Method Article

Online learning environments to stimulate in students the processes of mutual interaction between digital and analog artefacts to enhance student learning

Antonio Marzano*, Sergio Miranda

University of Salerno Italy

A B S T R A C T

In the recent years, numerous papers have discussed the use of concept maps in education. In this paper, we use the Dynamic Concept Maps (DCMs) in online learning environments as tools able to stimulate in students the processes of mutual interaction and hybridization between digital artefacts (DCMs) and analog artefacts (books) so as to encourage the development of significant learning. This method, called "DynaMap Remediation Approach" (DMRA), encourages and stimulates learners to study topics in greater detail, and supports the development of their own learning. The advantages of this method are listed below:

- DMRA is significantly effective in terms of reducing study time and improvement of learning outcomes.
- DMRA valorises the active role of the learners during their process of knowledge construction and may have significant implications for educators who would like to use innovative and engaging online learning environments to enhance student learning.
- DMRA is a simple and highly reproducible method.

Specifications table

Subject area:	Computer Science
More specific subject area:	Education
Method name:	The DynaMap Remediation Approach (DMRA)
Name and reference of original method:	-
Resource availability:	-

Background

The theory of signs and tools of Vygotsky [11] is particularly useful for understanding the relationships between materials (artefacts) and mind as well as investigating the issues related to the potential of devices and tools used for online learning. The result is a triadic model [10] where the relationship between the subject and the object of knowledge is mediated by artefacts (cultural mediation). In a wide variety of available resources able to support learning and teaching, concept maps have always been tools that are mainly used for purposes of knowledge management and organization. The authors mean concept maps as graphic representations of knowledge domains within which the main topics and the logical relationships among them are clearly identified [7]. The knowledge representation itself, by means of these cognitive artefacts [6], may help students in their learning experiences. In particular, the adoption of concept maps improves their performances by helping them to identify basic topics and connections with the reference science, by better developing their critical thinking, by increasing their motivation and their results in reaching their learning goals [5,9].

In this paper, we use the Dynamic Concept Maps (DCMs) in online learning environments as tools able to stimulate students to deepen the study topics by using traditional media (in our case, the textbooks). Since it is true also the opposite, this process is mutual. To point out this reciprocal and synergic interaction between digital artefacts (DCMs) and analog artefacts (books), the term "remediation" is adopted [1]. By assuming the thesis that asserts "the content of a medium is always another medium" [4], Bolter and Grusin actualized this intuition in the light of the contemporary media scenario characterized by the digital technologies of network. For these two authors "a medium is what remedies".

In DMRA, the use of DCMs is aimed to trigger a synergistic process of signification and comprehension in the students according to a multi-modal vision of the learning process in terms of the power of the remediation [3]. The use of DCMs may stimulate the remediation with the textbooks and, moreover, the remediation itself, by encouraging the deepening from a medium to another one and vice versa, triggers the development of significant learning.

In the last few years, several papers have discussed the use of concept maps in education. However, no studies have been published on knowledge maps and remediation by meaning this last one as a way to transpose a media into another one. This allows the authors reconsidering their DCMs as possible remediators of media as books, as newer ways to represents them and consolidating their method described in this paper.

The proposed method is based on the original combination of the previously presented concepts [3], as it will be shown in the following subsections.

The architecture of DCMapp

DCMapp is an application accessible through internet by means of a web browser. It has been designed with the aim of manage and deliver the Dynamic Concept Maps (DCMs). It has been realized by integrating the following technologies:

- e-LENA;
- Single-Sign On plug-in;
- PHP engine;
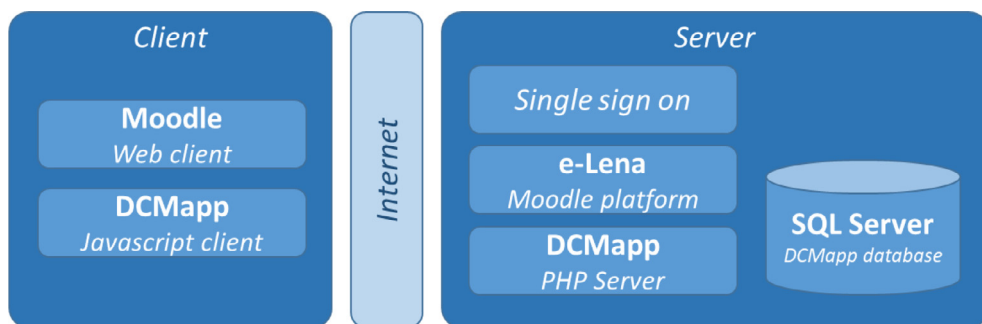- Javascript client interface;

Fig. 1. The architecture of *DCMapp*.

- SQL Server database.

e-LENA is a Moodle-based e-learning platform customized for all the issues and other initiatives of the Rimedi@ Lab. The second component is a *Single Sign On* plug-in implemented to allow users signed into the Moodle platform to access *DCMapp*. The third component is a PHP system capable of managing and delivering the DCMs. The fourth component is a client JavaScript-based user interface that allows users to interact with the DCMs. The last component is a SQL server database where the maps are stored in terms of nodes, edges and content and where the users' logs are recorded during their learning activities. Fig. 1 shows the architecture of *DCMapp*.

The accesses provided by DCMapp are the following two: the teacher and the learner. The user with the role of teacher may create new DCMs by defining nodes, relationships and uploading content for each of them. The user with the role of learner may navigate the maps, open nodes by discovering their children nodes, existing relationships and watch all the available content. The navigation of the learners is tracked on the database in order to carry out any analysis during and after the learning experiences.

The teacher may add to an existing course the created DCM as a Moodle resource. For each user, DCMapp creates a concept navigation path and a content navigation path. In the first one, there are the concepts discovered, the order followed during his learning experience and the time spent on them. In the second one, there are the contents read, the order followed during the learning experience and the time spent on them. By elaborating the tracking records, it is possible to create two different kind of reports. The first one allows seeing, for each domain and for each user, the concepts and related child nodes opened by each user. The second allows seeing, for each domain and for each user, the contents watched by each user. In both these reports it is written the time the users spent in on-line activities.

The DynaMap remediation approach (DMRA)

By following the semantic network of Quillian [8], from the chosen topics, the teachers and the educators elaborate their DCMs and keep them available into their Moodle courses as learning resources.

The users may access the e-LENA Moodle platform and, then, to the course where a *DCM* has been added as a learning resource. The experience starts by showing only one concept: the root node of the map. Then, the learner may click on it and choose what to do: opening children nodes, showing related content, getting back, and so on. The children nodes are opened one layer at a time in order to get users involved in a knowledge discovering experience (see Fig. 2).

The DCMs mediate the relationship between the subject and the object of knowledge. Since the learners interact with the DCMs, they are stimulated to study in greater detail with a book. Each learner, by approaching paper materials after having clarified the conceptual structure of the
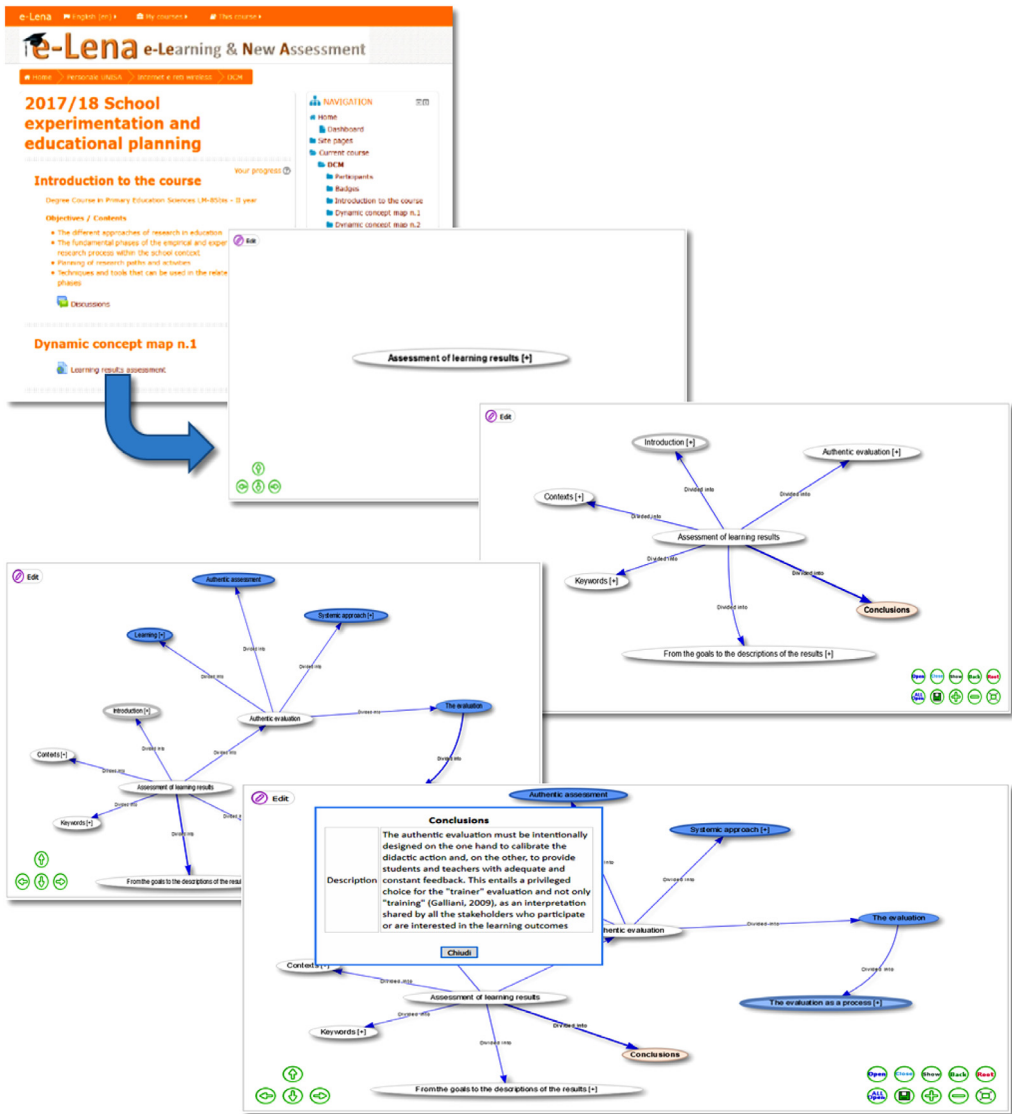
Fig. 2. The navigation of the user into *DCMapp.*

arguments, is able to restructure and systematize his own knowledge. In this sense, both media (the DCMs and the book) are under a continuous hybridization determined by their remediation.

The use of DCMs is able to stimulate and enhance in students the processes of remediation between digital artefacts (DCMs themselves) and analog artefacts (books). DCMs favour a more efficient organization in terms of reducing study time. DCMs help greater effectiveness in terms of improving learning outcomes.

The method proposed by the authors is strongly based on the developed *DCMapp.* DMRA can encourage and stimulate learners to study in greater detail the topics and favour the development of their own learning. Fig. 3 represents the involved cognitive processes.
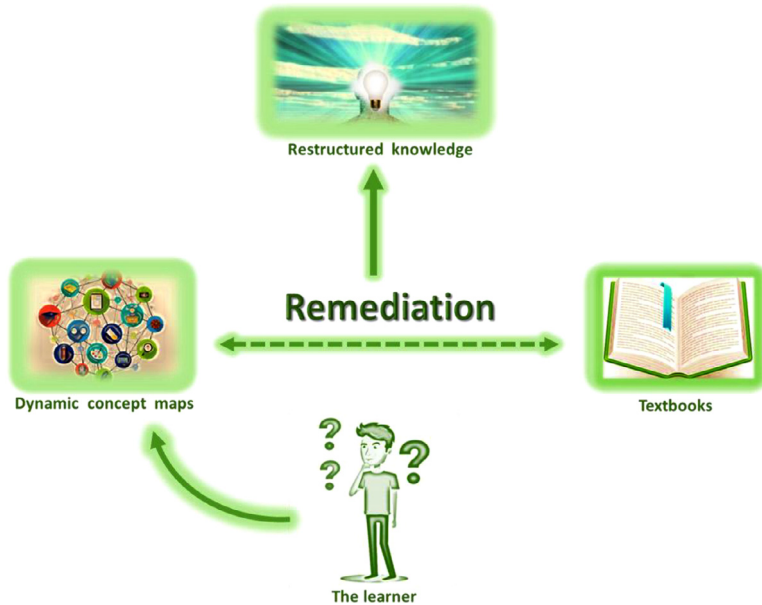
Fig. 3. The DynaMap Remediation Approach.

Method validation

Description

An empirical survey involved the students of the University of Salerno attending the lectures of the course "*School Experimentation and Educational Planning*". The educational activities started on October 1st, 2018 (ending on December 6th). The second part of the lessons consisted of the study of four chapters taken from two books recommended for individual study. Participants would be notified, with a post on *Facebook* the previous Saturday morning, the chapter being studied to support the written test to be carried out the following Monday. Each test was based on multiple-choice questions. The experiment consisted of dividing the students participating in the research into two groups. The students of the first group would use the book for the preparation of the test; the students of the second group would use *DCMapp*. The first group (afterwards FFG) was made up of 92 students who worked face to face by using only the book. The second group (afterwards OLG) of 91 students who worked online by using *DCMapp*. Four tests were administered on the themes treated in the respective four parts of the course that were considered in the experiment. Each of them consisted of ten multiple choice questions (MCQs) with the aims to evaluate the knowledge about the relative topics.

In summary, the activities started by engaging students in studying the first chapter and having, then, the first test. The activities went on in the same way for the second, third and final fourth chapters. The students had to study each chapter and had, after the period of study, a test on that part. To detect study times, 4 questions were proposed, to which the students answered at the end of each of the 4 tests. The OLG students had to: indicate the hours devoted to the study of the dynamic maps; specify if they had studied using the book (filter question); indicate the hours dedicated to the study using also the book if they had answered affirmatively to the question 2; indicate the total hours of study. The FFG students had to indicate the total number of hours devoted to the study of the assigned materials (question 4). During the studying sessions, students of FFG used only the book, meanwhile students of OLG used *DCMapp*.

After closing the last test, the students received a questionnaire (called *DynaMap Remediation Questionnaire*, DMTQ) to check whether the DCMs are able to stimulate processes of remediation between digital and analogue artefacts (the book). The questionnaire consists of three sections: *Section A* (9 items), given to all the students to collect the demographic information; *Section B* (7 items), given to all the students to collect information on study methods and used materials and resources; *Section C* (12 items), given to OLG students to collect specific information on the effectiveness of DCMs and reciprocal remediation processes between the DCMs and the book. The questionnaire was developed by considering those validated in a previous study [2].

Data analysis and results

The collected data consisted of a review of the student results in the learning units, the answers of the students at the end of each of the 4 tests, the participants' responses to the DMTQ and the navigation paths on concepts and contents on the DCMs. Quantitative data were studied by using statistical analysis (Descriptive statistics, Exploratory factor analysis, Statistical reliability**)**.

The DMTQ consisted of 19 closed questions with four rating levels (Likert scale) and a filter question. In order to assess the consistency of the subscales, an exploratory factor analysis was used to identify the factor structure of the two sections of the questionnaire (all the students filled in section B; only the OLG students filled in section C). The analysis included a rotation procedure, an orthogonal method (Varimax) and the Kaiser criterion (Kaiser). The exploratory factor analysis produced an unrotated two-factor structure for each section showing that the subscales were two-dimensional.

The two components from DMTQ (section B), which accounts for 52% of the variation in the data, may be labelled as: (1) *Digital approach*; (2) *Analog approach*. The first component groups the items related to the use of the software, IT support tools (study materials and resources), to the research of resources available on internet, to the use of computer media, electronic files and e-books. The second one refers to the propensity of the students to elaborate synthesis and maps related to the studied materials (the books) by using paper and pen.

The two components from DMTQ (section C), which accounts for 69% of the variation in the data, may be labelled as: (1) *DCMs and remediation process*; (2) *DCMs and personal study*. The first component groups the items related to the effectiveness of the DCMs in stimulating students to use the book (remediation process) after their fruition and promoting, in the same time, the inverse process. The second one refers to effectiveness of the DCMs for personal study (organizing contents, identifying the highlights of the topics).

The reliability analyses were determined by measuring the internal consistency of each subscale calculating the Cronbach's alpha. The Alpha coefficients (section B, Cronbach's alpha: 0.74; section C, Cronbach's alpha: 0.84) were above the 0.70 standard of reliability.

Descriptive statistical analyses were carried out on both sections B and C of the DMTQ. In section B, seven statements are presented. They refer to the methods of personal study and the possible use of software and IT support tools. In majority, the students use the resources available on the internet and computer supports; only partially, they use computer media, electronic files and e-books (component 1, *Digital approach*). They prefer to elaborate synthesis, summaries and conceptual frameworks of study materials (component 2, *Analog approach*) with pen and paper.

Section C consisted of 12 items (addressed only to students belonging to the OLG). About the component *DCMs and remediation process*, the majority of OLG students said that the DCMs stimulate to study the topics in greater detail with a boo, allow to identify the salient points of the topics to be studied and allow for a better organization of the study to be carried out with the help of a book. Studying with paper material improves learning if accompanied by the use of DCMs and it is facilitated after the consultation of the DCMs. About the component *DCMs and personal study,* according to what the students declared, the use of DCMs improves learning, facilitates the organization of contents and allows identifying the highlights of the topics to be studied.

In the filter question was asked whether the book was used to study in greater detail. 87.9% of the students said they had also used the book to study in greater detail. In the last two questions, again,
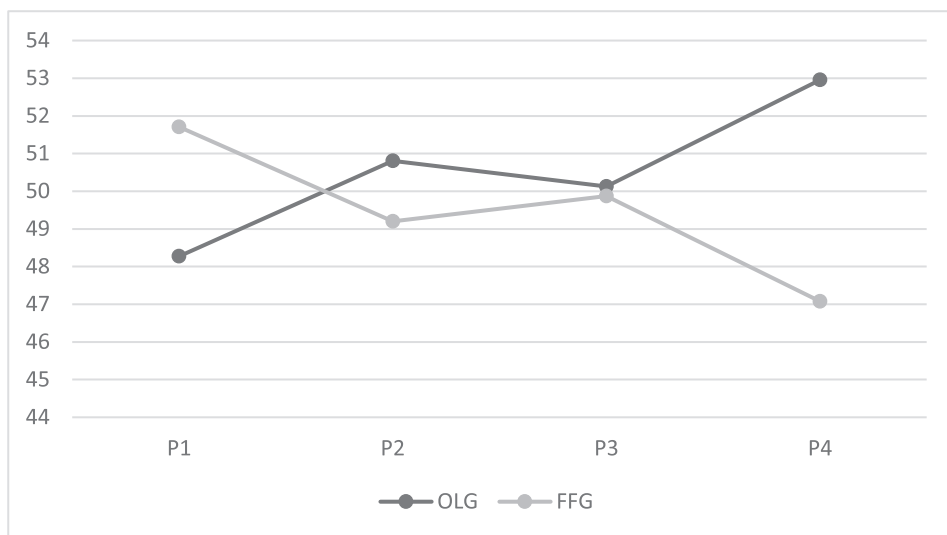
Fig. 4. T-score of the test results.

the tendency of students is to consider that it was useful to study the topics in greater detail in a book and that the DCMs had facilitated the subsequent study from the book.

Four tests were administered with the aims to evaluate the knowledge about the relative topics. Each of them consisted of ten multiple choice questions (MCQs). The reliability analyses were determined by measuring the internal consistency of each subtest (*P1, P2, P3, P4*) calculating the Cronbach's alpha (Cronbach). Alpha coefficients of each subtest were all above the 0.70 standard of reliability: $\alpha P1 = 0.71$; $\alpha P2 = 0.76$; $\alpha P3 = 0.73$; $\alpha P4 = 0.72$.

Discussion

To highlight the differences between the two groups, the test scores were standardized (T-score) on the entire sample. Fig. 4 shows how the scores of the FFG decrease while those of the OLG increase.

After the administration of each of the four tests, the students were asked to answer useful questions to identify the hours employed in the study of the assigned materials. The analysis of the data highlighted a decrease in the study times of the students belonging to the OLG together with an increase in the study times of the students belonging to the FFG. DCMapp tracked all the actions carried out by the users during their own navigation. The times of the fruition were used to verify the reliability of the answers given by the students of the OLG to DMRQ. From the comparison of data, the times declared for the study only with maps were consistent with the navigation paths detected on the platform.

To highlight the differences between the two groups, the study times (ST1, ST2, ST3 and ST4) have been standardized on the whole sample (T-score) by considering five ranges of answers as scores on the scale. Fig. 5 shows how the study time of the FFG increases while that of the OLG decreases.

May an intentionally structured online environment be able to stimulate and enhance in students the processes of remediation between digital artefacts and analog artefacts (books) so as to encourage the development of significant learning?

By analysing the data of the questionnaire and the tests, after this experimental research, it is possible to assert that three main goals have been reached by adopting DMRA. The first one is about the ability of DCMs to stimulate and enhance the remediation between themselves and the books. The second one is about the more efficient organization in terms of reducing study time that this
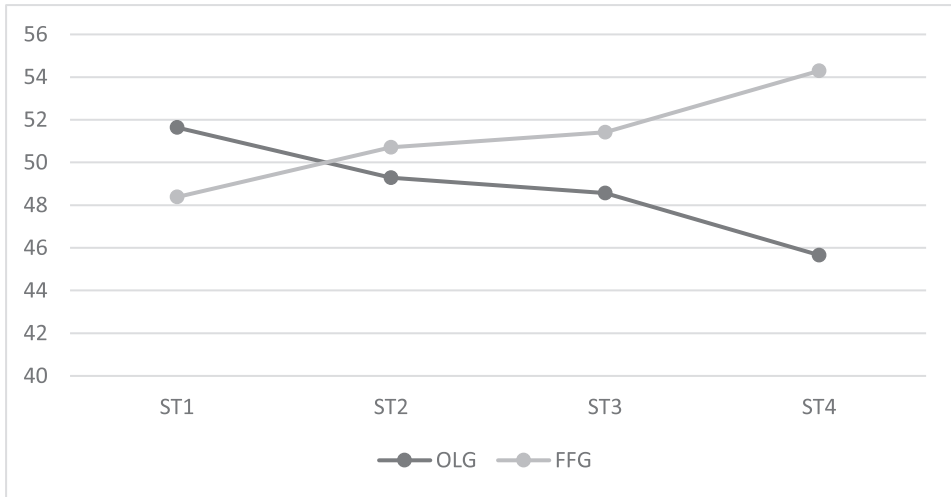
Fig. 5. T-score of *study time.*

approach may encourage. The third one is related to the greater effectiveness in terms of improving learning outcomes.

Conclusions

The presented approach depicts a different way of viewing the cognitive processes involved in the construction of knowledge. DCMs mediate the relationship between the subject and the object of knowledge. DCMs stimulate the learners to study on the books in a dynamic process of remediation and help them to approach materials and clarify topics and return back to their representations.

DMRA enhances the students' active role and favours the development of their own learning, thus, it may have significant implications in education and, in particular, may represent an innovative and effective reference for the online learning environments.

Despite this research led the authors to significant results, it may be extended. In particular, this approach may be applied to wider samples by involving much more students coming from different Universities and by referring to different disciplines and topics. It may be integrated by final summative tests able to better identify the knowledge level reached by the engaged students. Finally, other tools may be kept available to the participants inside the learning environment in order to encourage other collaborative activities, also by allowing them to share DCMs each other or navigate them with their friends.

Acknowledgements

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] J.D. Bolter, R. Grusin, Remediation. Understanding New Media, MIT Press, Cambridge (MA), 1999.

[2] A. Marzano, Dynamic concept maps and remediation processes in on-line learning environments, Eu. J. Res. Education Teach. (3) (2017) 245–278 XV.

[3] A. Marzano, S. Miranda, The DynaMap remediation approach (DMRA) in online learning environments, Comput. Education 162 (2021) (2021) 1–18 104079, doi:10.1016/j.compedu.2020.104079.

[4] M. McLuhan, Understanding Media: The Extensions of Man, McGraw-Hill, New York, 1964.

[5] A. Montagrin, C. Saiote, D. Schiller, The social hippocampus, Hippocampus 28 (9) (2018) 672–679, doi:10.1002/hipo.22797.

[6] D.A. Norman, Cognitive artifacts, in: J.M. Carroll (Ed.), Designing Interaction: Psychology at the Human-Computer Interface, University Press, Cambridge, 1991.

[7] J.D. Novak, D.B. Gowin, Learning How to Learn, Cambridge. University Press, New York, 1984.

[8] M.R. Quillian, Semantic Memory, in: M. Minsky (Ed.), Semantic Information Processing, MIT Press, Cambridge, 1968.

[9] T.A. Slieman, T. Camarata, Case-based group learning using concept maps to achieve multiple educational objectives and behavioral outcomes, J. Med. Education Curricul. Develop. 6 (2019), doi:10.1177/2382120519872510.

[10] L.S. Vygotsky, Mind and Society. The Development of Higher Mental Processes, Harvard University Press, Cambridge, MA, 1978.

[11] L.S. Vygotsky, Sign and tool in the development of the child, in: R.W. Rieber (Ed.), The Collected Works of L. S. Vygotsky, Plenum Press, New York, 1999, pp. 3–68. *Vol. VI*(Original work written 1931, published 1984).