A clear understanding of the regulatory landscape for medical technologies in the European Union	0.53
29.	Increased awareness of clinical constraints during design of biomedical devices	0.54
30.	Increased awareness of commercialisation strategies as they related to design of biomedical devices	0.56
3.	An understanding of the importance of relating potential benefits to patient health to potential risks.	0.93
13.	Follow ethics rules in the design process.	1.00

Count	Std. Dev.	Variance	Min	Max	Average	Median
5	0.21	0.04	0.53	1.00	0.71	0.56

	Cluster /Statement	Bridging
	5. Commercialization	**0.70**
50.	Ability to present outcomes in a commercially compelling way	0.54
51.	Ability to write a business plan	0.54
49.	Ability to recognise commercial opportunities	0.54
47.	Describe the components of a business plan	0.54
46.	Understand intellectual property	0.89
41.	Increase the awareness in medical students that technology is the future of the health system	0.93
35.	Bridge the gap between healthcare and engineering	0.93

Count	Std. Dev.	Variance	Min	Max	Average	Median
7	0.18	0.03	0.54	0.93	0.70	0.54

	Cluster /Statement	Bridging
	6. Knowledge integration	**0.39**
83.	Be able to integrate knowledge from the technological-scientific field	0.29
82.	Be able to integrate knowledge from the medical-scientific field	0.32

85.	Ability to participate in an active way to discussions with technical specialists	0.36
5.	To promote student integration of knowledge across disciplines and thereby create rich and complex knowledge structures	0.40
32.	Encourage interdisciplinary learning in engineering and medical undergraduates	0.44
84.	Ability to participate in an active way to discussions with medical specialists	0.51

Count	Std. Dev.	Variance	Min	Max	Average	Median
6	0.07	0.01	0.29	0.51	0.39	0.38

	Cluster /Statement	Bridging
	7. Communication	**0.57**
10.	To learn to communicate understandings of your own discipline to those from other disciplines	0.49
9.	To learn to negotiate common ground and understandings with team members from different disciplines	0.51
27.	Learn to work in a team with individuals from other disciplines	0.55
7.	To value the unique contributions of different disciplines	0.61
20.	Being tolerant to differences in working groups.	0.68

Count	Std. Dev.	Variance	Min	Max	Average	Median
5	0.07	0.01	0.49	0.68	0.57	0.55

	Cluster /Statement	Bridging
	8. Collaboration	**0.40**
57.	To develop the ability to make connections among disparate concepts, fields, or contexts	0.25
43.	Create a network from which students would benefit in their future carrier	0.37
42.	Raise interest for collaborative research	0.39
26.	Understand differences in the way people solve problems.	0.43

25.	Understand that everybody is creative but in different way.	0.43
11.	To learn to work effectively in teams	0.48
28.	Appreciate that teams are more than the sum of their parts (individual disciplines)	0.49

Count	Std. Dev.	Variance	Min	Max	Average	Median
7	0.07	0.01	0.25	0.49	0.40	0.43

	Cluster /Statement	Bridging
	9. Higher order skills	**0.03**
65.	To promote high level thinking processes (synthesis)	0.00
66.	To promote high level thinking processes (analysis)	0.00
64.	To promote high level thinking processes (problem solving)	0.00
63.	To promote high level thinking processes (experimentation)	0.00
62.	To promote high level thinking processes (creativity)	0.06
6.	To be open to different perspectives in solving problems	0.10

Count	Std. Dev.	Variance	Min	Max	Average	Median
6	0.04	0.00	0.00	0.10	0.03	0.00

	Cluster /Statement	Bridging
	10. Problem solving process	**0.18**
40.	Develop the hand on solving problem abilities in students	0.12
54.	Ability to systematically formulate a solution	0.13
19.	Being able to identify different creative problem solving styles.	0.15
78.	The ability to process independently new insights	0.17
76.	The ability to process independently new results	0.19
53.	Ability to deconstruct a real life problem	0.19
24.	Skilful in applying different methods for idea generation.	0.24

21.	Being able to analyse the problem situation.	0.24
77.	The ability to process independently new methodologies	0.24

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.04	0.00	0.12	0.24	0.19	0.19

	Cluster /Statement	Bridging
	11. Connecting domains	**0.20**
56.	To develop the ability to recognize connections among disparate concepts, fields, or contexts	0.10
55.	To develop the ability to evaluate connections among disparate concepts, fields, or contexts	0.10
52.	Ability to report in an academic fashion	0.29
12.	Introducing clinical/medical students to problem solving strategies employed in other domains which may lead to more creative clinical problem solving	0.33

Count	Std. Dev.	Variance	Min	Max	Average	Median
4	0.11	0.01	0.10	0.33	0.20	0.19

	Cluster /Statement	Bridging
	12. Learning goals	**0.10**
79.	To broaden the students' problem solving power	0.05
80.	To broaden the students' synthetic thinking power	0.05
81.	To broaden the students' analytical thinking power	0.05
14.	Can critically reflect on his/her own way of creative problem solving thinking.	0.07
33.	To raise awareness in university educated students that problem solving/critical thinking is the PRIMARY goal of their chosen degree program.	0.09
60.	To develop student initiative	0.11

58.	To develop student intentional learning	0.11
59.	To develop student decision making	0.16
61.	To develop student responsibility	0.19

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.05	0.00	0.05	0.19	0.10	0.09

Appendix C: Rating figures on importance

	Cluster /Statement	Average Rating
	1. Attention to end user	**3.75**
70.	The ability to take the potential of the user of the end product into account (doctor, nurse, patient)	4.33
69.	The ability to take the limitations of the user of the end product into account (doctor, nurse, patient)	4.33
39.	Solve real-life problems using simple concepts make a bridge between two languages/vocabularies (medicine and engineering)	4.22
72.	The ability to take the medical constraints into account	4.11
86.	Ability to translate technical concepts to their medical partners (for engineers)	3.89
2.	An awareness of the importance of data and record integrity particularly when such data and records can be used to demonstrate efficacy from a medical perspective	3.33
44.	Raise the interest for using latest technology in medical students	3.00
1.	Understand how to provide documentary evidence (electronic or paper records) that innovative medical technologies will consistently produce results meeting predetermined design specifications	2.78

Count	Std. Dev.	Variance	Min	Max	Average	Median
8	0.58	0.34	2.78	4.33	3.75	4.00

	Cluster /Statement	Average Rating
	2. New approaches	**3.57**
31.	Development of user-oriented engineering design solutions	4.33
71.	The ability to take the technological constraints into account	3.89
48.	Ability to engage in an engineering approach (for medical students)	3.78
75.	To apply new insights to design new medical-technological products	3.78
74.	To apply new methodologies to design new medical-technological products	3.56
73.	To apply new results to design new medical-technological products	3.44

34.	Make engineers aware of the technological needs of healthcare	3.33
36.	Addressing biological/biomedical problems in a quantitative fashion	3.22
37.	Extending course modules (say, structural engineering) to fresh and contemporary applications	2.78

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.42	0.18	2.78	4.33	3.57	3.56

	Cluster /Statement	Average Rating
	3. Design process	**3.66**
68.	The ability to apply design methodologies in real-life situations, resulting into a functional product (device, software, procedure)	4.38
8.	To learn to deconstruct authentic clinical problems	4.22
38.	Learn a design based approach to developing healthcare technology	4.11
23.	Skilful in applying different methods for evaluating the ideas generated.	3.89
15.	Can address usability issues.	3.89
22.	Being able to conduct needs analysis.	3.78
18.	Skilful in applying methods for testing prototypes.	3.44
45.	To build a working prototype	3.33
67.	The ability to satisfy the design specifications	3.22
16.	Being able to conduct task analysis.	3.22
17.	Include different evaluation activities through the whole design cycle.	2.89

Count	Std. Dev.	Variance	Min	Max	Average	Median
11	0.46	0.21	2.89	4.38	3.67	3.78

	Cluster /Statement	Average Rating
	4. Regulation and ethics	**3.61**

3.	An understanding of the importance of relating potential benefits to patient health to potential risks.	4.22
29.	Increased awareness of clinical constraints during design of biomedical devices	4.11
13.	Follow ethics rules in the design process.	3.44
30.	Increased awareness of commercialisation strategies as they related to design of biomedical devices	3.22
4.	A clear understanding of the regulatory landscape for medical technologies in the European Union	3.00

Count	Std. Dev.	Variance	Min	Max	Average	Median
5	0.48	0.24	3.00	4.22	3.60	3.44

	Cluster /Statement	Average Rating
	5. Commercialization	**3.05**
35.	Bridge the gap between healthcare and engineering	3.89
50.	Ability to present outcomes in a commercially compelling way	3.38
41.	Increase the awareness in medical students that technology is the future of the health system	3.11
47.	Describe the components of a business plan	2.78
49.	Ability to recognise commercial opportunities	2.78
51.	Ability to write a business plan	2.78
46.	Understand intellectual property	2.67

Count	Std. Dev.	Variance	Min	Max	Average	Median
7	0.41	0.17	2.67	3.89	3.05	2.78

	Cluster /Statement	Average Rating
	6. Knowledge integration	**3.78**
32.	Encourage interdisciplinary learning in engineering and medical undergraduates	4.33

82.	Be able to integrate knowledge from the medical-scientific field	4.00
83.	Be able to integrate knowledge from the technological-scientific field	3.78
85.	Ability to participate in an active way to discussions with technical specialists	3.56
5.	To promote student integration of knowledge across disciplines and thereby create rich and complex knowledge structures	3.56
84.	Ability to participate in an active way to discussions with medical specialists	3.44

Count	Std. Dev.	Variance	Min	Max	Average	Median
6	0.31	0.09	3.44	4.33	3.78	3.67

	Cluster /Statement	Average Rating
	7. Communication	**4.07**
27.	Learn to work in a team with individuals from other disciplines	4.44
10.	To learn to communicate understandings of your own discipline to those from other disciplines	4.33
9.	To learn to negotiate common ground and understandings with team members from different disciplines	4.22
20.	Being tolerant to differences in working groups.	3.78
7.	To value the unique contributions of different disciplines	3.56

Count	Std. Dev.	Variance	Min	Max	Average	Median
5	0.34	0.12	3.56	4.44	4.07	4.22

	Cluster /Statement	Average Rating
	8. Collaboration	**3.51**
11.	To learn to work effectively in teams	4.33
57.	To develop the ability to make connections among disparate concepts, fields, or contexts	3.89

28.	Appreciate that teams are more than the sum of their parts (individual disciplines)	3.67
42.	Raise interest for collaborative research	3.44
25.	Understand that everybody is creative but in different way.	3.22
26.	Understand differences in the way people solve problems.	3.11
43.	Create a network from which students would benefit in their future carrier	2.89

Count	Std. Dev.	Variance	Min	Max	Average	Median
7	0.46	0.21	2.89	4.33	3.51	3.44

	Cluster /Statement	Average Rating
	9. Higher order skills	**4.39**
64.	To promote high level thinking processes (problem solving)	4.56
62.	To promote high level thinking processes (creativity)	4.44
63.	To promote high level thinking processes (experimentation)	4.44
66.	To promote high level thinking processes (analysis)	4.44
65.	To promote high level thinking processes (synthesis)	4.33
6.	To be open to different perspectives in solving problems	4.11

Count	Std. Dev.	Variance	Min	Max	Average	Median
6	0.14	0.02	4.11	4.56	4.39	4.44

	Cluster /Statement	Average Rating
	10. Problem solving process	**3.78**
21.	Being able to analyse the problem situation.	4.44
24.	Skilful in applying different methods for idea generation.	4.22
53.	Ability to deconstruct a real life problem	4.22
40.	Develop the hand on solving problem abilities in students	4.00

54.	Ability to systematically formulate a solution	4.00
78.	The ability to process independently new insights	3.44
19.	Being able to identify different creative problem solving styles.	3.33
76.	The ability to process independently new results	3.22
77.	The ability to process independently new methodologies	3.11

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.47	0.22	3.11	4.44	3.78	4.00

	Cluster /Statement	Average Rating
	11. Connecting domains	**3.56**
12.	Introducing clinical/medical students to problem solving strategies employed in other domains which may lead to more creative clinical problem solving	3.89
56.	To develop the ability to recognize connections among disparate concepts, fields, or contexts	3.67
55.	To develop the ability to evaluate connections among disparate concepts, fields, or contexts	3.56
52.	Ability to report in an academic fashion	3.11

Count	Std. Dev.	Variance	Min	Max	Average	Median
4	0.28	0.08	3.11	3.89	3.56	3.61

	Cluster /Statement	Average Rating
	12. Learning goals	**3.83**
14.	Can critically reflect on his/her own way of creative problem solving thinking.	4.38
81.	To broaden the students' analytical thinking power	4.22
33.	To raise awareness in university educated students that problem solving/critical thinking is the PRIMARY goal of their chosen degree program.	4.22

80.	To broaden the students' synthetic thinking power	4.22
79.	To broaden the students' problem solving power	4.00
61.	To develop student responsibility	3.56
59.	To develop student decision making	3.44
60.	To develop student initiative	3.33
58.	To develop student intentional learning	3.11

Count	**Std. Dev.**	**Variance**	**Min**	**Max**	**Average**	**Median**
9	0.44	0.20	3.11	4.38	3.83	4.00

Appendix D: Figures of rating on difficulty

	Cluster /Statement	Average Rating
	1. Attention to end user	**2.98**
70.	The ability to take the potential of the user of the end product into account (doctor, nurse, patient)	3.71
86.	Ability to translate technical concepts to their medical partners (for engineers)	3.57
69.	The ability to take the limitations of the user of the end product into account (doctor, nurse, patient)	3.57
39.	Solve real-life problems using simple concepts make a bridge between two languages/vocabularies (medicine and engineering)	3.29
72.	The ability to take the medical constraints into account	3.29
44.	Raise the interest for using latest technology in medical students	2.43
2.	An awareness of the importance of data and record integrity particularly when such data and records can be used to demonstrate efficacy from a medical perspective	2.14
1.	Understand how to provide documentary evidence (electronic or paper records) that innovative medical technologies will consistently produce results meeting predetermined design specifications	1.86

Count	Std. Dev.	Variance	Min	Max	Average	Median
8	0.68	0.46	1.86	3.71	2.98	3.29

	Cluster /Statement	Average Rating
	2. New approaches	**3.03**
48.	Ability to engage in an engineering approach (for medical students)	4.00
75.	To apply new insights to design new medical-technological products	3.57
74.	To apply new methodologies to design new medical-technological products	3.29
73.	To apply new results to design new medical-technological products	3.14
71.	The ability to take the technological constraints into account	3.00
36.	Addressing biological/biomedical problems in a quantitative fashion	2.71

37.	Extending course modules (say, structural engineering) to fresh and contemporary applications	2.71
31.	Development of user-oriented engineering design solutions	2.71
34.	Make engineers aware of the technological needs of healthcare	2.14

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.52	0.27	2.14	4.00	3.03	3.00

	Cluster /Statement	Average Rating
	3. Design process	**3.00**
18.	Skilful in applying methods for testing prototypes.	3.57
68.	The ability to apply design methodologies in real-life situations, resulting into a functional product (device, software, procedure)	3.29
67.	The ability to satisfy the design specifications	3.29
8.	To learn to deconstruct authentic clinical problems	3.14
23.	Skilful in applying different methods for evaluating the ideas generated.	3.00
45.	To build a working prototype	3.00
15.	Can address usability issues.	2.86
16.	Being able to conduct task analysis.	2.86
22.	Being able to conduct needs analysis.	2.71
17.	Include different evaluation activities through the whole design cycle.	2.71
38.	Learn a design based approach to developing healthcare technology	2.57

Count	Std. Dev.	Variance	Min	Max	Average	Median
11	0.29	0.08	2.57	3.57	3.00	3.00

	Cluster /Statement	Average Rating
	4. Regulation and ethics	**2.63**

3.	An understanding of the importance of relating potential benefits to patient health to potential risks.	3.00
30.	Increased awareness of commercialisation strategies as they related to design of biomedical devices	2.86
29.	Increased awareness of clinical constraints during design of biomedical devices	2.57
4.	A clear understanding of the regulatory landscape for medical technologies in the Europen Union	2.43
13.	Follow ethics rules in the design process.	2.29

Count	Std. Dev.	Variance	Min	Max	Average	Median
5	0.26	0.07	2.29	3.00	2.63	2.57

	Cluster /Statement	Average Rating
	5. Commercialization	**2.94**
35.	Bridge the gap between healthcare and engineering	3.86
50.	Ability to present outcomes in a commercially compelling way	3.43
49.	Ability to recognise commercial opportunities	3.14
51.	Ability to write a business plan	3.00
41.	Increase the awareness in medical students that technology is the future of the health system	2.57
46.	Understand intellectual property	2.43
47.	Describe the components of a business plan	2.14

Count	Std. Dev.	Variance	Min	Max	Average	Median
7	0.56	0.31	2.14	3.86	2.94	3.00

	Cluster /Statement	Average Rating
	6. Knowledge integration	**3.02**
82.	Be able to integrate knowledge from the medical-scientific field	3.29

85.	Ability to participate in an active way to discussions with technical specialists	3.14
83.	Be able to integrate knowledge from the technological-scientific field	3.14
84.	Ability to participate in an active way to discussions with medical specialists	3.14
5.	To promote student integration of knowledge across disciplines and thereby create rich and complex knowledge structures	2.86
32.	Encourage interdisciplinary learning in engineering and medical undergraduates	2.57

Count	Std. Dev.	Variance	Min	Max	Average	Median
6	0.24	0.06	2.57	3.29	3.02	3.14

	Cluster /Statement	Average Rating
	7. Communication	**3.34**
10.	To learn to communicate understandings of your own discipline to those from other disciplines	3.71
7.	To value the unique contributions of different disciplines	3.57
20.	Being tolerant to differences in working groups.	3.29
27.	Learn to work in a team with individuals from other disciplines	3.14
9.	To learn to negotiate common ground and understandings with team members from different disciplines	3.00

Count	Std. Dev.	Variance	Min	Max	Average	Median
5	0.26	0.07	3.00	3.71	3.34	3.29

	Cluster /Statement	Average Rating
	8. Collaboration	**3.14**
57.	To develop the ability to make connections among disparate concepts, fields, or contexts	4.29
26.	Understand differences in the way people solve problems.	3.14

11.	To learn to work effectively in teams	3.14
42.	Raise interest for collaborative research	3.14
25.	Understand that everybody is creative but in different way.	3.00
43.	Create a network from which students would benefit in their future carrier	2.71
28.	Appreciate that teams are more than the sum of their parts (individual disciplines)	2.57

Count	Std. Dev.	Variance	Min	Max	Average	Median
7	0.51	0.26	2.57	4.29	3.14	3.14

	Cluster /Statement	Average Rating
	9. Higher order skills	**3.48**
65.	To promote high level thinking processes (synthesis)	3.57
64.	To promote high level thinking processes (problem solving)	3.57
66.	To promote high level thinking processes (analysis)	3.57
62.	To promote high level thinking processes (creativity)	3.43
63.	To promote high level thinking processes (experimentation)	3.43
6.	To be open to different perspectives in solving problems	3.29

Count	Std. Dev.	Variance	Min	Max	Average	Median
6	0.11	0.01	3.29	3.57	3.48	3.50

	Cluster /Statement	Average Rating
	10. Problem solving process	**3.51**
77.	The ability to process independently new methodologies	3.71
76.	The ability to process independently new results	3.71
78.	The ability to process independently new insights	3.71
19.	Being able to identify different creative problem solving styles.	3.57

53.	Ability to deconstruct a real life problem	3.57
54.	Ability to systematically formulate a solution	3.43
24.	Skilful in applying different methods for idea generation.	3.43
40.	Develop the hand on solving problem abilities in students	3.29
21.	Being able to analyse the problem situation.	3.14

Count	Std. Dev.	Variance	Min	Max	Average	Median
9	0.19	0.04	3.14	3.71	3.51	3.57

	Cluster /Statement	Average Rating
	11. Connecting domains	**3.43**
55.	To develop the ability to evaluate connections among disparate concepts, fields, or contexts	4.00
56.	To develop the ability to recognize connections among disparate concepts, fields, or contexts	4.00
52.	Ability to report in an academic fashion	2.86
12.	Introducing clinical/medical students to problem solving strategies employed in other domains which may lead to more creative clinical problem solving	2.86

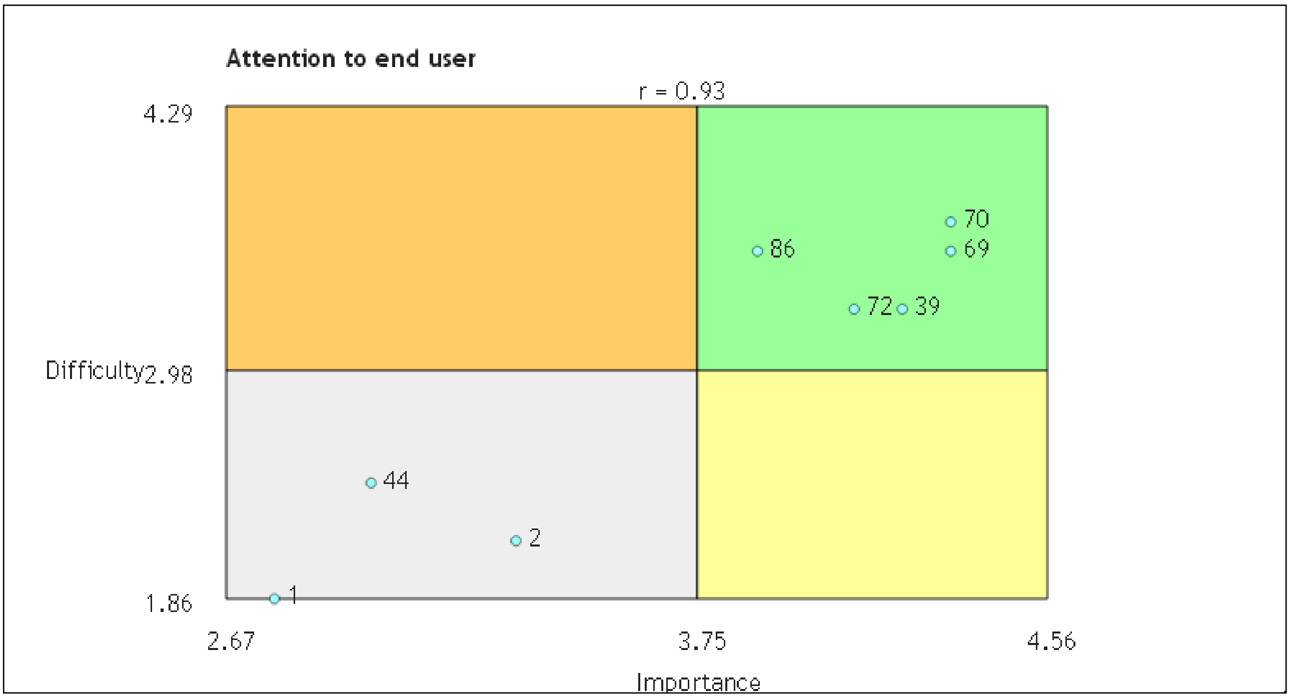
Count	Std. Dev.	Variance	Min	Max	Average	Median
4	0.57	0.33	2.86	4.00	3.43	3.43

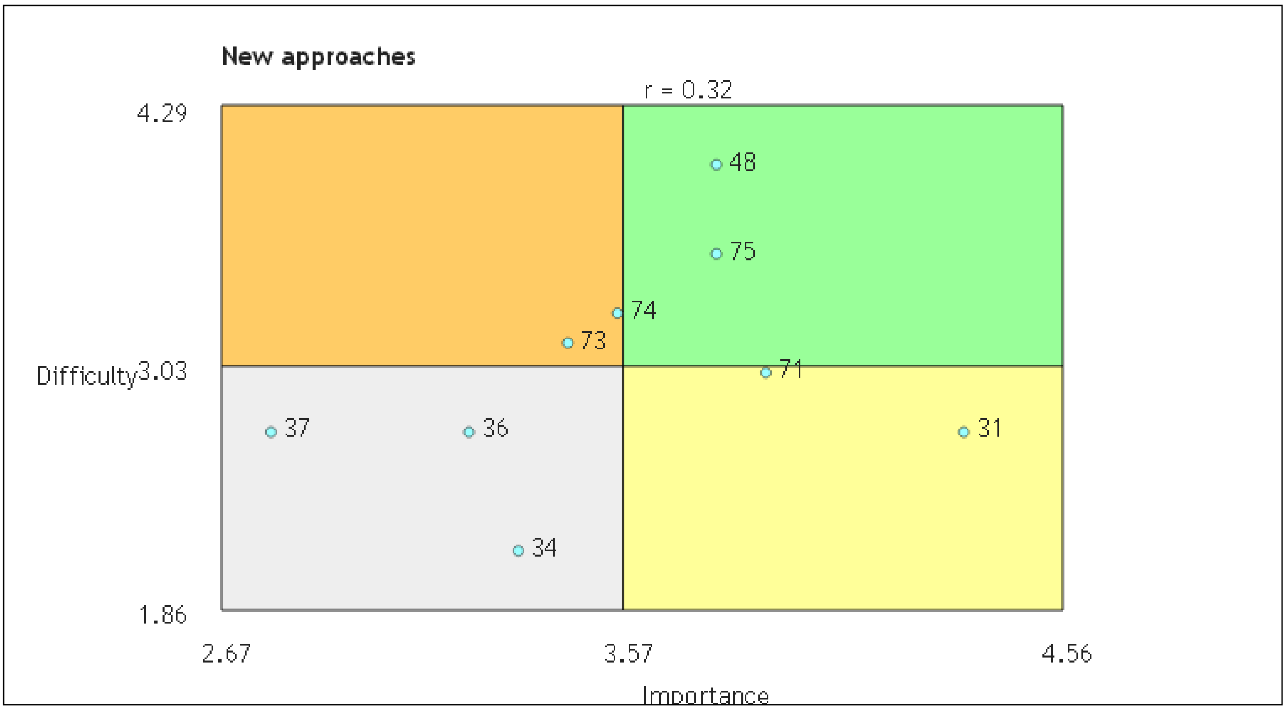
	Cluster /Statement	Average Rating
	12. Learning goals	**3.35**
14.	Can critically reflect on his/her own way of creative problem solving thinking.	3.71
59.	To develop student decision making	3.57
79.	To broaden the students' problem solving power	3.57
80.	To broaden the students' synthetic thinking power	3.43

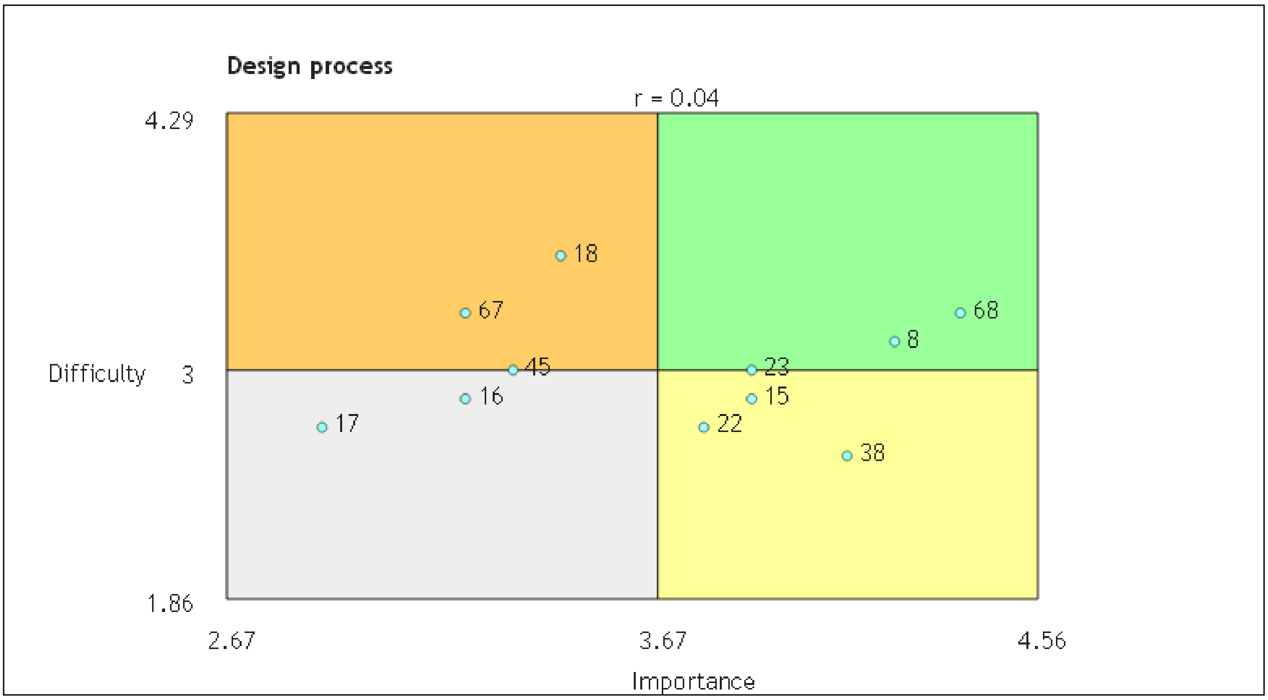
81.	To broaden the students' analytical thinking power	3.43
60.	To develop student initiative	3.29
61.	To develop student responsibility	3.29
58.	To develop student intentional learning	3.00
33.	To raise awareness in university educated students that problem solving/critical thinking is the PRIMARY goal of their chosen degree program.	2.86

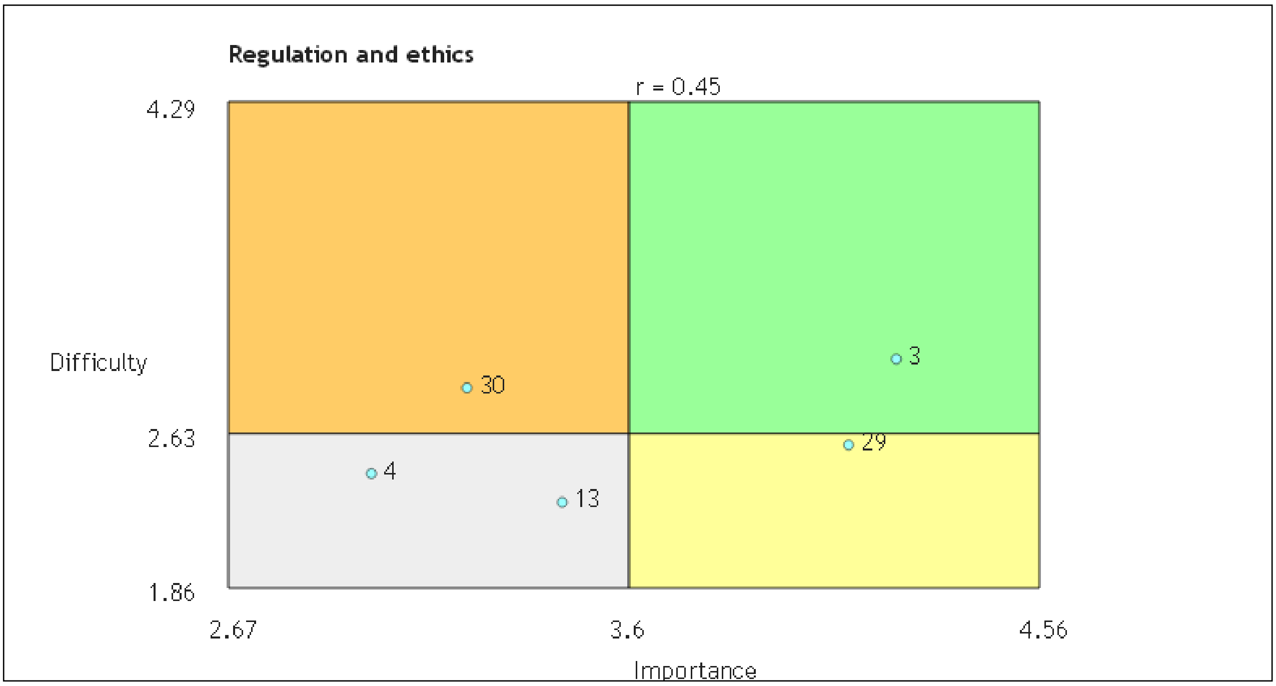
Count	**Std. Dev.**	**Variance**	**Min**	**Max**	**Average**	**Median**
9	0.26	0.07	2.86	3.71	3.35	3.43

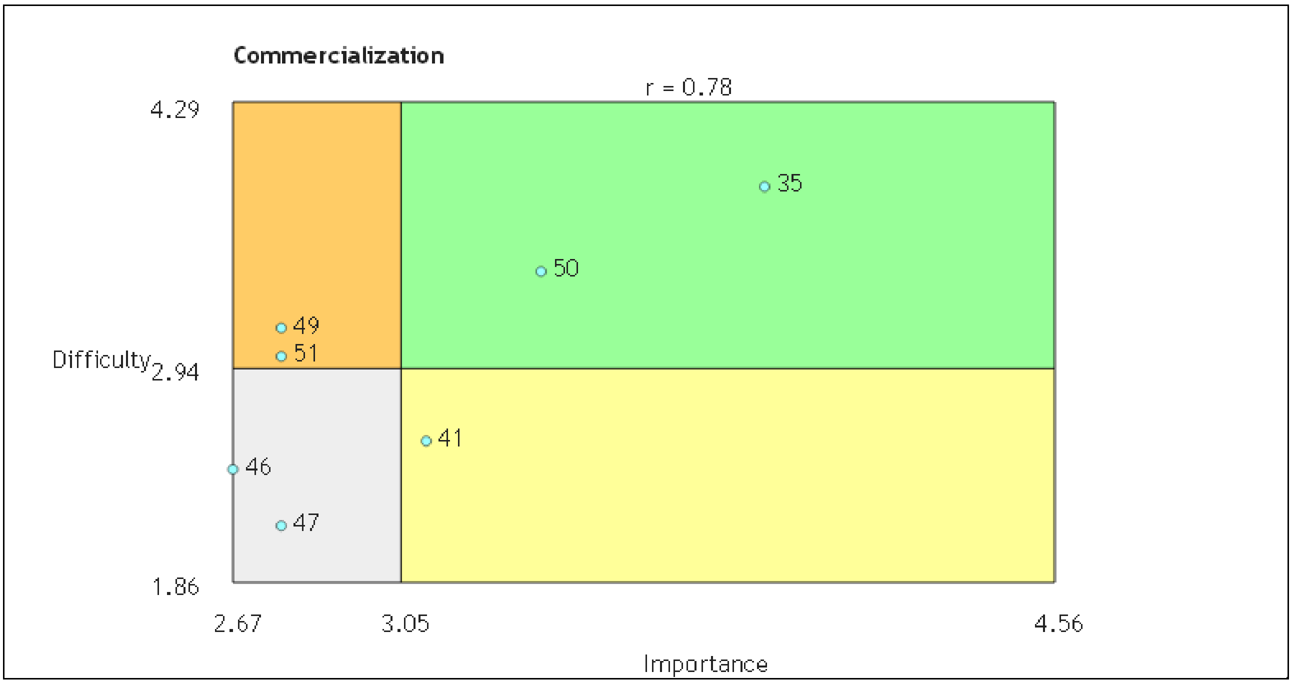
Appendix E: Go-zones

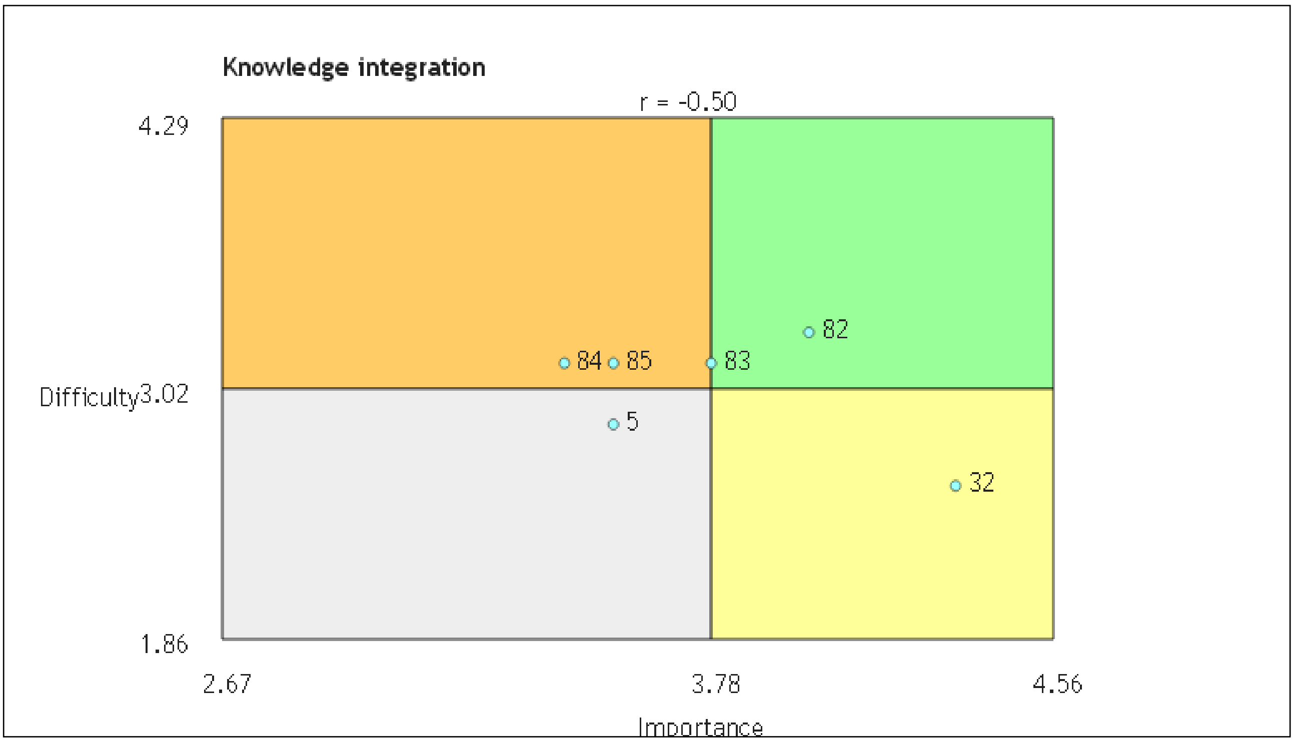


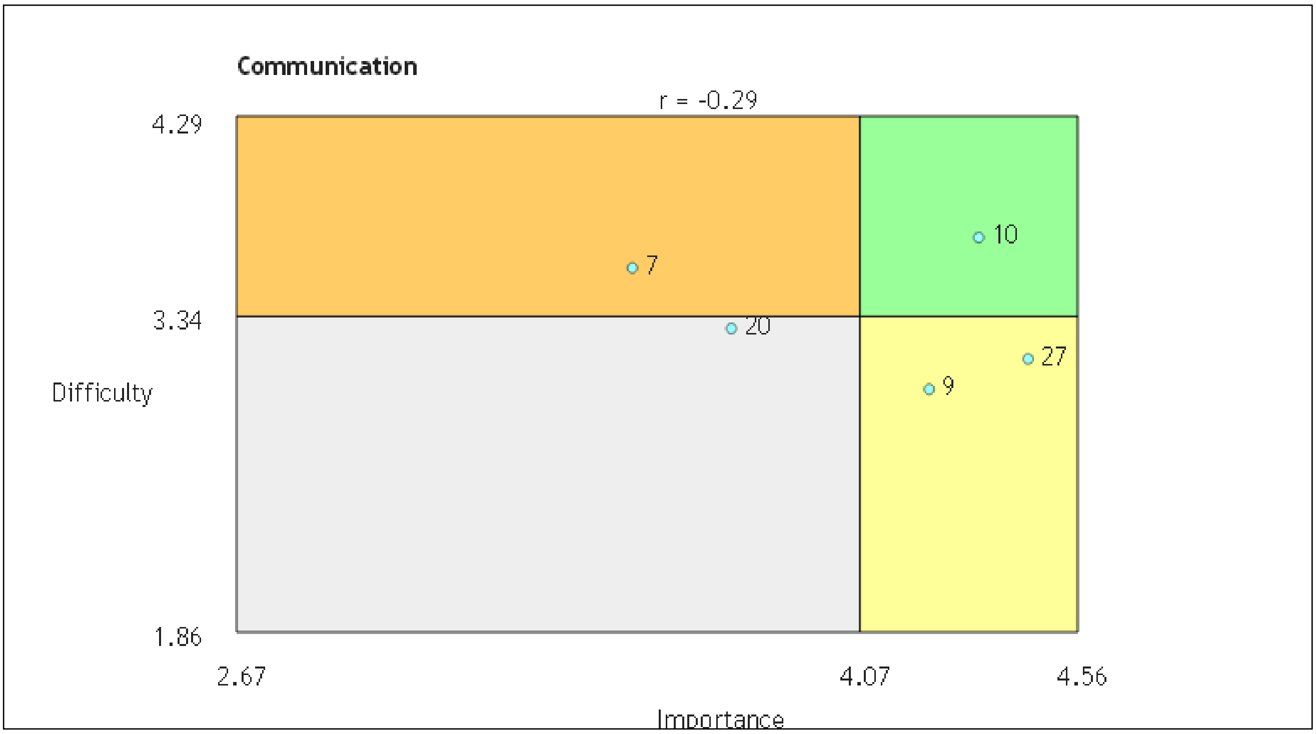


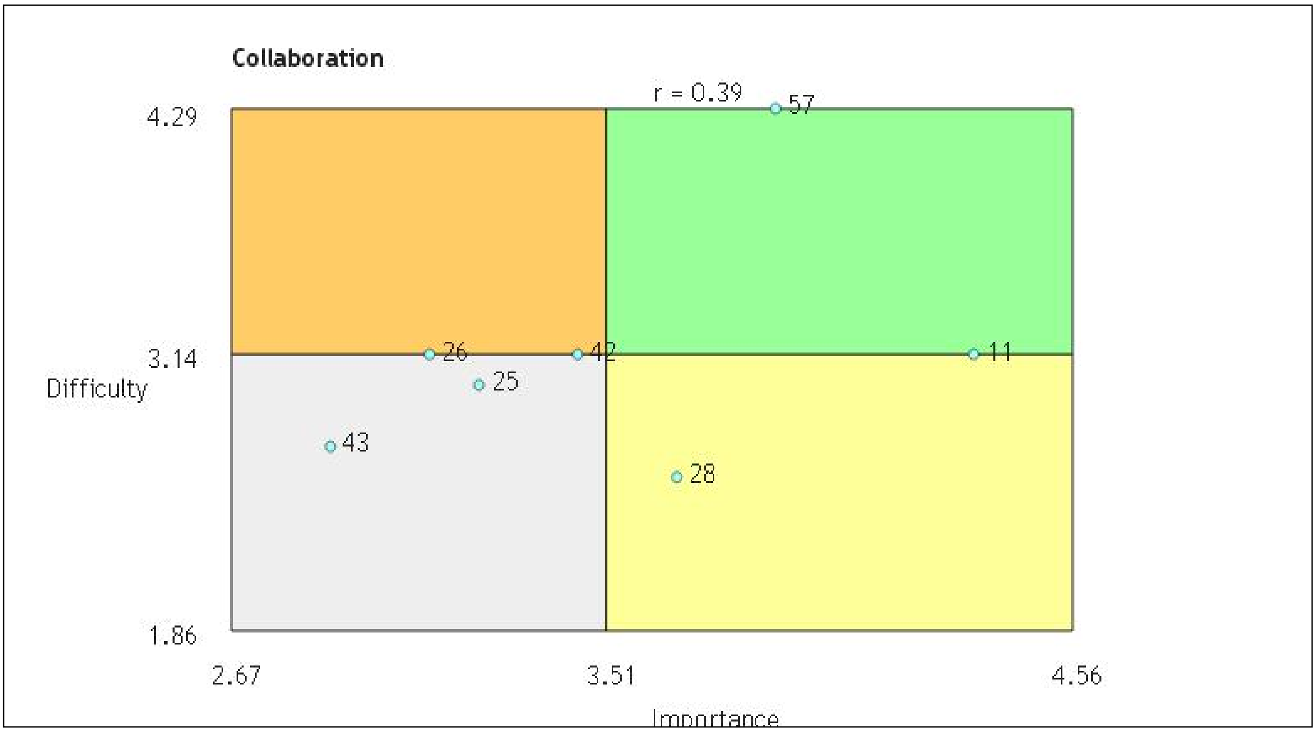

Design process
r = 0.04
4.29
Difficulty
3
1.86
2.67
3.67
4.56
Importance
18
67
68
8
45
23
16
15
17
22
38

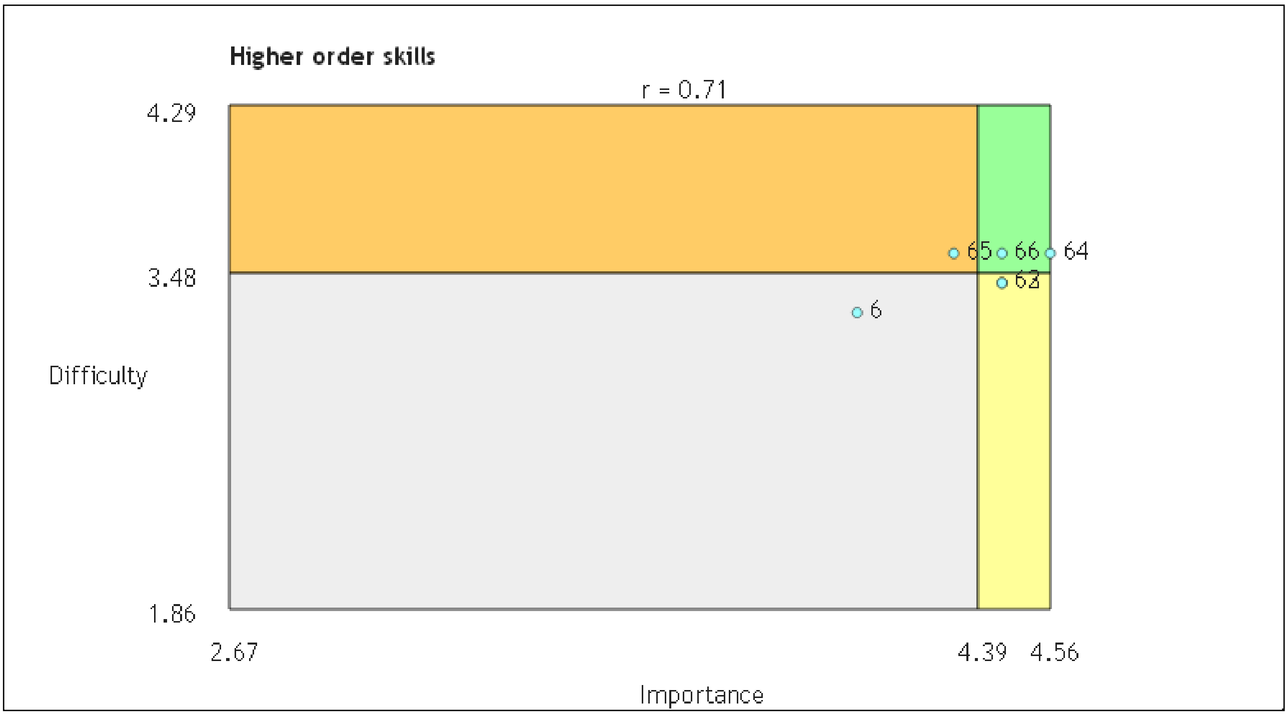

Regulation and ethics
r = 0.45
4.29
Difficulty
2.63
1.86
2.67
3.6
4.56
Importance
3
30
29
4
13

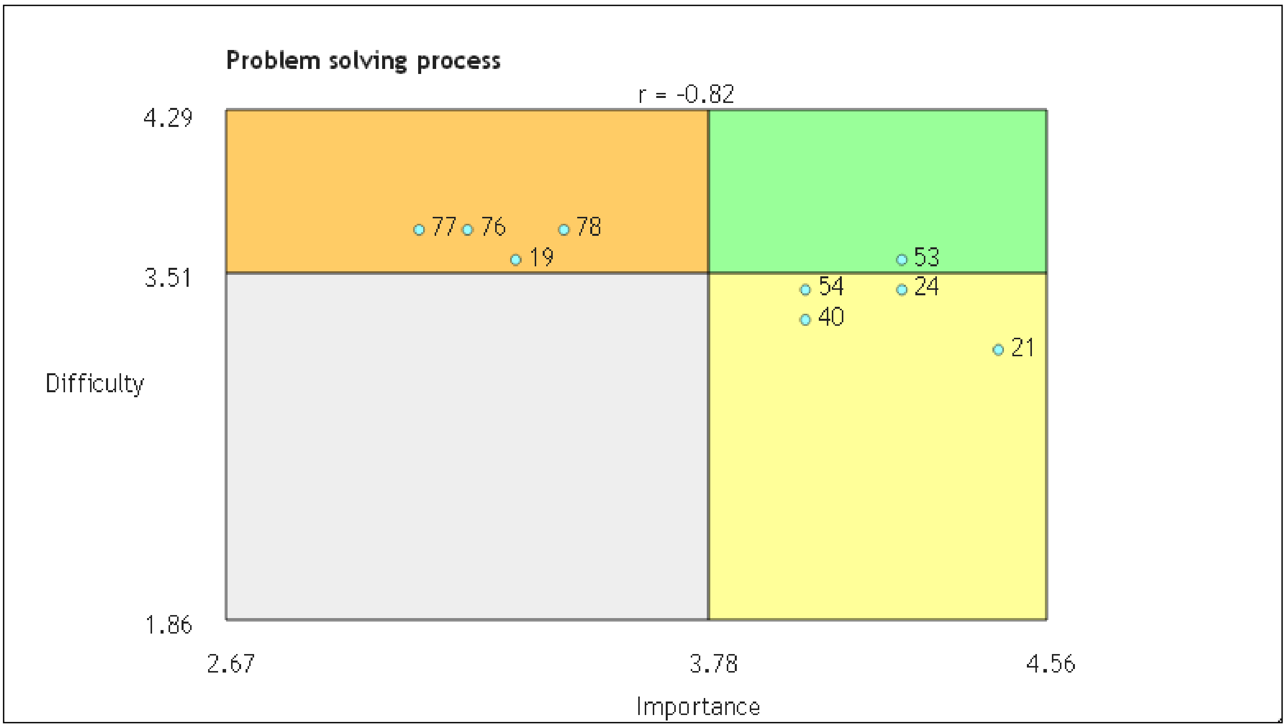

Commercialization
r = 0.78
4.29
35
50
49
51
Difficulty
2.94
41
46
47
1.86
2.67
3.05
4.56
Importance

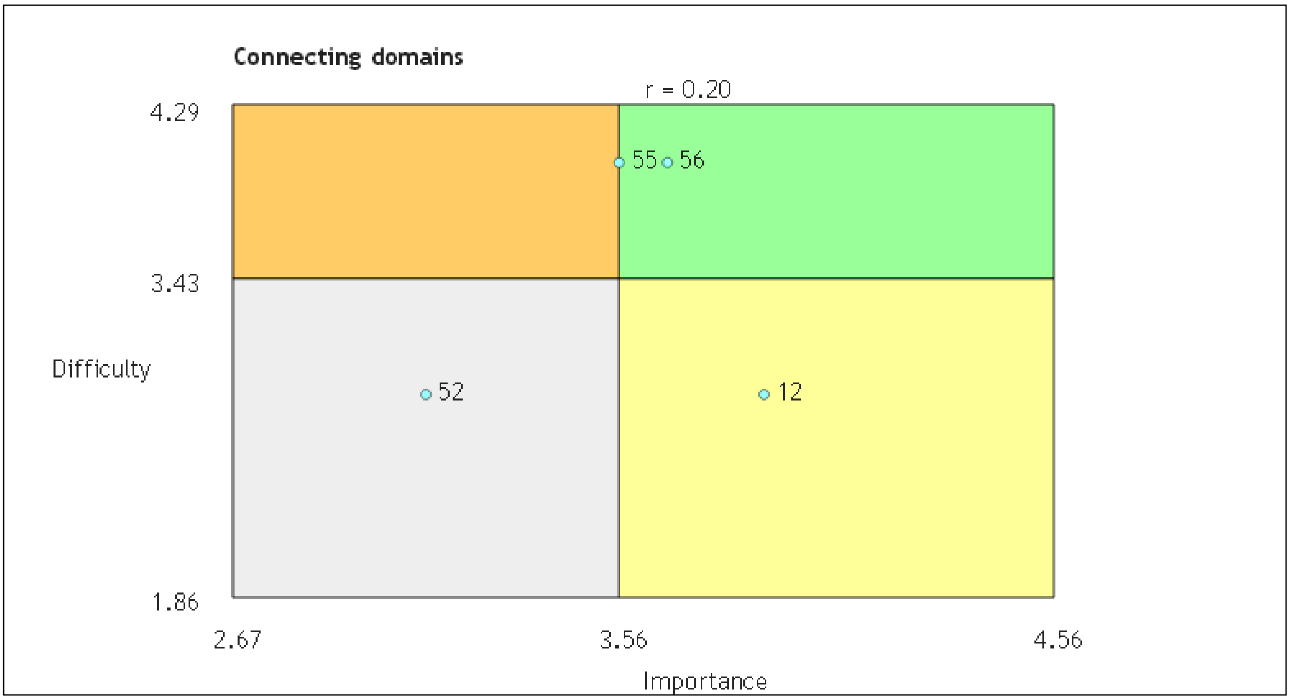

Knowledge integration
r = -0.50
4.29
82
84
85
83
Difficulty
3.02
5
32
1.86
2.67
3.78
4.56
Importance

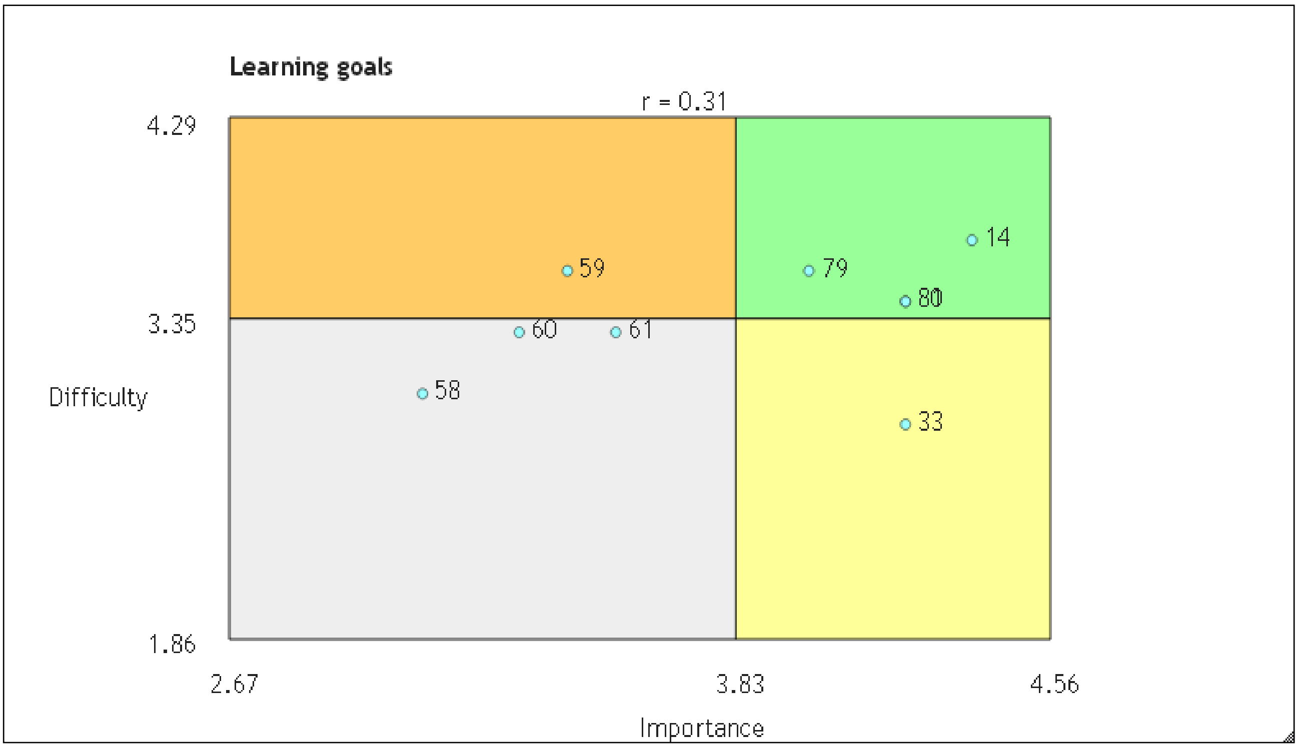

Communication
r = -0.29
4.29
3.34
1.86
Difficulty
7
10
20
27
9
2.67
4.07
4.56
Importance


Collaboration
r = 0.39
57
4.29
3.14
1.86
Difficulty
26
42
11
25
43
28
2.67
3.51
4.56
Importance


Higher order skills
r = 0.71
4.29
3.48
1.86
Difficulty
2.67
4.39
4.56
Importance
65
66
64
63
6


Problem solving process
r = -0.82
4.29
3.51
1.86
Difficulty
2.67
3.78
4.56
Importance
77
76
78
19
53
54
24
40
21


Connecting domains
r = 0.20
4.29
3.43
1.86
Difficulty
55
56
52
12
2.67
3.56
4.56
Importance


Learning goals
r = 0.31
4.29
3.35
1.86
Difficulty
14
59
79
80
60
61
58
33
2.67
3.83
4.56
Importance