

Digital mind maps in teaching materials science at the university level

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Abstract. Mind maps increase attractiveness of classes and motivation of students to create their own associations and stimulate them to expand the knowledge acquired during the course. The aim of the work was to review information technology (IT) tools for building digital mind maps in terms of their use for teaching materials at the university level and to examine students' opinions on their use as a tool to support the acquisition of knowledge. The results of questionnaire surveys among university students from two different non-technical majors confirmed research hypotheses about the increase in student acceptance for introducing new educational techniques.

1 Introduction

Introduction of new majors of study, adapted to the changing requirements of the labour market, increases the curriculum requirements while limiting the time frame of classes. Especially the first year students encounter difficulties in adjusting to the organization of teaching at a university and in time management devoted to study. Problems with adapting to new requirements result in poor learning outcomes and, consequently, interruption of study in the first year of education [1].

Modern IT are an important factor expanding the range of knowledge transfer resources in education [2]. In addition, the diversity of teaching methods is aimed at encouraging students to learn independently. The motivation to learn, the students' interest in the issues discussed and the form of communication makes the learning process more effective [3, 4].

On the other hand, boredom and other negative emotions are associated with a decline in learning outcomes [5]. Results of the studies by Twyman and Heward [6] showed that students actively participating in classes acquire more information than those who are passive observers. An important feature of the learning tendency is involvement in the activation of basic educational behaviours, i.e. focusing attention and concentration. It is worth emphasizing that the more students want to learn something, the more their concentration increases [5].

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2 Theoretical framework

Taking notes is one of the phases of transferring and acquiring knowledge [7]. Successful taking notes requires a distinction between more or less relevant and irrelevant information [6]. It is worth emphasizing that university teachers expect students to deal with a large amount of information and learning skills [1]. Acquiring the ability to learn is related to knowing and choosing the right educational technique.

Mind maps (MMs) are an alternative to traditional linear notes. MM is a kind of diagram showing content (single words or phrases) with arrows or lines showing hierarchical connections between particular contents. The effectiveness of MMs in learning processes is based on assisting in gathering information, creating concepts by showing relationships between concepts and identifying gaps [8, 9]. MMs may help lecturers to determine in which areas the students are weak and need reinforcement [10]. In addition, the open and independent nature of studying motivates more [11]. The multi-sensory nature of MMs facilitates the conversion of information from periods of short to long memory [12]. The use of traditional learning techniques affects only the left hemisphere of the brain while MM stimulates both hemispheres, which speeds up and improves the learning process [11]. Preparing notes in the form of MM allows the students to add new information without disturbing the readability of notes, as is the case with traditional notes [7]. Rosciano [13] indicates that 93% of respondents think that creating MMs increases their creativity. Creativity is recognized as one of the key learning skills. An important feature of creative learning is to capture the possibility of engaging in intellectual enquiry [14]. MMs create such opportunities for example by identifying gaps. In some countries (France, Finland, Great Britain) MMs have been included in educational programs [9]. Jeffrey [14] emphasizes the significance of introducing educational programs which stimulate creative learning.

The MM technique can be used at all stages of education: from early school to university. The use of MM allows students to take notes, to complete linear notes with their own associations, to make presentations of lectures and summaries of a specific subject. Janowicz [7] emphasizes that MMs may be ineffective when taking notes in class, but are perfect for making summaries. Information saved in the form of MMs is limited to simple associations. The form of these notes may be too complicated, and this causes difficulties in interpretation [11].

There are two methods of creating MMs: DMMs (digital mind maps) and PMMs (paper mind maps). Research carried out by Jbeili [8] showed that students who used DMMs achieved better results than students using PMMs. It has been emphasized that PMMs are considered by some specialists to be of little use due to the time-consuming nature of creation. DMMs are more transparent and enable storage of more material than PMMs [8].

In teaching materials science, the classifications of materials together with descriptions of their properties, play an important role. To make full use of engineering knowledge, it is important to understand the relationship between the chemical composition, structure and technology for making products. There are presented and explained physical, chemical and mechanical phenomena occurring in the structure of engineering materials during their manufacture, shaping of products, changes in their properties and usage. MMs may help to understand how subjects are related to each other, thus effectively help to organize new knowledge [15].

Traditional linear notes could be varied by MMs. This would enable students to write their own associations related to the use or properties of the engineering materials in question. The introduction of a new method would activate students and lead to creative quotation, which would allow for deeper processing of the discussed issue. In addition, the introduction of IT tools to create MMs would be a novelty for most students.

The research described in the article was motivated by the desire to diversify and improve the methods of transferring knowledge in the field of materials science at a non-technical university. The need to introduce changes results from the fact that students report difficulties in understanding the analysed issues that relate to the classification, properties and use of selected engineering materials. The study analysed the potential of MMs as a note-taking tool that will help students to organize and thus acquire new and existing knowledge.

The aim of the work was to review the currently available IT tools for the construction of DMMs in terms of their use for teaching materials science at the university level and to examine students' opinions on using MMs technology as a tool supporting acquisition of knowledge.

3 Constructing mind maps

The principle of constructing PMM and DMM is similar. In the central part of the surface of the paper sheet (screen) the name of the main topic from which the branches are radiating, is placed. The further away from the centre, the concepts are more detailed. The branches are set automatically, only the iMindMap program allows creating them.

DMMs programs are offered in two groups: 1. freeware, free and open source, 2. proprietary. Analysis of individual program solutions of free access due to the availability of most of the necessary functions indicates the possibility of using them in education at the academic level. Available on the Internet selected IT tools for constructing DMMs along with the manufacturers' websites, are presented in Table 1.

Table 1. Selected DMMs and their Internet addresses.

Freeware, free and open source		Proprietary software	
Name of software	An Internet page	Name of software	An Internet page
bubbl.us	https://bubbl.us	iMindQ	https://www.imindq.com
CmapTools	https://cmap.ihmc.us	Mindmeister	https://www.mindmeister.com
Coggle	https://coggle.it	MindManager	https://www.mindjet.com
Freeplane	https://www.freeplane.org/wiki/index.php/Home	iMindMap	https://imindmap.com
InfoRapid KnowledgeMap	http://www.inforapid.de/html/knowledgemapeng.htm	MindMapper	http://www.mindmapper.com
MindMup	https://www.mindmup.com	Mindomo	https://www.mindomo.com/
Visual Understanding Environment	http://vue.tufts.edu	Solina Mind Mapping Software	http://www.solutionlanguage.com/

In the authors' opinion, the program particularly worth recommending to support the teaching of materials science is the InfoRapid KnowledgeMap. It is a complete knowledge management system that consists of two components: a program for creating DMM and a smart KnowledgeMap server, analysing the content of text documents and integrating them with DMM. There are two versions of the program: The Private Edition (free) and Professional Edition (proprietary). Using InfoRapid KnowledgeMap allows for creating

DMM very quickly and easily, which can be a form of summarizing a given portion of study material. The program allows for creating any number of relationships between the issues, it is also possible to insert descriptions that appear after hovering the mouse cursor over a given issue. This function allows for avoiding chaos and focusing on a given portion of study material. The screen displays only the information currently used so that the DMMs are clear and understandable.

Online software (Web-Based Software) can also be used to create DMM. The advantage of this solution is no need to install the software on the computer. By using the <https://bubbl.us> website via an internet browser, up to three DMMs can be created for free. The widespread use of DMM in teaching may be limited by the lack of access to computers for a group of students during the course. The Coggle program is a free web application that allows for creating a DMM with rich colours and varying them with photos, icons, links to websites (Figure 1). The advantage of Coggle is the ability to construct DMM using smartphones. Mobile technologies are easily available and diverse, but they are not sufficiently used in education. Availability of smartphones at affordable prices results in increased use of applications in many aspects of life, including education.

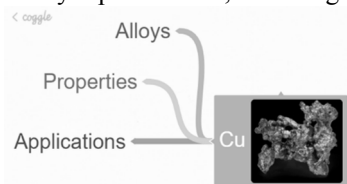


Fig. 1. An example MM concerning copper prepared with the use of coggle.it.

The usefulness of this application for teaching at the academic level was studied by Papushina et al. [4] among first-year students of the "Consumer Behaviour in Global Environment" major. After analysing the results of the questionnaires, the authors recommend using the program in education, remembering to conduct constant supervision at the technological and methodological level. They emphasize the following advantages of the application: no restrictions on the number of published charts, the ability to conduct "chats" and comments. However, before applying the application, they recommend studying students' motivation and "their switching costs".

Attempts to use mobile devices in education indicate many benefits, but these solutions are still not commonly used. The main limitations include the lack of effective mobile learning policy, the lack of qualified staff for the implementation of mobile methods and the cost of equipment. On the other hand, the use of mobile devices eliminates restrictions related to the place of study. Students can learn anywhere, anytime, and this translates into the optimal use of time.

The authors deliberately present exemplary DMMs that relate to the classification, properties and use of selected metals and alloys, because they see the potential to use DMMs when discussing these issues. Authors' own observations indicate that some students know some of the properties and applications of the discussed materials. Drafting notes in the form of DMMs would enable them to organize information and write their own associations clearly. In order to ensure that learning proceeds properly, DMMs should be developed on the basis of reliable sources. Our observations indicate that not all students have critical approach to information contained on the Internet. Instead of using sources recommended and checked by the teachers, they choose other, sometimes containing incorrect information. Application of the potential of mobile tools is a complex and multi-stage process. The authors' intention is to present a few selected MMs in the field of classification of materials during lectures. It will be the first stage of making students familiar with a new educational technique. Online DMM can be used in the laboratory to

brainstorm and generate discussions about the selection of materials for different products. This will encourage students not only to participate, but also to fully understand the subject and its nuances by creating links between ideas. DMMs that have been created online, can be easily printed and shared among students. The next stage should be to suggest the students to make summaries of a given material in the form of MMs. It is worth emphasizing that the introduction of MMs is aimed at supporting traditional activities, rather than completely replacing linear notes.

4 Materials and methods

In 2014 and 2018, questionnaire surveys were conducted in the group of the second year students (Table 2) of full-time studies majoring in Environmental Engineering (EE) and in the group of first-year part-time students majoring in Management and Production Engineering (MaPE). The research was carried out at the University of Life Sciences in Lublin.

Table 2. The number of respondents majoring in MaPE and EE in 2014 and 2018.

Major / year of survey	2014	2018
MaPE	28	7
EE	29	16

After informing the students about the purpose and subject of the study, they were asked to complete an anonymous questionnaire containing 20 questions: personal, concerning the access to and acceptance of information technology, the preferred learning styles and use of MM in education, subjective assessment of English language skills, computer skills, which aimed at checking students' motivation to learn materials science. In addition, the questionnaire contained questions checking the reliability of the answers to survey questions. In the case of non-compliance of the answers with the results of the checking questions, the questionnaires were eliminated from the test results. The test results were analysed using the Statistica 13.1 program (Dell).

5 Results and Discussion

The results of the research are presented in the form of percentages showing the size of positive responses to questions and variability of respondents' opinions after four years. An auxiliary statistical analysis was conducted only in the case of uncertainty in determining the relationship between the major of study and the answer given.

5.1 Students' opinion on the use of multimedia, Internet and IT tools during classes

Multimedia and the Internet have long been used in teaching, diversifying teaching techniques. Often, students asked about the sources of information they use in discussions with the teacher, indicate the Internet, less often the media, and the least often professional literature. Despite this, the survey showed that in 2014, only 10% of EE students believed that using multimedia tools and computer in laboratory classes increased their attractiveness, but four years later the percentage increased to 100%. In the survey conducted among students of MaPE in 2014, 75% of respondents shared the above view,

and in 2018 - 86%. Thus, in both majors of study, growth in the number of affirmative answers was observed, confirming the hypothesis that the use of multimedia and Internet tools during laboratory exercises increase their attractiveness.

By placing the below mentioned two questions in a questionnaire addressed to students of EE and MaPE majors, the authors wanted to confirm the tendency of the students' interest in computerization of classes. The survey indicated that 79% of respondents declared their willingness to participate in classes at which the acquisition of knowledge would be facilitated by IT tools. Otherwise, 15% of students had no opinion on this issue and 6% of respondents did not want to participate in this type of classes. In the next survey, the EE students did not change their opinion, and among MaPE students, there was a decrease in interest. EE students, despite the fact that they less appreciate the impact of using IT tools on the attractiveness of classes, are more likely to use them during learning.

The analysis confirms that the authors' aspirations to introduce new IT tools in the classroom are justified. In the opinion of the majority of students, the use of IT tools also affects the attractiveness of classes. Disturbing is the fact of a large group of passive students whose activation during classes can be difficult.

5.2 Declared students' interest in the subject of materials science

The results of the study indicate, regardless of the major of study, that the majority of respondents declared interest in using a computer program to select materials for a mobile phone casing (70% of MaPE students in 2014 and 86% in 2018, 75% of EE students in 2014 and 69% in 2018).

On the basis of the students' answers to this question, the authors wanted to obtain information whether the interest in issues related to materials science was different depending on the major of study. The following research hypotheses have been put forward:

H₀: The interest in material engineering does not depend on the major of study

H₁: The interest in material engineering depends on the major of study

The analysis of qualitative variables was carried out using χ^2 independence test. Using the χ^2 test, it was checked whether there is a relationship between the field of study and the answer given. The value of Pearson's χ^2 is 5.28, $p = 0.51$, so there is no reason to reject the null hypothesis. It means that there is no relationship between the field of study and demonstrating interest in the subject being taught. This is good news for the authors, because without interest of students in particular issues, it is impossible to achieve effective results regardless of the chosen teaching method. The fact that students show interest in issues related to materials science confirms that the actions of authors aimed at introducing changes in the way of teaching, are justified.

5.3 Does combining different forms of teaching increase their attractiveness?

Among the respondents, 44% considered the most attractive laboratory classes combining various forms of teaching, i.e. the presentation of educational films, performance of assigned tasks alone or in groups, mapping of microstructures of materials, which the teacher discusses. There were large differences in the responses of MaPE students. In 2014, 33% of all students preferred combining different forms of teaching, and in 2018 - 71%. The opinion of EE students has not changed. The authors try to combine different forms of teaching with the purpose not only to increase the attractiveness of classes. The use of educational films enables, among others, the presentation of methods of manufacturing. Available laboratory facilities do not allow the presentation of these processes in reality. The authors see the potential to use MMs also for taking notes during the presentation of

educational films. The content presented in the film is discussed by the teacher. Replacing linear notes by MMs would facilitate adding of additional information and students' own associations in a transparent way.

5.4 Respondents' earlier knowledge of the MM technique

Two questions were asked to check the respondents' knowledge of the MM technique:

- Have you ever heard about the MM idea?
- Have you ever used MM in previous education?

The concept of MM was known to 18% of MaPE students in 2014 and 43% of MaPE students in 2018. In 2014, 41% of EE students declared knowing the concept of MM, and 38% of them in 2018. There is a significant increase in the percentage of MaPE students familiar with the concept of MM and a slight decrease among the EE students. In 2014, 29% of EE students and 4% of MaPE students used MM, and 19% of EE students confirmed this in 2018. Despite the fact that 43% of MaPE students in 2018 declared that they had known the concept of MM, none of them decided to use this tool while studying. The authors intend to extend the conducted surveys and determine why students do not use new educational tools.

The results of the surveys show that there is a relationship between the major of study and the use of MMs in previous education by the respondents. The way MMs will be introduced in class is worth considering. For the vast majority of extramural students it will be a new form of taking notes, so it would be advisable to deliver a lecture at which not only the concept of MMs would be discussed, but mainly, the advantages of using them and the way of creating them. For students who previously knew the concept of MMs, it would be advisable to bring only a brief instruction on constructing MMs in the first place.

When introducing new teaching techniques, it is advisable to study students' opinions on the subject simultaneously. In the authors' opinion, new methods should reduce the time of learning, facilitate memorization and understanding of the subject, and consequently, produce better results in learning. In 2018, the questionnaire surveys were supplemented with the question: "Do you think that the use of MMs make learning easier?" and 67% of EE students gave positive answers while 33% of them did not notice any changes.

5.5 Opinion on the use of unknown so far educational techniques

In 2014, only 14% of EE students were willing to use previously unknown educational techniques, and in 2018 - 81%. In a survey conducted among students of MaPE in 2014, 75% of respondents shared the above view, and in 2018 - 86%. Most of the surveyed students (55%), however, are willing to use new educational techniques. It is worth emphasizing that among EE students in 2014, 69% of respondents did not have an opinion. An increase in the number of affirmative answers was observed in both majors.

Currently, students have wide access to information. When studying, they use information available on the Internet and easily process it in a word processor, which does not involve analysing it and memorize it better. When we analyse our research results, a conclusion can be drawn that some students remain passive recipients of the content presented in the classes. They have no opinion on many issues that relate to the way of presenting and acquiring new knowledge.

6 Conclusions

Teaching in a strictly defined program framework does not always allow teachers to choose an individual learning path based on knowledge previously acquired by the student. DMMs make possible to navigate the content of the subject according to strictly defined learning paths, the course of which is determined by the students. Taking into account the advantages of using DMMs and the simple way of creating them, it is worth using them in education in order to take notes, especially if the presented content is not very extensive. The research carried out shows that 67% of students have not been familiar with the MM concept previously. Therefore, an explicit determination by teachers of possibilities of DMM technology application for multimedia presentations, laboratory instructions and educational materials made available to students as part of e-learning, should be the condition for improving the effectiveness of materials science teaching. Students should use this technology at home to summarize individual topics and briefly present the content of papers, prepare for tests and exams. The use of DMM in the laboratory would require expensive reorganization of both the laboratory room equipment and computers for each student and changing the syllabus. A solution to this problem could be the use of on-line software for building DMM using their own commonly used smartphones, IPADs or Tablets PC and sharing results with colleagues or teachers. There are many solutions available but they are yet to reach the standard of desktop applications when it comes to. As far as creating and overviewing the map is concerned, the small screen size is a problem even for average sized maps. Typing fast and creating new branches to capture ideas in a brainstorming session requires practice.

Most students express their willingness to use new educational techniques. The main challenge is to verify whether students accept or reject new educational techniques. After determining that students accept the proposed form of taking notes, further research is needed to verify the hypothesis about the beneficial effect of using DMMs on exam results and on learning time.

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