On Enhancing Pre-service Teacher 21st century Skills using Cmap Tools

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ABSTRACT

This paper proposes an instructional design towards the enhancement of the pre-service teachers 21st century skills, by challenging *ways of thinking*, *ways of working* and *tools for working* More specifically, the proposed ID supports efforts for systemic thinking by integrating individual and collaborative concept mapping using the Cmap Tools software. Furthermore, on the basis of the learning analytics approach, it focuses on the identification of a higher level of abstraction upon the analysis of CMs that were 'construct-by-self' and 'construct-by-pair'. Towards this direction, clusters of concepts and their relations are researched and the role of the collaboration quality to their evolution is explored. The work contributes to informing about deeper synergies between collaborative learning and systemic thinking, reinforcing in this way the reflection upon experiential learning. Experimental data from the implementation of the proposed ID reveal its potentiality to contribute to the development of the pre-service teachers as reflective practitioners.

Key words: *21st century skills, pre-service teachers, learning analytics, concept mapping, online collaborative learning environment, quality of collaboration, Cmap Tools.*

1. INTRODUCTION

Historically, education has followed power reformations in the society, driven mostly by the economical domain, from the agrarian, to industrial and nowdays to information economies. The rapid evolution of the information and communications technology (ICT) along with the increased complexity that penetrates all the aspects of life in the contemporary world, pledges for flexible responses to complex problems, effective communication, dynamic information management, team-work and collaboration, effective use of ICT and production of new knowledge (Griffin, et al., 2011). An approach to the identification of the ten most important 21st century skills has been proposed by (Griffin, et al., 2011), which foresaw four groupings of them, i.e., a) *ways of thinking* (1.Creativity and innovation, 2. Critical thinking, problem solving, decision making, 3.Learning to learn, Metacognition), b) *ways of working* (4. Communication, 5. Collaboration (teamwork), c) *tools for working* (6. Information literacy, 7. ICT literacy). The need for a revolution to the education in order to contribute to the acquisition of such skills, is profound.
Within the above context, questions arise as to the aim of the teacher education for this evolution. Experiential learning educational settings may allow the adults pre-service teachers to purposefully

engage in direct experience and focused reflection in order to increase knowledge, develop skills, and clarify values” (Association for Experiential Education, n.d. para. 2).

Educational psychologists such as John Dewey (1859-1952), Carl Rogers (1902-1987), and David Kolb (b. 1939) grounded theoretically experiential learning, which presupposes active cognitive participation in the learning procedure (Northern Illinois University, n.d.). The effort to structure such a setting entails a number of steps i.e., a process, that provides a hands on collaborative and reflective learning experience in order to “fully learn new skills and knowledge” (Haynes, 2007).

According to Kolb's experiential learning theory (Kolb, 1984; Kolb & Kolb, 2005), the four modes of grasping experience are Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation in the form of a cycle. However, Kolb and Fry (1975) noted that the learning cycle process can begin at any one of the four modes. More specifically (Northern Illinois University, n.d.), the first mode refers to the concrete learning experience (action) the pre-service teacher that is involved in. The second mode refers to the reflection, i.e.., a cognitive inquiry in which experiences are analyzed on the basis of prior knowledge, practices and values in order to find meaning from the experience and define new ways of acting. Abstract conceptualization is the mode where the pre-service teacher may identify trends in the experience that can be related to real life principles, and finally the active experimentation mode refers to the application of what was learned in the experience to a similar of different situation.

Adopting the above perspective, the preparation of the pre-service teachers for teaching the 21st century skills, can be seen as a challenge to engage them as students in experiential learning of the aforementioned skills. As Amobi (2006) argues, "a shift in focus from preparing highly-qualified teachers to enabling the development of high-quality, self-renewing teaching could serve as basis for a unifying purpose and practice of reflection of the teacher on his/her own acting, either teaching and/or studying" (p.27).

On-camus microteaching provides an opportunity for pre-service teachers to elicit pre-service teachers' reflection on their teaching actions (Amobi & Irwin, 2009), whereas opportunities of experiential learning of skills as students may be provided upon, among other ways, with the use of ICT. Computer mediated learning environments can provide the setting for the concrete experience, i.e., the forst mode of Kolb's learning cycle and in parallel log raw data, in the form of digital traces, of the interactions that take place with it. Learning analytics make use of these traces to find and make use of patterns within this information. Siemens (2010) defines learning analytics as “the use of intelligent data, learner-produced data, and analysis models to discover information and social connections, and to predict and advise on learning.” The output of the learning analytics constitutes information at higher level of abstraction that can not be derived from the raw data and can inform the participator in the learning setting, e.g., students during the next modes of Kolb's learning cycle (reflection and abstraction).

In the present work an instructional design (ID) is proposed for pre-service teachers, namely students, that work to construct a concept map (CM), concerning the concept "models", in an on online collaborative learning environment (OCLE). A CM can also be seen as a model with a "two-dimensional representation of cognitive structures showing the hierarchies and the interconnections of concepts involved in a discipline or a sub-discipline” (Martin, 1994, p. 11). The ID foresees two distinct situations, the ‘construct-by-self’ and ‘construct-by-pair’ situations, i.e., working alone or collaborating in the OCLE for the construction of the CM. Upon these two working situations, the ID manages to propose a setting for the experiential learning of *ways of thinking*, *ways of working* and *tools for working*. In parallel, upon the students' digital traces that were logged during an experimental materialization of the proposed ID, reveals opportunities for the learning analytics approach. More specifically, it aims at examining the potentiality of students' quality of collaboration (QoC) within an OCLE as learning promoter when developing CM using the IHMC CmapTools software (cmap.coginst.uwf.edu/samples/ index.html). The QoC of the students when constructing CMs both as "construct-by-self", and "constructed-by-pair", are estimated. In this vein, identification of clusters of concepts and their relations along with the exploration of the role of the QoC to their evolution are feasible, leading to informing about deeper synergies between collaborative learning and systemic thinking. Moreover, statistical and time series-based analysis of the acquired data reveal how learners' behaviour (both as singles or collaborators) is critical to their learning using CM modelling and how the CM/OCLS act as technological facilitators in supporting learning, when learners develop and use CM models.

2. BACKGROUND

2.1 Collaborative Learning

According to Dillenbourg (1999), collaborative learning is not one single mechanism: if one talks about "learning from collaboration", one should also talk about "learning from being alone". In such perspective, individual cognitive systems do not learn because they are individual, but because they perform some activities (reading, building, predicting) that trigger some learning mechanisms (induction, deduction, compilation). Similarly, peers do not learn because they are two, but because they perform some activities which trigger specific learning mechanisms. This includes the activities/mechanisms individually performed, since individual cognition is not suppressed in peer interaction. Nevertheless, in addition, the interaction among subjects generates extra activities (explanation, disagreement, mutual regulation) that trigger extra cognitive mechanisms (knowledge elicitation, internalisation, reduced cognitive load). In fact, the field of collaborative learning is precisely about these activities and mechanisms, which may occur more frequently in collaborative learning than in individual condition. However, there is no guarantee that those mechanisms occur in any collaborative interactions; moreover, they do not occur *only* during collaboration. At some level of description, the mechanisms potentially involved in collaborative learning are the same as those potentially involved in individual cognition. For instance, the 'collaboration' contract implicitly implies that both learners contribute to the solution, but this is often not the case. In this way, the QoC could be defined through the analysis of the collaborative peers' interactions (Hadjileontiadou et al., 2004). Analysis of the latter may be either of a 'static' form, e.g., statistical analysis (WebCT: http://www.webct.com/), or of a 'dynamic' one, e.g., intelligent inferences upon them. When those inferences are of evaluative character, axons and criteria need to be set to structure the evaluation procedure. The axons define the expected outcome of the supporting procedure, e.g., collaboration of better quality, whereas the criteria define countable parameters to verify the fulfilment of the axons, e.g., evaluation of the participants' collaborative activity on the basis of their interactions.

As a bottom line, the words 'collaborative learning' describe a *situation* in which particular forms of interaction among people are expected to occur, which would trigger learning mechanisms, but there is no guarantee that the expected interactions will actually occur. Hence, a general concern is to develop ways to increase the probability that some types of interaction occur (Dillenbourg, 1999). This is fostered by the implication of the CMs at the collaborative setting, as a means to scaffold systemic thinking synergies within an OCLE.

2.2 Concept Maps (CMs)

CMs have been used for many years as a tool for people of all ages and all domains of knowledge to express their understanding about a topic. More specifically, in education CMs have been shown to be useful as a tool for teachers to assess students' understanding, whether at the beginning, process, or end of the study of a topic (Novak & Cañas, 2004). CMs are graphical tools for organizing and representing knowledge (Novak & Cañas, 2004). The structure of CMs includes (Novak & Cañas, 2004):

- *Concepts*, defined as a perceived regularity in events or objects, or records of events or objects, designated by a label; the latter for most concepts could be one or more words. The concepts are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below.
- *Propositions*, which are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement. Sometimes these are called *semantic units*, or *units of meaning*.
- *Cross-links* that are relationships or links between concepts in different segments or domains of the CM. Cross-links help to see how a concept in one domain of knowledge represented on the map is related to a concept in another domain shown on the map. In the creation of new knowledge, cross-links often represent creative leaps on the part of the knowledge producer.
- *Specific examples of events or objects*, which are helpful additions to a CM to clarify the meaning of a given concept.

In general, there are two features of CMs that are important in the facilitation of creative thinking, i.e., the hierarchical structure that is represented in a good map and the ability to search for and characterise new cross-links (Novak & Cañas, 2006). One of the powerful uses of CMs is not only as a learning tool but also as an evaluation tool, thus encouraging students to use meaningful-mode learning patterns (Mintzes et al., 1998). Moreover, CMs are also effective in identifying both valid and invalid ideas held by students, embedded, for example, in the context of systemic thinking in environmental education.

2.3 Systemic Thinking and Education

The systems approach is evolving on three fronts, i.e., the development of general systems theory, the development of methodology and the application of theory and methodology to practical problems (Rountree, 1997). For example, the awareness of ecological principles leads to recognizing that all human activity has a related ecological cost, which means that any intervention in systems and natural processes should take into account their sustainability and elasticity, as well as the base of natural resources. This awareness also emphasizes the need to understand the holistic nature of life, including biological, social and political life (Ferreira, 1996); thus, systemic reasoning arises. The latter seems more crucial now than ever before, because of the complexity that rules the world. 'Systemic collapses', i.e., problems such as global warming and 'holes' in the ozone layer, which do not have simple local causes, are clear examples of such complexity. These, and many others of environmental decay problems, reveal the importance of an urgent reformulation of the current production model and of environmental protection policies, as well as of an inevitable need for the implementation and enforcement of environment management plans and educational policies;

hence, placing the effort upon the structural bases of the environmental education by focusing upon process thinking models for understanding and applying important concepts in the environmental education, combined with the adoption of CMs to represent relational concept information.
Motivated by the aforementioned, the work presented here draws its research focus from the use of CMs in an OCLE involving the essence of the 'act-of-modelling' as a learning bed-set to foster peers' critical thinking and reflection upon modelling issues.

3. METHODOLOGY

3.1 The IHMC Cmap and CmapAnalysis Tools

Here the IHMC Cmap and CmapAnalysis Tools have been adopted as the methodological tools for the deployment of CMs in the OCLE. The IHMC CmapTools software (Cañas et al., 2004) actually brings together the strengths of concept mapping with the Internet-based interaction; it allows users to collaborate at a distance in the construction in their maps, publish their CMs so anybody on the Internet can access them and link resources to their maps to further explain their contents. CmapTools provides extensive support for collaborative work during the CM construction. The high degree of explicitness of CMs makes them an ideal vehicle for exchange of ideas or for the collaborative construction of new knowledge (Novak & Cañas, 2006).
Apart from their construction, CMs need to be assessed by the instructor to get an appreciation of the student's understanding (and possibly assign a grade). Many studies have shown that concept mapping is an appropriate tool for testing students' achievements (Reiska, 2005). Automatic assessment of concept maps has been included as part of several concept mapping tools, e.g. C-Tools (Harrison, 2004) and COMPASS (Gouli, 2003). On the top of them, CmapAnalysis (Cañas, 2010) is a software tool that facilitates the analysis of sets of CMs utilizing various algorithms, rubrics and techniques, presuming that the CMs have already been constructed and stored in the CXL format by the IHMC CmapTool.
In general, CmapAnalysis is a cross-platform application that enables users to define and execute analyses over sets of CMs with desired measures. The latter range from simple counts of concepts and propositions to more complex calculations, following the CM categories and evaluation measures described next.

3.2 CM Categories and Evaluation Measures

The content of a CM can be categorised into three general categories i.e., size, quality and structure (Reiska, 2005). *Size* describes how many concepts, linking words and propositions are in a CM. Typical measures in this category are *Number of Concepts* (or Concept Count), *Number of Linking Words* and *Number of Propositions*. Measures from this category also describe students' knowledge. Students with more knowledge about certain topic and focus question usually include more concepts and linking words in their concept maps. *Quality* describes what kind of concepts, linking words and propositions are in a CM. Typical measures in this category are *Number of Correct Propositions* (or *Correct Proposition Count), Average Rating of Propositions,* and *Relevance of Concepts*. *Structure* describes how the concepts are connected to each other. Typical measures in this category are *Centrality of Concepts, Number of Cross Links, Density,* and *Inter-Cluster Proposition Count.* The measures from this category provide information on how well the concepts are connected, such as whether there are any central concepts, are there any separate sub maps, is the map a 'chain', a 'tree' or a 'star' (one central concept) (Cañas, 2010).

4. EXPERIMENTAL AND IMPLEMENTATION ISSUES

The General Department of Education of the School of Higher Pedagogical and Technological Education, Greece namely ASPETE (http://dev.aspete.gr/index.php/en/) offers, among other, the one-year Pedagogical Training Programme (PTP). It is of a one-year duration and leads to the award of a “Certificate of Pedagogical and Teaching Competence”. The programme is tailored to meet the needs of in-service or pre-service teachers with degrees from all higher education disciplines and specializations. The programme integrates theoretical instruction and laboratory work, is supplemented by the Teaching Practice Sessions, and is supported by a variety of extra-curricular on-campus and off-campus activities. Apart from Athens, it is delivered in Thessaloniki, Patras, Volos, Ioannina, Heraklion-Crete, Volos, Sapes, Rhodes, Mytilene, and Kozani.

The experimental protocol included 20 students from the Sapes (PTP) branch of ASPETE. These students formed 10 pairs (P1-P10) in a consequent fashion, i.e., S1-S2 formed P1, S3-S4 formed P2, and so on. The students (8 Male and 12 Female, 25-35 yrs old) were university graduates serving as potential secondary level school teachers of various disciplines. that participated in a one-year training program on pedagogical issues. The experimental protocol included the construction of a CM upon a three-page text, initially by each student alone and then as pairs (after 3 weeks) using the IHMC CmapTool locally (mode: Cmaps in my computer) and in public server, respectively (mode: Shared Cmaps in places). The text concerned the definition, the types and role of models towards the knowledge construction. The outputted results from CmapAnalysis Tool were further processed by using Matlab 2012b (The Mathworks, Natick, USA).

5. RESULTS AND DISCUSSION

A characteristic example of the CMs constructed by S1 and S2, along with the one derived when working as a pair (P1), are shown in an aggregated mode in Figure 1. In the latter, the whole CM corresponds to the case of P1, with the concepts in black frame representing the common ones (i.e., used in both CMs of S1 and S2), whereas the ones in white and grey frames correspond to those that only appear to the CMs of S1 and S2, respectively. From the inspection of Figure 1, it is clear that S1 dominated in the creation of the peripheral concepts during the CM of P1, with the S2 exhibiting limited contribution, both in the single and pair cases. Nevertheless, it is important that despite this imbalanced behaviour, the main concepts in P1 (denoted within the black frames) are common in the CMs of both S1 and S2, showing a mutual understanding of the core concepts of the input text presented to them during the experiments. Moreover, unlike S2, S1 uses more decentralised CM structure, showing a deeper exploration of the text concepts and extension to further ‘knowledge resolution’ in a more fine-grained mode.

In Figure 2, the CM evaluation measures (explained in figure caption) for the ‘construct-by-self’ (Figure 2(a)) and ‘construct-by-pair’ (Figure 2(b)) cases are depicted, respectively. When comparing the results of Figures 2(a) and (b), a noticeable reduction in the maximum values of Concept Count (CC), Linking Phrase Count (LPC) and Proposition Count (PC) is observed, when shifting from the ‘construct-by-self’ to the ‘construct-by-pair’ case, showing a more ‘restrained’ expression in the CM domain, possibly due to the co-existence in the OCLE and the experienced social interaction that sometimes soothes individual spontaneous interactions.

Moreover, Figure 3(a) illustrates the boxplot of the distributions of the eight CM evaluation measures (see Figure 2 caption) across the ‘construct-by-self’ (top) and ‘construct-by-pair’ (bottom) cases, whereas Figure 3(b) shows their stacked bar-plot for each student (S) that belongs to a pair (P), and for the pair itself.

Figure 1 about here

Figure 2 about here

Figure 3about here

Focusing on Figure 3(a), it is seen that, from a statistical behaviour, the distribution of the eight CM evaluation measures are more symmetrically distributed (less lengthy whiskers, more centralised medians, less outliers) in the case of pairs than in the single case, especially for BPC, CC, LPC, and PC, complying, in part, the aforementioned behaviour seen in Figure 2. The differences between S1 and S2 and the domination of S1 over S2 in P1 seen in Figure 1 is also clear in the first top panel of Figure 3(b). Moreover, from Figure 3(b) it is also seen that in most cases (e.g., P1, P2, P3, P5, P6, P8 and P9), peers' collaboration fostered the cardinality of the CM evaluation measures, especially the CC, LPC and PC, enhancing the QoC, whereas there are some cases (e.g., P7 and P10 mostly and significantly less in P4), where this phenomenon is reversed, due to the negative influence of the one peer with the lowest CM evaluation measures to the other.
In general, CM proves to be an efficient domain in order to reflect the structure of conceptual thinking and causality and, in most cases, seems to creatively enhance differences and agreements between the peers constructing the joint CM, as a means to approach systemic thinking through the actual process of interacting through mutual modelling and increased QoC.

The proposed ID provided a setting for pre-service teachers experiential learning, by challenging *ways of thinking* e.g., systemic, critical thinking and decision making, for the creative construction of the open-ended concept map. On the basis of the learning analytics, it prduced information at a higher level of abstraction that may reinforce the reflective character of *the way of thinking*. Moreover, it revealed challenging reflections upon the *ways of working* proving the potentiality of the collaborative work to support and enhance the *ways of thinking*. Finally, the proposed ID foresaw the use of the Cmap Tools, contributing to the provision of *tool of working* and to the ICT literacy enhancement.

6. CONCLUSIONS

In this paper, an effort to capture students' internalisation of the modelling processes of higher level of abstraction expressed in the domain of CMs has been attempted, by analysing the CMs that were either 'construct-by-self' and 'construct-by-pair', i.e., within an OCLE, using the IHMC CmapTools and CmapAnalysis software. Experimental results (employing CM evaluation measures) from a dataset of 20 pre-service of ASPETE, performing systemic thinking in the modelling process itself, have shown increased knowledge resolution in concept topology and higher QoC, contributing to more effective learning synergies. Further experiments should follow to justify the current findings and shed more light upon the interconnections and dependencies between internalisation and externalisation processes within the proposed instructional design.

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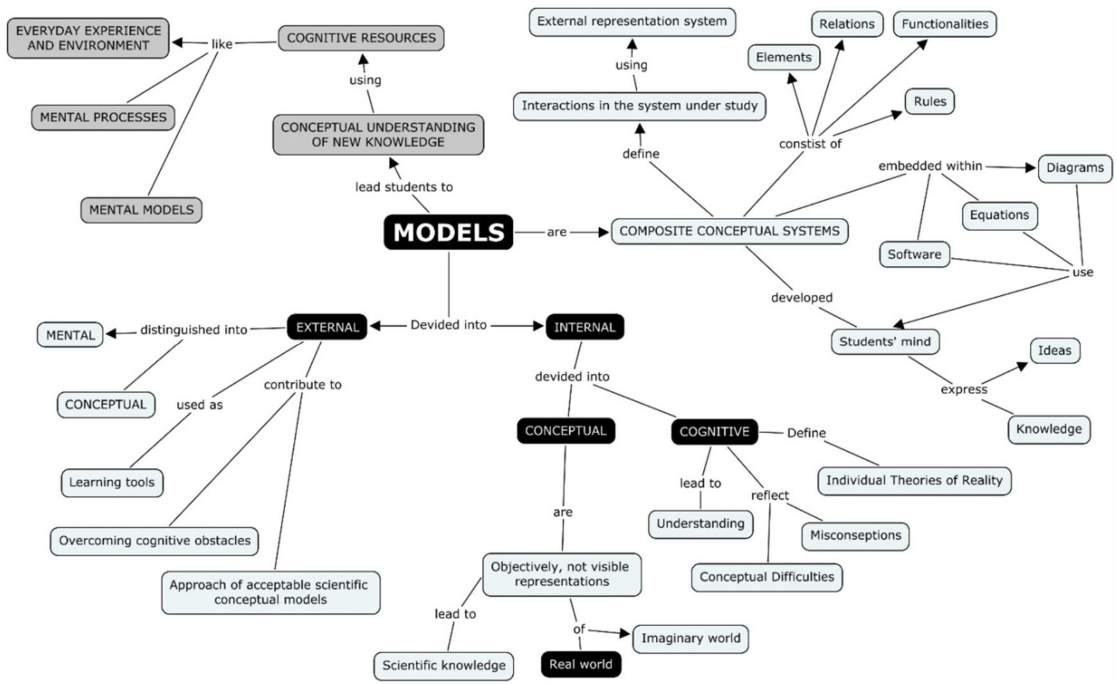
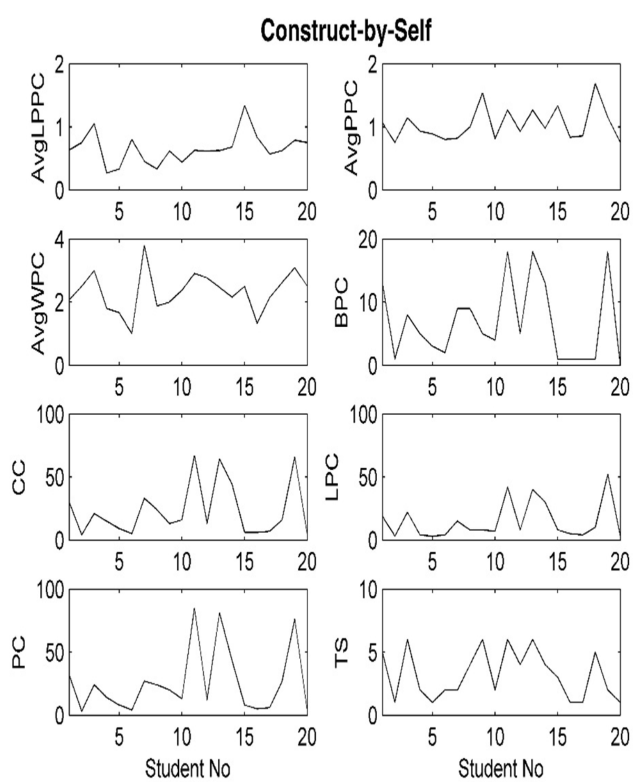
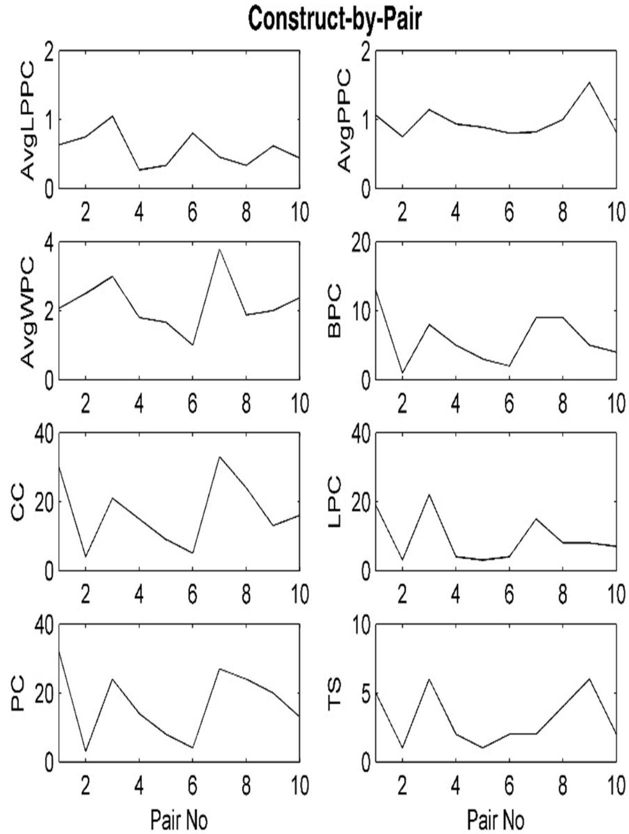


Figure 1. The constructed CM by S1 and S2 and when working as a pair (P1) in an aggregated mode. Concepts in black, white and grey frames correspond to the ones used both by S1 and S2 in their individual CMs, to those used in S1's CM only, and those used in S2's CM only, respectively.



(a)



(b)

Figure 2. The estimation of CM evaluation measures for the (a) 'construct-by-self' and (b) 'construct-by-pair' cases. AvgLPPC: Average Linking Phrases Per Concept, AvgPPC: Average Propositions Per Concept, AvgWPC: Average Words Per Concept, BPC: Branch Point Count, CC: Concept Count, LPC: Linking Phrase Count, PC: Proposition Count, TS: Taxonomy Score.

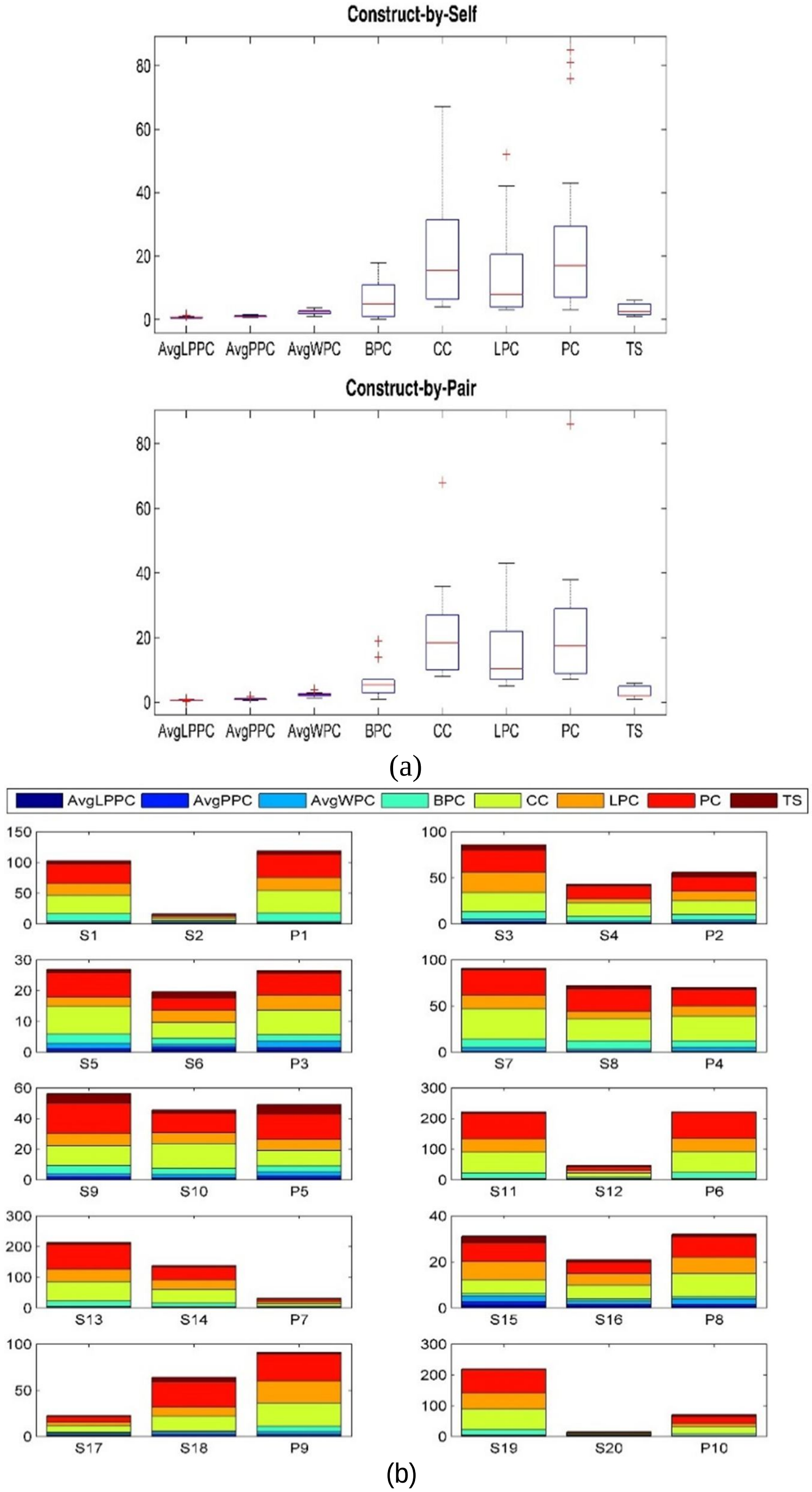


Figure 3. (a) The boxplot of the distributions of the eight CM evaluation measures used in Figure 2 across the 'construct-by-self' (top left) and 'construct-by-pair' (bottom left) cases. (b) Their stacked bar-plot for each student (S) that belongs to a pair (P), and for the pair itself.