Journal of Sustainable Development of Energy, Water and Environment Systems

http://www.sdewes.org/jsdewes

Year 2018, Volume 6, Issue 4, pp 742-754

Developing Energy Concept Maps – An Innovative Educational Tool for Energy Planning

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Cite as: Kovačič Lukman, R., Virtič, P., Developing Energy Concept Maps – An Innovative Educational Tool for Energy Planning, J. sustain. dev. energy water environ. syst., 6(4), pp 742-754, 2018,
DOI: https://doi.org/10.13044/j.sdewes.d6.0219

ABSTRACT

This paper represents a development process of the energy concept maps in higher education learning environment, in order to foster new and innovative learning experiences as well as improve the understanding of energy planning, especially from the interdisciplinary perspectives, including energy, environment, spatial planning. Energy concept maps were developed based on sustainable energy action plans to build a common knowledge base. The use of the energy concept maps developed were tested by 24 lecturers and 206 students from six European countries, comprising Slovenia, Croatia, Portugal, Italy, Spain and Malta. The learning processes were evaluated based on self-evaluation of competencies as well as external evaluation of students' knowledge and understanding of energy planning. The evaluation process revealed that participants included in learning activities gained new knowledge and competences in the energy planning and have a better understanding of a relationship between different concepts, subjects, developed a critical thinking, and proved their problem solving ability. Our study acknowledges the efficiency of the learning process in energy planning education by using concept maps.

KEYWORDS

Energy concept map, Sustainable energy planning, Active information-communication technologies learning.

INTRODUCTION

Teaching and learning of energy related sciences and their application in a real-world environment at the university level is demanding, since students need to be taught about the theory as well as its operational processes and usage. In order to motivate and challenge students for energy topics, an exciting and interesting learning environment should be created. One of the possibilities to educate students in an innovative way, improving their understanding and using new teaching methods is employment of Information-Communication Technologies (ICT). The development of ICTs has added a new dimension to the learning process [1], representing a significant learning option, reshaping and restructuring the learning environment, demanding new skills and

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fostering new competencies, such as effective problem solving, information processing, the ability to use various ICT tools, negotiation and communication skills and interdisciplinary environments [2]. One of the possibilities to use innovative teaching methods and tools is to employ concept maps. According to Cañas *et al.* [3], concept maps as a tool can develop and exercise higher-order thinking skills, including critical thinking, reflective thinking, synthesis and analysis, which are all of utmost importance for future energy planners. Following the existing literature, concept maps have been used for teaching purposes at various levels and fields, from the kindergartens to higher education [4], and from chemistry, physics, earth science, to biology, ecology, astronomy, medicine, history, economics and languages [5].

The origin of the concept maps dates back to 1972. A research program at Cornell University that sought to study the ability of first and second grade children to acquire basic science concepts and the effect of this learning on later schooling led to the need for a new tool to describe explicit changes in children's conceptual understanding. Thus, in 1972 a concept mapping was invented to meet this need. Underlying the research program and the development of the concept mapping tool was an explicit cognitive psychology of learning and an explicit constructivist epistemology [6].

A concept map is a graphical tool that refers to a knowledge representation form that shows various concepts at nodes, with linking words that connect to concepts and show the relationship between them [7]. Novak and Gowing [4], and Zwaal and Otting [8] argue that concept mapping supports problem-solving processes and fosters conceptual thinking and understanding. Zwaal and Otting [8] further claim that the activation of prior knowledge is an essential part for efficient and effective learning, especially of the complex systems, where students are able to integrate the existing knowledge with the new one. Thus, concept maps provide a unique view on how students organize, connect, and synthesize information [9]. Vanides *et al.* [9] also introduce the benefits of the concept maps, and opportunities for the student to:

- Think about the connections between the existing knowledge and terms being learned;
- Organize their thought and visualize the relationships between the key concepts in a systematic way;
- Reflect their understanding, so they can think deeply and learn more efficiently.

For the lecturers, the concept maps are valuable, because they provide information about the students' understanding, since highly sophisticated maps show highly integrated knowledge structures, which facilitates cognitive activities, such as problem solving [9], and reflects the students' knowledge [10]. Similar results regarding the concept maps were obtained by van Boxtel *et al.* [11], representing positive impacts of the concept maps, using collaborative learning, where concept mapping raises the learner's awareness regarding the learning topics or contents understanding as well as provoking a discourse. Also Chiou [12] tested the concept maps in the field of business and economics statistics, and recognized that concept maps significantly improved the learning achievements of the students. Veiga Marriott and Lupion Torrres [13] perceived the concept maps as facilitators of language learning, especially the visual aspects of the concept maps. Van der Bogaart *et al.* [14] tested the concept maps in the vocational education environment, reporting about positive aspects of the concept maps in terms of fostering learning and discussions.

Concept maps were also employed within the sustainability oriented courses, requiring a systemic knowledge and understanding of various high complexity fields, such as interlinkage between the environment, society and economy. Lourdel *et al.* [15], introducing a method of analysis of a student's sustainability's comprehension, based on cognitive maps, where the authors argued that cognitive map is a useful tool to improve the learning in qualitative terms, and allowing analyses of knowledge interlinkage by the

students. Another study was carried out by Segalàs *et al.* [16], measuring a learning process by the engineering students focusing on sustainable development, where the concept map has been used as a tool to measure the knowledge acquired and confirms a suitability of concept maps by learning the complex topics. In another study, employing the concept maps, Segalàs *et al.* [17] evaluated the complexity of the sustainability concept by the experts and students, where a comparison showed a mismatch among their understanding of sustainability, suggesting that sustainability courses should, besides environmental and technological aspects, emphasize social ones.

Based on the existing literature review in the Web of Science database, concept maps have not been used in the field of energy education. This paper introduces an application of concept mapping technique in energy education at the university level, focusing on energy planning topic. As energy planning is very interdisciplinary, comprehending several fields from spatial planning to energy management, the focus has been given on acquiring interdisciplinary skills as well as systemic and comprehensive knowledge. The concept maps have been designed, developed, and tested by 24 lecturers and 206 students in six countries, comprising Slovenia, Croatia, Italy, Spain, Malta and Portugal. The results represented in this paper evaluate the development of concept maps and outcomes of their employment by the lecturers and students.

METHODS

In order to construct the energy concept maps within the energy planning topic, sustainable energy plans have been considered as case studies. The following methods were employed for the construction and evaluation of the energy concept maps:

- In-depth analyses of three sustainable energy action plans in each of the six countries, comprehending the main concepts to be integrated into energy concept maps;
- Design energy concept maps via classroom lectures and online learning, embracing an introduction of the concept maps to the students, training students, creating individual maps;
- Evaluation of concept maps and self-evaluation of competences and knowledge acquired for energy planning.

Analyses of sustainable energy action plans

The intention of the analyses and case studies was to elaborate of a systematic, theoretical and operational framework regarding the present condition of energy planning in partner countries (Malta, Italy, Slovenia, Spain, Portugal and Croatia), in order to highlight criticalities and themes of particular interest to be developed in the educational experience. Common elements and local peculiarities were highlighted, acting as a basis for dialogue and comparison, but also as a tool for information and education, essential for supporting further studies. Educational tools on energy planning were surveyed to build a common knowledge base that was used to define the general background and structure of the Energy concept maps. This included a collection of materials, databases, legal frameworks, scientific articles, national and regional regulations, sector programmes, etc. Case studies reports were prepared, including 3 case studies in the aforementioned six countries, which was in total 18. These case studies were used as a basis for the learning activities with the lecturers and students.

Designing energy concept maps

Concept maps are graphical tools for organizing and representing knowledge, specifying the relationships between concepts. Use of concept maps is supported by semantic memory theory, which posits that students' knowledge networks are formed by

creating directed links between related concepts [18]. The concept maps have various characteristics:

- Hierarchical structure, where the most inclusive, general concepts are at the top of the maps and the more specific, less general concepts arranged hierarchically below;
- Relationships or links between concepts, where different segments or domains of the concept map are interlinked indicating a relation of concepts. In the creation of new knowledge, interlinkages often represent creative leaps on the part of the knowledge producer;
- Clarifications, where specific examples are given, helping to clarify the meaning of a given concept [19].

The recommended procedure for designing the concept map is to start with the focus questions, comprehending the understanding of the topics and which help to organize the knowledge in a cognitive structure [20]. For the design of the energy concept maps the online tool, developed by Cañas *et al.* [21] has been used (Textbox 1).

Textbox 1. A description of the software tool [22]

For educational purposes, CMap software, developed at the Florida Institute for Human and Machine Cognition (IHMC) was used. The learners were allowed to design the Energy concept maps on their personal computer, share them with other participants via CMap Servers anywhere on the Internet and edit the maps synchronously with other learners. The IHMC listed several features of the CMap Servers, including various fully integrated versions of the CMap, fully supporting the construction of Knowledge Models, supporting links to the resources, which are indexed and can be searched, synchronous real time collaboration, etc.

The CMap Tool enables students to collaborate with peers, e.g., share folders, synchronous real time collaboration and modifications of concept maps, annotations and discussions. This tool provides a fruitful environment for team learning and collaboration.

Evaluation of the concept maps

The evaluation of the concept maps produced by lecturers and students were evaluated on two levels:

- Individual evaluation of students (lecturers) with the online questionnaire;
- Lecturers' evaluation of the concept maps.

The individual self-evaluation of the concept maps consisted of a questionnaire, including 44 questions and covering three fields:

- Assessment of the training with the concept maps;
- Assessment of the CMap Tool;
- Development of general competences of the participants involved.

The responses, based on the 5-grade Liker scale could be given, from strongly disagree to strongly agree (see Appendix).

The lecturers' evaluation of the concept maps, design by the students, focus on the following factors, as suggested by Vanides *et al.* [9]:

- The complexity of the maps, where the structure of the concept maps was observed, where highly proficient students tend to create interconnected maps, while students without proficiency of knowledge of the topic tend to create simple, linear or circular maps, or tree with few branches;

- The existence of the important propositions, where it is expected that the students will understand and identify propositions and connections among them. When the student misses the connection, he or she might not understand the relationship among the key concept in the unit;
- Quality of the proposition or links on the concept maps indicates whether the student knows the connections among the concepts, evaluating it from the perspective of scientific correctness (e.g., wrong, partially correct/correct but scientifically thin, scientifically correct), providing a snapshot of the level of sophistication students have reached in their thinking.

RESULTS AND DISCUSSION

The results represent the outcomes of the state-of-the-art analysis of the sustainable action plans in six countries, and the designing of energy concept maps, followed by discussion.

Results of the state-of-the-art analyses

The regional/local/municipal/city energy plans were considered as the main instruments for designing energy concept maps. In order to build up the knowledge base for the energy concept maps, three case studies of sustainable energy action plans were selected in each participating country. Case studies provide the description of chosen energy plans: general introduction of case study, main goals, methodology of the plan, description of measures and activities to be implemented, definition of financial sources, legal framework and integration with spatial plans and other local/regional plans.

List of selected case studies:

- University of Maribor (Slovenia);
  - Sustainable Energy Action Plan of Krško;
  - Sustainable Energy Action Plan of Celje;
  - Sustainable Energy Action Plan of Velenje.
- Istrian Regional Energy Agency (IRENA) (Croatia);
  - Sustainable Energy Action Plan of Labin;
  - Sustainable Energy Action Plan of Pula;
  - Program of energy efficiency in final energy consumption of Region of Istria.
- Malta Intelligent Energy Management Agency (MIEMA) (Malta);
  - EcoGozo Plan;
  - Sustainable Energy Action Plan of L-Isla Local Council;
  - Sustainable Energy Action Plan of Pembroke.
- University of Algarve (Portugal);
  - Sustainable Energy Action Plan of Faro;
  - Sustainable Energy Action Plan of Lagoa;
  - Sustainable Energy Action Plan of Beja.
- University of Pablo de Olavide (Spain);
  - Sustainable Energy Action Plan of Seville;
  - Sustainable Energy Action Plan of Arahal;
  - The energy strategy of Andalusia.
- University of Roma Tre (Italy);
  - Plan for Energy and the Environment of the Province of Latina;
  - Sustainable Energy Action Plan of the Municipality of Latina;
  - Action plan for the development of renewable energies and the protection of landscape (area of Tusciaromana).

An analysis of the case studies chosen reveals several common outcomes:

- The emissions targets set in the Sustainable Energy Action Plans (SEAPs) will be achieved in a combination of technological improvements and "soft" measures (e.g. awareness raising), where technological improvements represent substantially higher share in all the measures introduced;
- A consideration of social aspects should be better integrated, especially planning in a line of the economic situation of the particular local community;
- An educated energy manager should be a prerequisite and a good solution in terms of SEAP implementation, follow-up, including better formal and informal integration of energy planning education;
- Integrated approaches within SEAPs are missing, e.g., holistic approach, inter-disciplinary, reducing the impacts on the climate change is not an issue which could be considered individually, but requires a holistic and systemic approach.

Energy concept maps

The regional/local/municipal/city energy plans were considered as the main instruments for designing energy concept maps. In order to build up the knowledge base for the energy concept maps, three case studies of sustainable energy action plans were selected in each participating country. Case studies provide the description of chosen energy plans: general introduction of case study, main goals, methodology of the plan, description of measures and activities to be implemented, definition of financial sources, legal framework and integration with spatial plans and other local/regional plans.

One of the preliminary activities in designing energy concept maps was the realization of the Energy CMap_00, a basic concept map on sustainable energy planning. The Energy CMap_00 was based on the outcomes of the intensive course for teaching staff held at the University of Roma Tre in June 2016. At the workshop staff members from all the six partner countries participated in designing the concept maps, based on the 18 case studies of the SEAPs. A common and comprehensive Energy CMap_00 was prepared, harmonizing and displaying the information collected in the previous phases, and organizing it according to sectors and levels of complexity. The steps for the creation of the concept maps were:

- Listing of meaningful and relevant concepts ("parking lot");
- Creation of meaningful linking phrases connecting the concepts;
- Creation of nested nodes identifying "domains of knowledge" and/or helping to define a hierarchy in the map;
- Creation of cross links between different sectors or nested nodes of the map.

This Energy concept map shows a nested structure with different levels and sub-levels, having useful information on technical and non-technical issues, and connections guide the users in the field of integrated energy planning. This concept map was used for designing an open educational resource for energy planning. Staff members were working on the Energy CMap_00, developing domains of knowledge (e.g., energy planning tools/instruments, actions/measures, financing mechanisms, monitoring tools/methods, data types and collection methods, EU target and goals), according to their expertise and based on the results of the teaching and learning activities that was carried out at each partner university from October 2016 till May 2017.

After the intensive course the self-assessment questionnaire was designed and carried out in order to evaluate the following three fields:

- Assessment of the training course;
- Assessment of the CMap Tool;
- Development of general competences of the staff involved.

The following responses, based on the 5-grade Liker's scale were given, from strongly disagree to strongly agree:

- The results of the questionnaires were the following. Staff members;

- Strongly agreed that this training event was useful for understanding the learning, based on the concept map software, and how this tool contributes to diversifying and innovating the teaching approaches;
- Strongly agreed that the training event contributed to fostering collaboration and connections among known subjects;
- Agreed that the training event and learning about CMap positively contribute to the distance working and learning and that the concept map tool was useful for enhancing the interdisciplinary, and could deepen the knowledge about energy planning, Renewable Energy Sources (RES) development and spatial planning;
- Agreed that the training event was useful for deepening the knowledge of the case studies and that the training event was useful for them in terms of improving the understanding of how the tool is functioning, understanding on how to create knowledge domains, how to develop a knowledge path, deepen their cultural and technical knowledge.

The self-evaluation shows that the training participants were in general satisfied with the CMap Tool, since they have mostly agreed and strongly agreed with the statements, only few »neutral« responses can be perceived. To sum up, they were positive about the CMap Tool, especially when considering the stimulation of the learning process and making it more interesting, improving the interdisciplinary between various fields and structure the concepts. Furthermore, the respondents claimed that the CMap Tool was useful for knowledge sharing, to work and learn in distance, that it stimulates the creativity and that it is user friendly. Furthermore, the participants agreed that they will further use the CMap Tool by the learning and professional activities, and will suggest this tool to other colleagues.

Regarding the evaluation of competencies, again, most of the responses were positive, since the participants agreed or strongly agreed about almost all the statements. However, 53% of the respondents were »neutral« about learning of foreign language via CMap Tool and about the cultural issues (40% of responses). To sum up, the participants agreed that they have gained new competences or improved the existing ones and deepen their knowledge, because after the training event they are better understanding the relationship between different concepts, subjects, they have developed a critical thinking, approved their problem solving ability and a team work. Furthermore, the participants agreed that they are using more effectively generic information.

As mentioned, energy concept maps (Energy CMap_01 and the final versions of Energy CMap_02) have been developed by students as well (see Figure 1), within the existing study programmes at the University of Roma Tre (Italy), University of Maribor (Slovenia), University Pablo de Olavide (Spain) and University of Algarve (Portugal) from October 2016 till May 2017. Altogether 206 students were involved in the designing of energy concept maps.

Their outcomes have been assessed using the evaluation criteria for the concept mapping, such as meaningfulness of the concept maps, syntactic correctness, number of concepts, phrases, nested nodes and cross links, use of graphic tools, presence of the essential map elements, and readability of the map (see Table 1).

By using the criteria in Table 1, the average of the marks assigned to the students' groups was 3.70, where the marks were between 2.90 and 4.90.

Also, an individual self-evaluation was carried out by students. The results have shown that students mostly agreed or strongly agreed with the statements that concept mapping was an adequate tool to stimulate the learning process and interdisciplinary, facilitate the organization of the ideas, that concept maps are useful tool to share knowledge among their peers and that concept mapping stimulates the creativity. The outcomes are in a line with the research by Weidmann and Kritzinger [23], arguing

that concept maps increase the efficiency of information retrieval, increase efficient teaching, enhance collaborative learning, and increase students' understanding. Schwendimann [5] also claims that concept maps support knowledge integration process and of complex ideas, which also showed up during students' trainings. However, it is important to point out, that based on the results from the self-evaluation questionnaires, students were doubtful about the usage of the concept maps outside the "professional or study work", where students were not able to perceive the link. Concept maps also contributed to the better understanding of the courses contents and overall concept maps have been perceived as a positive learning experience, which was in a line with findings of Rao [24], where also students expressed a very positive attitude towards concept maps.

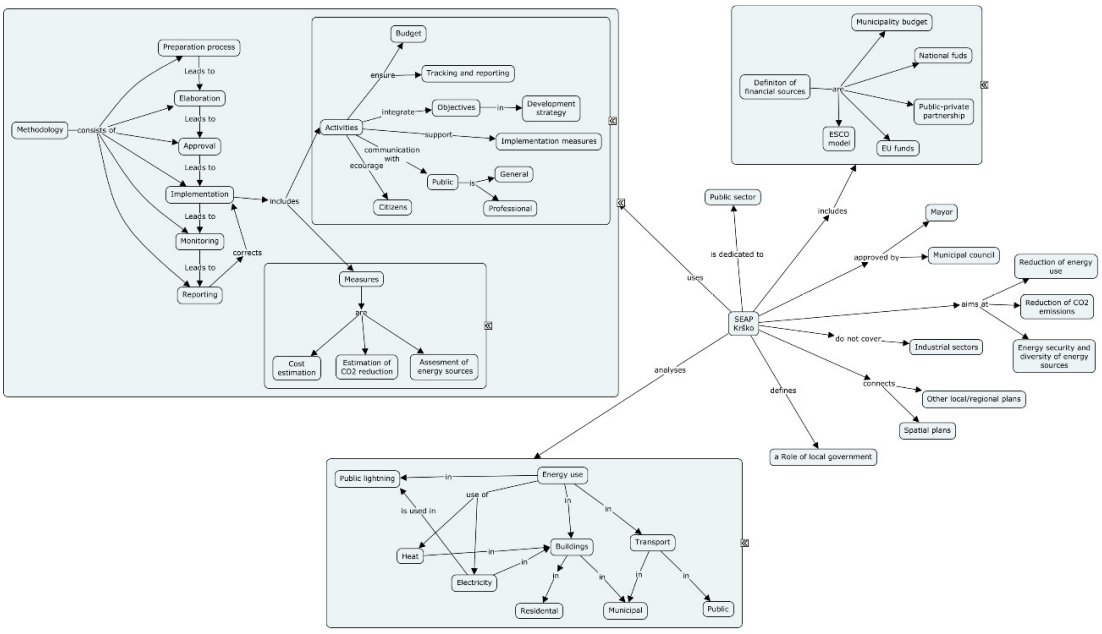

Figure 1. Energy CMap for SEAP for the municipality Krško, produced by the University of Maribor, Slovenia

Table 1. Criteria chosen for an evaluation of the energy concept maps

Criterion	Quality assessed by criterion	Min/max value
Meaningfulness of the extrapolated concepts and their connections with respect to the contents of the analysed document	General understanding of the given document, and capacity to describe it through its essential and most meaningful concepts and through suitable linking phrases	1 / 3
Correctness of syntax	Capacity of linking the chosen concepts in a meaningful and easily understandable way	1 / 3
Number of concepts	Capacity to analyse the given document deeply and to search for and understand the connections among its concepts	1 / 3
Number of phrases		1 / 3
Number of nested nodes	Capacity to understand/create a hierarchy within the concepts and to organise the personal knowledge	0 / 2
Number of cross links	Capacity to reach new knowledge by deeply analysing the given document and finding connections among its different parts	0 / 2
Use of graphical tools	Capacity to communicate the gained knowledge more effectively	0 / 1
Presence of all arrows	Correctness of use of the basic tools of a concept map	0 / 1
Presence of all connections	Correctness of approach to the use of a concept map	0 / 1
Readability of the map at all hierarchical levels	Capacity to clearly express the hierarchy of the gained knowledge through a correct use of the nested nodes (if present)	0 / 1
Total (to be divided by 4)		1 / 5

CONCLUSIONS

This paper provides outcomes of developing energy concept maps and using them in a higher education learning environment to foster innovative learning experiences for lecturers and students as well as improve the understanding of energy planning and acquire new interdisciplinary competencies. The evaluation of sustainable energy plans revealed that energy planning requires interdisciplinary approaches and collaboration of many professionals. However, the energy planning education at the involved universities is not available at the higher education level and it is rather integrated within the offered courses. Eighteen case studies analysed represented a knowledge base for designing the energy concept maps, which were designed in three steps. The first step was to design Energy CMap_00, followed by Energy CMap_01 and final Energy CMap. The educational activities addressed to the staff were useful and necessary preliminary step for:

- Transmitting the necessary information about the functioning of the tool and its multiple potentials;
- For implementing a specific educational program around a theme that will provide the contents for the elaboration of the concept maps themselves;
- Designing the energy concept maps.

The self-assessment questionnaire showed that training has a positive impact on the knowledge and skills of the staff members. The added value was related to the fact that the learning activities were carried out on the basis of a method that makes use of a tool (Energy-CMap) that is adaptable and implementable according to the most specific educational and research needs. Also, by the students' training and designing of the energy concept maps, their usage introduced a new ways of active learning if many positive effects, such as supporting knowledge integration and interdisciplinary, organization of ideas and better understating of concept as well as improving a communication among learners.

ACKNOWLEDGEMENT

The work presented in this paper has been partially financed by the ERASMUS+ Programme, project KA2-HE-17/15. The authors would like to thank two anonymous reviewers, and editors of the JSDEWES for their constructive and valuable comments, suggestions and directions in improving the earlier versions of this manuscript.

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Paper submitted: 03.02.2018
Paper revised: 09.05.2018
Paper accepted: 13.05.2018

APPENDIX

Questionnaire for self-evaluation of the concept maps.

Questions for the assessment of the training course

1. I consider this training event was useful for understanding the learning, based on the CMap software.
2. I consider this training event was useful for understanding how the CMap software can contribute for diversifying and innovating the teaching approaches.
3. I consider this training event was useful for understanding how the CMap software can contribute for fostering interactions and connections among known subject matters.
4. I consider this training event was useful for understanding how the CMap software can contribute to deal with operational aspects of specific thematic matters.
5. I consider this training event was useful for understanding how the CMap software can contribute to work and learn at distance.
6. I consider this training event was useful for understanding the potentialities of the CMap Tool for interdisciplinarity.
7. I consider this training event was useful for understanding the potentialities of the CMap Tool for collaborative work.
8. I consider this training event was useful for deepen the knowledge about the energy planning, RES development and spatial planning.
9. I consider this training event was useful for deepen the knowledge about the case studies provided.
10. I consider that the explanation of the CMap software helped me how to use this tool.
11. I consider that the exercise of manipulating CMap helped me to understand how to use this tool.
12. I consider that the exercise of manipulating CMap helped me to understand how to create knowledge domains.
13. I consider that the exercise of elaborating new CMaps, starting from the case studies helped to understand how to develop the knowledge path.
14. I consider that the comparison and discussion of the resulting CMaps helped me to deepen my cultural and technical knowledge.
15. I consider that my participation had contributed for the good achievement of this training event.
16. I consider that the contents of this training event were in accordance with my learning objectives.
17. I consider that the teaching materials and training resources available were sufficient and adequate to my learning objectives.
18. I consider that the duration of this training event was adequate.
19. I consider that the timing of this training event was adequate.
20. I consider that this training event was an appropriate way to test the CMap Tool.
21. I consider that this training event was an appropriate way to test the CMap Tool.

Questions for the assessment of the CMap Tool

1. Being an Open Educational Resource (OER), conceptual map is an adequate tool for stimulating the learning process.
2. CMap Tool promotes interdisciplinarity between different subjects.
3. CMap Tool facilitates the organization of ideas, namely the ability to hierarchize and relate concepts.
4. CMap Tool is useful to share knowledge.
5. CMap Tool is useful to work at distance.

6. CMap Tool can be adapted and transformed for continuous use, according to the users' needs.
7. CMap Tool can be continuously updated according to the user's interaction.
8. CMap Tool can be continuously enriched with more information and knowledge.
9. CMap Tool stimulate creativity.
10. CMap Tool can be oriented toward operational aspects and applied to specific geographic areas.
11. CMap Tool can be used as a facilitating tool, used to transfer from general characteristics to specific local needs.
12. CMap Tool is user friendly.
13. I will use CMap Tool again in my learning activities.
14. I will use CMap Tool again in my daily professional activities.
15. I will suggest the use of this tool to my colleagues.

Development of general competences

1. Now, i have a better understanding of the program contents of this training event.
2. Now, i have a better understanding of the relationship between the subjects and contents that were covered at this training event.
3. Now, i have a greater ability to solve problems related to the subjects of this training event.
4. Now, my critical thinking is more developed.
5. Now, i am more able to relate myself with others and work as a team.
6. Now, i use more effectively generic information technologies.
7. Now, i am more able to communicate in a foreign language (speaking and writing).
8. Now, i am more able to know and learn about different cultures and realities.