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Abstract

In this work, the effects of the combination of computer-based concept mapping with the Learning Management System (LMS) Moodle use and Face-to-Face support for the construction the Concept Map (CM) in self- and collaborative-mode are explored. This approach builds upon the hybrid interconnection of blended (b-) and collaborative (c-) learning perspectives to form an extended teaching/learning environment. Experimental results from one hundred and twenty-eight adult participants during six week constructions of CMs upon a given text, comply with the findings from previous studies regarding the positive effect that shifting from self- to collaborative-mode has on the constructed CMs, but extends further the notion of the additional positive effect of the use of LMS Moodle on the taxonomy score of the constructed CMs and the peers' interaction during the collaborative CM construction. The hybrid b-/c-learning approach proposed here sets new directions towards the enhancement of LMS use and computer-based concept mapping, contributing to the enrichment of the Higher Educational Institutions services and re-examination of educational practices.

Keywords: Blended (b-)/Collaborative (c-) learning, Computer-based concept mapping, LMS Moodle, Self-/Collaborative-mode

Introduction

According to Novak (2010), a Concept Map (CM) is a (hierarchical) network comprised of concept-terms (nodes) and directed lines linking pair of nodes; at the same time, CMs provide a window into students' mind, reflecting students' knowledge structures. Seen as an instructional tool CM encourages students to explicitly organize and make public their knowledge. CMs are considered effective as teaching and learning tools that assist the development of conceptual knowledge, allowing visual observation of relationships and connections between multiple areas and pieces of information (Novak & Gowin, 1984).

Several studies have investigated the use/potential of CMs as supporting processes of self-knowledge management (Conceição, Desnoyers & Baldor, 2008; Vodovozov & Raud, 2015). Other authors, on the other hand, have explored the potential of collaborative CMs to facilitate knowledge construction as a study/collaborative tool (Lee, 2013; Rafaeli & Kent, 2015). Although originally developed to assist individual learners, collaborative use of CMs emphasizes brainstorming among group members, leading to visualization of new ideas and synthesis of unique concepts (Novak, 2010), requiring communication/negotiation processes, which guide learners to growth in their conceptual understanding (Kwon & Cifuentes, 2009). Concept mapping has been described as a technique that can increase

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student's learning in the traditional classroom (Novak & Cañas, 2008; Álvarez-Montero, Sáenz-Pérez, & Vaquero-Sánchez, 2015). However, several studies have clearly demonstrated the efficacy of computer and/or online concept mapping techniques in supporting the learning process (Kwon & Cifuentes, 2007; Omar, 2015).
Such flexibility allows the integration of the CM in blended (b-) learning experiences that are formed through the mediation of Information and Communication Technologies (ICTs), rather than being completely online or Face-to-Face (F2F) (Michinov & Michinov, 2008). The option for a b-learning structure is justified by its flexibility, ease of access, and the possibility of integration of sophisticated and personalized technologies (Johnson et al., 2015). Blending different delivery modes/tools can be seen as an imaginative solution in educational contexts, since it has the potential to balance out and optimize the learning development (Dias, Diniz, & Hadjileontiadis, 2014). In this line, Learning Management Systems (LMSs), e.g., Moodle, have become very popular among educators to improve teaching-learning processes, incorporating tools, such as discussion forums, Wikis and other interactive tools that make them especially useful for constructing enriched computer-based learning (CBL) environments (Dias et al., 2014). Moreover, metrics like the Quality of Interaction (QoI) of the user with the LMS can be estimated (Dias & Diniz, 2013).
From the aforementioned, it is evident that although the benefits from the collaborative construction of CMs are already identified, no research effort has explored the effect of the concept mapping placed within the b-/c-learning environment, by examining the alterations of the CM characteristics when shifting from self- to collaborative-mode and the LMS use, which defines the aim of this exploratory study. In particular, the analysis axes are based on the CMs topological taxonomy score, peers' interaction during the collaborative construction of CMs, and the presence/absence of the LMS Moodle use. The experimental results, derived from 128 eight adult participants during six week constructions of CMs upon a given text, verify the potentiality of this approach in bridging the fields of b- and c-learning into a hybrid and enhanced teaching-learning environment.

Methodology

In this section, the proposed analysis framework along with the experimental implementation are presented.

The proposed analysis framework

The proposed analysis tackles the effects of the shifting from self- (SELF-) to collaborative- (COLL-) mode, along with the use or not of the LMS Moodle, both upon the structural characteristics of CM and the peers' collaborative interactions within a CBL. To quantify these effects, the following parameters are considered:

CM-related: Topological Taxonomy Score (TaxScore)
In SELF-MODE, the $\text{TaxScore}_{\text{SELF-MODE}}$ ranges from 0 to 6 and it is calculated according to five criteria defined in (Novak & Cañas, 2006), i.e.: a) use of concepts rather than of chunks of text, b) establishment of relationships between concepts, c) degree of branching, d) hierarchical depth, and e) the presence of crosslinks. Higher topological taxonomy scores typically indicate higher quality of CMs (Novak & Cañas, 2006).
In COLL-MODE, the difference of TaxScore is calculated, i.e., $\text{TaxScore}_{\text{Diff.}}$ The latter considers the difference between the topological taxonomy score of the collaboratively produced CM from the pair $(\text{S}_\text{i}, \text{S}_\text{j})$ and the lowest topological taxonomy score of the

individually constructed CMs by S_i and S_j, expressing, thus, the maximum level of improvement in the topological taxonomy score when shifting from the SELF- to COLL-MODE. In particular, the $\mathrm{TaxScore_{Diff}}$ is given by:

$$\mathrm{TaxScore_{Diff}} = \mathrm{TaxScore}^{(S_i,S_j)}_{\mathrm{COLL-MODE}} - \min\left(\mathrm{TaxScore}^{S_i}_{\mathrm{SELF-MODE}}, \mathrm{TaxScore}^{S_j}_{\mathrm{SELF-MODE}}\right), \quad (1)$$

where $\mathrm{TaxScore}^{S_i}_{\mathrm{SELF-MODE}}$ and $\mathrm{TaxScore}^{S_j}_{\mathrm{SELF-MODE}}$ denote the topological taxonomy score of the CMs constructed by peers S_i and S_j under the SELF-MODE, respectively, whereas the $\mathrm{TaxScore}^{(S_i,S_j)}_{\mathrm{COLL-MODE}}$ denotes the topological taxonomy score of the CM constructed by the pair (S_i, S_j) under the COLL-MODE; $\min(\cdot)$ denotes the minimum value and indices i, j range from 1 to the maximum number of peers participated in each group of pairs.
Peers' collaborative interaction: *Turn-taking* ($TT_{COLL-MODE}$)
Turn-taking refers only to COLL-MODE, i.e., $\mathrm{TT_{COLL-MODE}}$, and is measured between the peers S_i and S_j across their collaboration during the construction of the collaboratively produced CM. The $\mathrm{TT_{COLL-MODE}}$ takes into account all the alterations between the peers' active role (mouse control), when producing the CM.

Peers' collaborative interaction: Absolute difference of the peers' balance (Bal_{Diff})
Again, collaboration balance is considered in the COLL-MODE only, and takes into account the number of $\{\mathrm{CON, REF, ORG}\}$ set contributions of each peer, normalized to the total number of the $\{\mathrm{CON, REF, ORG}\}$ set contributions in the pair. The $\{\mathrm{CON, REF, ORG}\}$ set includes CM-based structural elements, which relate with CM construction (CON), i.e., Add, Move and Connect, expression of user's reflection (REF), i.e., Delete, Resize and Modify, and CM organization (ORG), i.e., Concept, Linking Phrase. More specifically, the $\mathrm{Bal_{Diff}}$ is defined as:

$$\mathrm{Bal_{Diff}} = \left|\mathrm{Bal}^{S_i} - \mathrm{Bal}^{S_j}\right|_{\mathrm{COLL-MODE}} (\%), \quad (2)$$

where $|\cdot|$ denotes the absolute value and Bal corresponds to the peer's balance within the pair, defined as the number of $\{\mathrm{CON, REF, ORG}\}$ set contributions of each peer, normalized to the total number of the $\{\mathrm{CON, REF, ORG}\}$ set contributions in the pair, i.e.:

$$\mathrm{Bal}^{S_i} = \frac{\mathrm{card}(\{\mathrm{CON, REF, ORG}\}^{S_i})}{\mathrm{card}(\{\mathrm{CON, REF, ORG}\}^{(S_i,S_j)})} \times 100\ (\%) \quad (2a)$$

$$\mathrm{Bal}^{S_j} = \frac{\mathrm{card}(\{\mathrm{CON, REF, ORG}\}^{S_j})}{\mathrm{card}(\{\mathrm{CON, REF, ORG}\}^{(S_i,S_j)})} \times 100(\%) \quad (2b)$$

where card denotes the cardinality of the $\{\mathrm{CON, REF, ORG}\}$ set contributions.

LMS Moodle-related: *Quality of Interaction (QoI)*
Moodle interactions allowed as in the 14 basic categories (C1-C14), namely (Dias & Diniz, 2013): C1: {Journal/Wiki/Blog/Form (J/W/B/F)}, C2: {Forum/Discussion/Chat (F/D/C)}, C3: {Submission/Report/Quiz/Feedback (S/R/Q/F)}, C4: {Course Page (CP)}, C5: {Module (M)}, C6: {Post/Activity (P/A)}, C7: {Resource/Assignment (R/A)}, C8: {Label (L)}, C9: {Upload (UP)}, C10: {Update (U)}, C11: {Assign (A)}, C12: {Edit/Delete (E/D)}, C13: {Time Period (TP)}, and C14: {Engagement Time (ET)}. These are used as inputs to the FuzzyQoI model (Dias & Diniz, 2013), to output the LMS Moodle user's QoI.

Experimental implementation

One hundred and twenty-eight pre-service vocational education teachers undertaking an one-year Pedagogical Training Program, completed voluntarily the entire study. The participants were of age 28±2.7 yrs., all Greeks and graduates from Greek universities. To avoid the potential extraneous factors of vocational specialty and gender in the experiment, the participants were paired upon their random listing within sex clusters to form the groups G1 and G2, of 64 students (32 pairs) each. All of them had experience in diagrammatic depictions (without linking phrases), yet none of them of CM and of using CM-related software, such as the CmapTools (either in the self- or in collaborative mode), and the Moodle LMS. Moreover, none of them had any experience concerning computer-mediated collaboration. The study lasted six weeks (W1:W6), in the second semester and both groups performed CM in both modes, i.e., SELF-MODE (W1-W3) and COLL-MODE (W4-W6), yet G2 only was instructed to additionally use LMS Moodle during the whole period (W1-W6). Upon a written essay at the beginning of the second semester, the background of the participants was considered homogenous in relation to the text that was given to them (see Appendix), in order to transcribe it to CM in SELF- and COLL-MODE. The same researcher (the first author) performed the training and the experimental procedures.

The implementation took place on the basis of:

- the use of the CmapTools that allows other users and oneself access to the constructed CMs from anywhere/anytime, allowing to work in pair or teams on them (Hanewald & Ifenthaler, 2014). Moreover, upon the feature of the CmapTools software to record/replay of the construction procedure of the CM in both modes, i.e., SELF- and COLL-MODE, that extracts a `.txt` log file with all the time-stamped interactions that were performed by its author/s, i.e., the $\{\mathrm{CON}, \mathrm{REF}, \mathrm{ORG}\}$ set of contributions, is produced. All the adult participants agreed not to use any extra reading apart from the Appendix for the construction of the CM
- the LMS Moodle was prepared from the beginning to provide to its users spaces for interaction that could trigger metrics in all the aforementioned 14 basic categories (C1-C14) for the measurement of the QoI via the FuzzyQoI model (Dias & Diniz, 2013). Moreover, the text in the Appendix was uploaded to the LMS Moodle for the participants of the G2 (e-mailed to the participants of the G1), who agreed to use only the LMS Moodle as supporting tool, and
- the F2F weekly communication, where clarifications were provided by the researcher to both G1 and G2 for the use of the CmapTool and only to the G2 for the use of the LMS Moodle.

Data acquired from CmapTools software and LMS Moodle use set the experimental corpus. The Cmapanalysis (Canãs et al., 2013) plugin was used for the estimation of the taxonomy score; for the between-subjects (G1 vs. G2) statistical analysis the one-way analyses of variance (ANOVA test) was employed, whereas for the within-subjects (SELF-MODE vs. COLL-MODE) statistical analysis the two-sided Wilcoxon rank sum test was used, both implemented in Matlab 2015a (The Mathworks, Inc., Natick, USA).

Results and discussion

In Figure 1, the values of the outputted parameters from the experimental implementation are presented. More specifically, Figures 1(a) and (b) present the estimated $\mathrm{TaxScore}_{\mathrm{SELF-MODE}}^{\mathrm{G1,G2}}$ values across all students per group, and $\mathrm{TaxScore}_{\mathrm{Diff}}$ values across the pairs of both G1 and G2 groups, i.e., $\mathrm{TaxScore}_{\mathrm{Diff}}^{\mathrm{G1,G2}}$, calculated via (1), respectively. Clearly, in this case, the shift from SELF- to COLL-MODE had a positive effect in the quality of the constructed CMs, as reflected in the increase of the topological taxonomy scores in both G1 and G2 groups, complying with the findings of (Kwon & Cifuentes, 2009). Moreover, for the case of G1 (Figure 1(b)-blackface circles), the shifting from SELF- to COLL-MODE has produced, in general, positive $\text{TaxScore}_{\text{Diff}}^{\text{G1}}$values, yet with some negative ones (6 out 32) and some equal to 0 (8 out of 32). The $\text{TaxScore}_{\text{Diff}}^{\text{G2}}$ values (Figure 1(b)-whiteface circles), however, are all positive and all ≥ 2, showing the beneficial effect of the LMS use in the quality of the collaboratively constructed CMs.

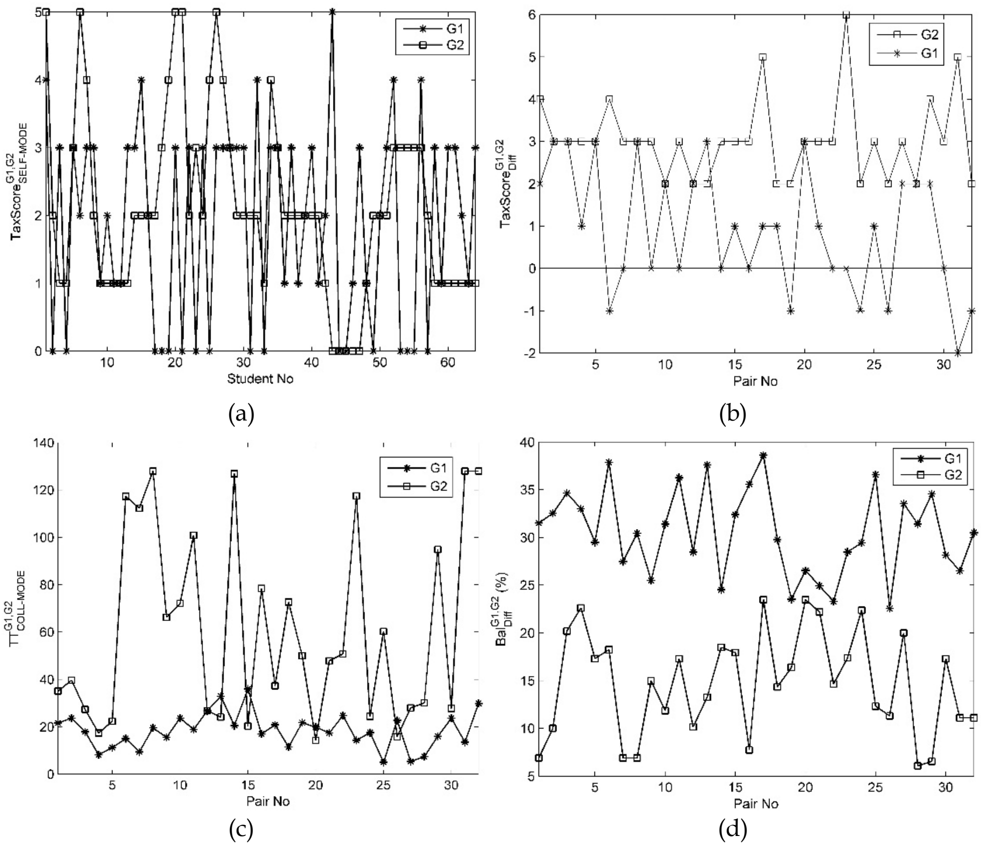

Figure 1. (a) The estimated $\text{TaxScore}_{\text{SELF-MODE}}^{\text{G1,G2}}$ values across all students per group, (b) The $\text{TaxScore}_{\text{Diff}}$ values across the pairs of both G1 and G2 groups, i.e., $\text{TaxScore}_{\text{Diff}}^{\text{G1,G2}}$ (c) The $\text{TT}_{\text{COLL-MODE}}$ values across the pairs of both G1 and G2 groups, i.e., $\text{TT}_{\text{COLL-MODE}}^{\text{G1,G2}}$, and (d) The Bal_{Diff} values across the pairs of both G1 and G2 groups, i.e., $\text{Bal}_{\text{Diff}}^{\text{G1,G2}}$.

From the SELF-MODE perspective (Figure 1(a)), there is a similar behavior in the resulted $\text{TaxScore}_{\text{SELF-MODE}}$ values between the G1 and G2 groups, showing that LMS Moodle use did not affect the quality of the CM construction reflected in the relevant topological taxonomy score under this mode. A statistically significant difference was found between the $\text{TaxScore}_{\text{Diff}}^{\text{G1}}$ and $\text{TaxScore}_{\text{Diff}}^{\text{G2}}$ ($p = 4 \cdot 10^{-9}$), but not a significant one between the $\text{TaxScore}_{\text{SELF-MODE}}^{\text{G1}}$ and $\text{TaxScore}_{\text{SELF-MODE}}^{\text{G2}}$ ($p = 0.3398$).

In Figure 1(c), the $\text{TT}_{\text{COLL-MODE}}$ values across the pairs of each group, i.e., $\text{TT}_{\text{COLL-MODE}}^{\text{G1,G2}}$, were estimated and illustrated for the COLL-MODE in both G1 and G2 groups. In almost all cases (exception of 4 pairs out of 32) the $\mathrm{TT}^{\mathrm{G2}}_{\mathrm{COLL-MODE}}$ values were greater than the $\mathrm{TT}^{\mathrm{G1}}_{\mathrm{COLL-MODE}}$ ones, exhibiting a mean value of $\mathrm{TT}^{\mathrm{G2}}_{\mathrm{COLL-MODE}}$ almost three times higher than the one of the $\mathrm{TT}^{\mathrm{G1}}_{\mathrm{COLL-MODE}}$. This difference was also statistically justified, as a statistically significant difference between $\mathrm{TT}^{\mathrm{G1}}_{\mathrm{COLL-MODE}}$ and $\mathrm{TT}^{\mathrm{G2}}_{\mathrm{COLL-MODE}}$ values was found ($p = 1.79 \cdot 10^{-7}$). This implies that the employment of the LMS Moodle use triggered further both G2 peers to participate in the collaborative activities during the collaborative construction of the CM. Furthermore, in Figure 1(d), the $\mathrm{Bal}_{\mathrm{Diff}}$ values, estimated via (2), across the pairs of both G1 and G2 groups, i.e., $\mathrm{Bal}^{\mathrm{G1,G2}}_{\mathrm{Diff}}$, are illustrated. From the latter it is evident that the pairs of G2 group exhibited more balanced collaboration compared to the ones from G1 group, as the $\mathrm{Bal}^{\mathrm{G2}}_{\mathrm{Diff}}$ values are always less than the $\mathrm{Bal}^{\mathrm{G1}}_{\mathrm{Diff}}$ones, lying at a mean value around 15%, in contrast to the mean value of $\mathrm{Bal}^{\mathrm{G1}}_{\mathrm{Diff}}$ that lies around 30%. This was also statistically justified, as a statistically significant difference between $\mathrm{Bal}^{\mathrm{G1}}_{\mathrm{Diff}}$ and $\mathrm{Bal}^{\mathrm{G2}}_{\mathrm{Diff}}$ was found ($p = 9.5 \cdot 10^{-19}$).These results support the perspective that the LMS Moodle use potentially contributes to the avoidance of any possible domination of one peer to another within the pair, in terms of more balanced collaboration during the collaborative construction of the CM. The proposed approach, when placed within the panorama of the works that combine hybrid perspectives with the educational contexts, fills a gap that relates to the way the users interact with LMS and collaborate with CMs within a b-/c-learning context. When compared with the previous works, the findings here comply with the works of Coutinho (2009), Kwon and Cifuentes (2009), and Hwang, Shi, and Chu (2011), fostering the positive effect of shifting from SELF- to COLL-MODE in the CM construction. Nevertheless, none of these work extend the vision of combining the CM with the LMS Moodle use, as it was examined here, adding to more alternative teaching/learning practices and strategies (e.g., by using different tools).

From the results presented in this study it was made clear that the involvement of the LMS Moodle use was quite effective in the increase of the quality of the constructed CMs (as derived from the topological taxonomy score), under the COLL-MODE. This was based on the fact that LMS Moodle boosted the role of CM as a kind of template or scaffold to help to organize knowledge and to structure it, even though the structure must be built up piece by piece with small units of interacting concept and propositional framework (Novak, 1990). Moreover, it was shown that shifting from not using to using LMS Moodle affects the CM-based collaboration, in terms of turn taking and balance of collaboration.

Overall, the findings of this study support the combination of the LMS Moodle use with the collaborative construction of the CMs, as an integrated learning environment that fosters hybrid b-/c-learning towards the merging of the social constructivist approach of LMS Moodle with the knowledge scaffolding of CMs. To our knowledge, this is the first attempt to combine these two fields as a new means of fostering the students' learning and collaborating processes within the hybrid b-/c-learning environment. Further research in more large-scale dataset is needed to generalize the results of the presented empirical study.

Conclusions

The hybrid approach presented here has shown that the combination of the LMS use with the collaborative construction of CMs, results in CMs with higher quality, in terms of the topological taxonomy scores, and more productive collaboration, as it is reflected in peers' active participation and balanced collaboration during the collaboratively constructed CMs. The proposed approach sets new directions towards the enhancement of LMS use and computer-based concept mapping, forming a combined basis for a more pragmatic approach of Online Learning Environments (OLEs) and b-/c-learning environments, within the context of Higher Education. It is totally transparent to the user during the time when the CM-based collaborative and/or LMS-based interactions take place, supporting and enriching, in this way, OLEs and promoting, at the same time, peer-to-peer collaboration within the computer-based concept mapping environments.

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Appendix

The concept of modeling (Jimogiannis & Siorenta, 2007, pp. 242-244). Educational research and modern scientific theories of learning have demonstrated that understanding and learning of new concepts is an internal process for each student. New knowledge does not 'transfer' but is built based on previous knowledge and individual experiences. Cognitive theories of learning have as a basic principle that new knowledge is the result of conceptual changes that occur as a result of continuous and intense interaction between pre-existing knowledge and formal knowledge of teaching. The conceptual change and learning, as well as the development of high level skills are progressive procedures performed over time. Cognitive sources used by students for the development of knowledge include:

a. their daily experience and the environment where they operate and grow,
b. the mental processes that they develop, and
c. the representation systems and mental models they use.

The models are a technical representation of behavioral conditions, procedures or systems of the natural, technological or imaginary world. A model is defined as a mental schema or tool that is familiar or accessible on existing knowledge and helps individuals to reach a conceptual understanding of new knowledge. It is an internal representation that plays the role of a substitute for reality. Between the model and the reality it describes, there is continuous communication, both during the construction phase and during the operational use, in order to interpret and understand new concepts, processes, systems or phenomena. A model allows:

a. the representation of a system to solve problems,
b. the forecasting of the development and changes of the system, without the need to observe the same reality, and
c. the explanation of the evolution of the system associating several factors that contribute to it.

Models are usually conceptually complex systems consisting of elements, relations, functions and rules, which define the interactions of the analysis system using an external representation system. They grow in the students' mind and incorporated into equations, diagrams, software or other means, which are used by students to express their ideas and knowledge, regardless of their relationship with reality. In building new concepts and knowledge we can distinguish three different worlds: a) the real world, where the various objects or systems and happening of events, processes, and the correlations between them 'live', b) the conceptual world, created based on scientific theories and models and includes concepts, objects and processes of the real world, and c) the mental world, consisting of subjective, individual perceptions created by people for the real world.

Accordingly, we can distinguish three kinds of models portraying the knowledge of the real world:

a. conceptual models: created by the activity and cooperation of experts in the field under study; they are objective but not visible representations of real or imaginary world and lead to scientific knowledge,
b. mental models: created in the minds of students and determine their individual theories about reality; they are usually incomplete and reflect misunderstandings and conceptual difficulties that students encounter in a cognitive area; it should be noted that a person reaches the understanding a conceptual model only if s/he can generate a sufficient mental model for each representation, and
c. external models: they represent mental or conceptual models and are used as teaching and/or learning tools.

There is a dynamic and reciprocal relationship between internal (conceptual, cognitive) and external models. These representations reflect the content and structure of knowledge in a given cognitive area and give to the students the opportunity to communicate and externalize their own knowledge. The use and development of these models by the students themselves contribute to the overcoming of cognitive barriers and in approaching scientifically acceptable conceptual models.