Concept Maps as a Learning Assessment Tool

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Abstract

Over recent decades, the process of teaching/learning has become ever more complex. The increasing school population, and the advent of new IT applications and of networking, together with the requirement for continuous training, have comprehensively overturned the simplistic approach to the process that had previously been pursued. As a result, the evaluation of the process has also been overhauled – having once been a selective practice, it is now considered to be an activity that generates quality in teaching. However, it appears that the tools used to carry out evaluations have been lagging behind in terms of innovation. In an effort to close this gap, the authors here offer a study of the possibility of using closed tests that can be analysed in terms of rigorous algorithms, are replicable through automated software and use the concept map structure in a variety of ways.

Keywords: concept maps, evaluation, e-learning, assessment.

Introduction

Recent decades have seen an increasing awareness that the adoption of refined procedures of evaluation contributes to the enhancement of the teaching/learning process. In the past, the teacher's evaluation of the pupil was expressed in the form of a final mark given on the basis of a scale of values determined both by the culture of the institution and by the subjective opinion of the examiner. This practice was rationalised by the idea that the principal function of school was selection - i.e. only the most fully equipped (outstanding) pupils were worthy of continuing their studies and going on to occupy the most important positions in society.

According to this approach, the responsibility for failure at school was to be attributed exclusively to the innate (and, therefore, unalterable) intellectual capacities of the pupil. The learning/teaching process was, then, looked upon in a simplistic, linear way: the teacher transmits (and is the repository of) knowledge, while the learner is required to comply with the teacher and store the ideas being imparted.

The rapid economic and social progress that has taken place since the second half of the 20th century, alongside the diffusion of the concept of democracy among more and more peoples of the world, has led to a redefinition of the role of the school and of its evaluation practices. It is not by chance that one of the United Nations' stated objectives is to ensure the provision of primary education for all by the year 2015. The new goal of school is to train free-thinking persons, promoting their personal development while respecting their individuality. As such, evaluation has become the crucial element, the yardstick with

which to determine what represents high-quality education/training and what does not. Against this new backdrop, no educational activity is delivered without taking evaluation into account as an intrinsic part of the activity. 'Evaluation' is here intended as the series of operations (concerning both the teacher and the learner) that accompanies the training process, providing constant feedback on its progress, and giving rise - in response to the information supplied - to adjustments that are geared towards compensating for the weaknesses exposed and are calibrated to meet the needs of the learners, with a view to reanalysing the results achieved at the conclusion of a given educational activity.

Accordingly, it can be said that evaluation has today become a continuous, systematic form of monitoring, which has as it main aims the regulation of educational actions on the one hand, and, on the other, the provision of support to learners in their efforts to develop their own potential.

In line with the approach taken by the scientific community of reference, it is possible to map out the elements that, as a whole, constitute the evaluation process:

- initial/diagnostic evaluation, aimed at collecting data on the starting point of the learners, in order to then identify their resources (strong points) and those areas in which they are lacking (weak points). This evaluation makes it possible to draft and implement educational strategies that, in all probability, will allow each learner to reach his of her training objectives fully
- formative evaluation, which also plays a diagnostic role in that it is geared towards defining the compensatory intervention should the monitoring operations (carried out at various phases in the teaching/learning process) show that the learner is having difficulties progressing through his or her training programme
- summary evaluation (final), aimed at evaluating the skills and knowledge acquired by the learner after having completed a substantial part of the training programme.

It is also important to note that, to take sufficient account of the evaluation process, it is necessary to look at the set of tools that it is recommended to prepare and deploy during the various phases of the process itself. While a tool in itself is never entirely neutral, it must meet certain conditions:

- it must be valid, meaning that it must clearly allow for the monitoring of performance indicators that are related to the objectives which it has been established are to be assessed
- it must be reliable, meaning that it must allow for the collection of data in the most unambiguous way possible.

For the most part, it is possible to create assessment tests through tools that provide closed stimuli and open stimuli. For each of the two types of stimuli, there will be corresponding possibilities of response.

The information given above defines the frame within which the authors are operating, and it also represents the condition that gave rise to the approach the authors intend to flesh out through this work.

In particular, the issue highlighted can be attributed to the evaluation environment in online educational scenarios, since these are scenarios that - compared with face-to-face situations - have new levels of complexity, due, above all, to the need to make explicit those functions that, in face-to-face-situations, are implicit and can be understood in terms of the cognitive and emotional states of the learners. It follows that, in distance-learning, the monitoring of the teaching/learning activities assumes greater importance, since it becomes an "element of regulation" in relation, amongst other things, to the emotional openness of the learners, the consolidation of learning and the differentiation of the training programme. Moreover, faced with such complexities, it is essen-

tial that every phase of the assessment in which monitoring takes place should be highly analytical in order to allow for appropriate adjustments to be made, at different levels, to the training programme.

Our Proposal: Ontologies and Maps for Evaluation

The structuring of the disciplinary context in an ontological key is something that has always been present in education, but has been significantly grounded by the methodological and technological evolution of e-learning – in other words, by the strategic re-engineering of training processes that has resulted from the availability of new, online digital technologies.

In other words, there has been the necessity, on the one hand, to enhance the quality and versatility of educational material deriving from the responsibility to substitute, in the delivery of the content, the person-to-person lesson, and on the other hand, the potential for the dynamic reconstruction of documents and the use of graphics afforded by digital technologies, which involve the possibility/necessity of designing and constructing documents intended to represent the mapping of consciousness and interactive modes based on these documents. To a large extent, the aim is to characterise ontologically the information (the "learning message"), increasing its semantic transparency and interoperability in order to promote its use, on the part of the learner, as a tool through which to interpret reality.

Disciplinary ontology, in a "metagenetic" relationship with the representation of consciousness through concept maps (the term "metagenetic", borrowed from the field of biology, where it denotes precisely the relationship between the gamic and agamic forms of ascomycetes, works very well as a definition for the relationship between ontologies and concept maps: the ontology is transformed into a map through graphical representation, and the map thereby constructed in collaborative form is both a tool for analysing the context and an ontological composition in itself), is then a fundamental tool in educational development linked to the use of innovative technologies, and is extraordinarily effective in terms of the potential it opens up within educational processes, in relation to making consciousness dynamic, in relation to the interaction between the stakeholders of the training process (in particular, those inclined towards constructivism: the collaborative construction of the map-based/ontological structure makes the example undeniably concrete), in relation to the representation/management of the cognitive context and, last of all, (though this relates to interaction as a whole) in relation to the evaluation of learning.

How, then, can concept maps be used in the ongoing and ex-post evaluation of training processes? The tool created by Novak, which is generating considerable interest on the part of the scientific and educational communities, has various potential methods of utilisation that differ markedly from each other. In order to highlight certain possible applications of concept maps to the act of evaluation, let us look now at the fundamental elements of which they are composed – i.e. concepts and relationships. The concepts can be translated into nouns (indicating the objects) and adjectives (the properties of those objects), whereas the relationships can be translated into verbs (actions or states) and adverbs (specifications of those actions or states).

While this division between concepts and relationships is not rigorously strict (think, for example, of the concept of reification in the semantic web: a concept may contain two terms, as well as the relationship that binds them together), it does clarify Novak's intuition and, at the same time, proves its usefulness in relation both to the macrostructural dimension (the hierarchical index of a cognitive context, which we can find in a specific essay or we can draw from the essays generally available in the sector, can be developed into a conceptual map through the insertion and labelling of non-hierarchical relationships between the topics it contains), and to the microstructural dimension, as demonstrated by numerous instances of the application of maps, including in primary educational contexts, to the graphical transposition of single phrases. The objective tests that use

structural maps can, then, refer both the macrostructural aspects of the context and to closer, more specific analysis of the different topics.

The construction of objective tests of the evaluation of learning can be developed in the two ways indicated above – i.e. open and closed. In the former case, the analysis of an open test occurs at the structural, conceptual and semantic levels. From the structural level, it is possible to draw some indications about the cognitive style of the subject. From the conceptual level it is possible to reconstruct the cognitive paths taken by the subject (taking into consideration the correspondence between single concepts and specific categories, as well as the relationships between multiple concepts). The semantic level, in contrast, allows for information to be gleaned about the subject's capacity for comprehension in relation to a text: the text is taken to represent the outcome of an act of communication (not simply, then, texts in verbal language, but also images, sounds, electronic objects – i.e. anything that, in accordance with the type of language used, requires competence in order to be understood). At the semantic level, the test can be used to verify the acquisition and comprehension of the cognitive/relationship-based fabric of the discipline. This is, then, an important result if one considers the limits to which even complex closed texts are subject: the use of a single linguistic code (verbal language) in the construction of the message, and the reference, in many cases, to notional or purely mnemonic notions.

This research is currently oriented towards the latter direction – i.e. the composition of closed tests that can be analysed in line with strict algorithms (meaning they can be replicated through software automation) that use the structure of concept maps in a variety of ways. The first method is the reconstruction of the map relating to a context that is inherent to the discipline (a general context or one that is specific to a certain part of the context) through the combination of the conception-based and relationship-based elements supplied in two separate lists (or, alternatively, in a single list: the recognition of the character of the concept or relationship can also be part of the test) that are complete ("complete" in the sense that they contain all of the elements of the map to be reconstructed: the lists may, on the other hand, and with a view to rendering the tests more complex, not be "exclusive", meaning that they can also contain other distracting elements). In other words, and to give a small example, the test consists of the reconstruction of the concept map, inherent to the discipline of Graph Theory, and includes the following concepts:

1. graph
2. linked graph
3. tree
4. oriented graph
5. nodes
6. arcs

and the following relationships (the indication of the two syntagms separated by a slash indicates the different readings of the relationship starting from the two concepts that it links):

1. belongs/includes
2. is composed by N/N compose
3. is composed by N-1/N-1 compose
4. is composed by/compose
5. is greater than/less than *a* (this relationship is a distractor).

The test is correct if the following are linked:

> the concept of the "tree" to the "graph" and to the "linked graph" with the relationship "belongs/includes"
>
> the concept of the "linked graph" to the "graph" with the relationship "belongs/includes"
>
> the concept of the "oriented graph" to the "graph" with the relationship "belongs/includes"
>
> the concepts of the "nodes" and "arcs" to the "graph" with the relationship "is composed of/compose" and the same concepts to the "tree" with the respective relationships "N compose/is composed by N", "N-1 compose/is composed by N-1".

The evaluation derives from the relationship between correct indications, erroneous indications and omissions: an initial approach assigns two points to correct indications, minus two points to erroneous indications and minus one to omissions. In the case of the example shown above, the maximum score that can be achieved is, then, 14 points, and the definitive test score is recalculated on the basis of the proportion between the score achieved and the maximum possible score. Naturally, the "quality" of the test (meaning its validity and reliability) is proportional to the size of the relationship-based fabric to be reconstructed – i.e. to the number of nodes and arcs indicated. We feel that, as a rule, any sufficiently complex problem must contain at least 20 concepts and 15-20 types of relationships.

A second method, which is similar to the first but slightly simplified, involves supplying a network of concepts and relationships in which the concepts are identified from the start by labels, and the relationships must be selected and positioned on the map by the learner on the basis of a complete, but not exclusive, list. The opposite approach - i.e. when only the relationships are indicated - can be discounted as being overly similar to a "puzzle", and is aimed more at highlighting oversights on the part of the learner rather than his or her ability to reconstruct the context.

The third method, which is based on the learner's observational and critical skills, involves supplying a complete map containing errors, such as indications of non-existent relationships, the erroneous labeling of existing relationships and the insertion of concepts outwith the context. In such cases, the evaluation depends on the quantity of errors detected, with different scores awarded on the basis of the different types of errors, as a proportion of the total quantity of errors.

Alongside these three methods, there are also others, some newly designed and some based on the interpolation of the pre-existing methods. As such, it is important to underline that the choice of the method adopted, the composition of the test and the explanation of its functionality to the learners (through an initial made-up example) are complex activities, and so the teacher must pay a great deal of attention to the natural difficulties of calibrating such an innovative evaluation methodology and to considerations of the impact of such innovations on learners who are not accustomed to working with conceptual maps.

Conclusions

The purpose of our study is to set in place a testing structure that effectively meets the needs highlighted by e-learning in relation to the question of evaluation. In practice, it is necessary to demonstrate, on the one hand, the presence or absence of a significant relationship between the results of the evaluation through objective tests carried out using maps (which are extremely useful in testing comprehension of the relationship-based fabric of the discipline) and, on the other, to carry out traditional, oral-based tests (based on subjective judgement) and structured (objective) tests. We feel that such a composite approach will make it possible to demonstrate the valid-

ity and reliability of evaluation methods based on maps, which are currently used only to a very limited extent in education, and to verify the "distance" of the result in relation to the others.

References

Canas, A. J., Hill, G., Carff, R.,Suri, N., Lott, J.,Eskridge, T., Gomez, G., Arroyo, M. & Carvajal, R. (2004). *CmapTools: A knowledge modeling and sharing environment*. *1st InternationalConference on Concept Mapping*, Pamplona: Direccion de publicaciones de la Universidad Publica de Navarra

Dennett, D. C. (1993). Learning and labeling. *Mind and Language, 8* (4), 540-547.

Gattullo, M., (1968). *Didattica e docimologia. Misurazione e valutazione nella scuola*. Roma: Armando Armando.

Kremer, R. (1994). *Concept mapping: Informal to formal*. In W. Tepfenhart, J. Dick, & J. Sowa (Eds.), Proceedings of the *Third International Conference on Conceptual Structures, Knowledge Acquisition Using Conceptual Graphs Theory* Workshop. University of Maryland College Park, MD., Aug 19, 1994. pp. 152-167.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept Mapsas facilitative tools in schools and corporations*. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.

Macnamara, J. (1982). *Names of things: A study of human learning*. Cambridge, MA: M.I.T. Press.

Pedroni, M., (2006). *e-learning e rappresentazione della conoscenza*, Ferrara: Tecomproject.

Quine, W. O. (1953, 1961, 1980). *Da un punto di vista logico. Saggi logico-filosofici*, Milano: Raffaello Cortina (ed. it. 2004).

Tamayo, M. F. A. (2004). *El mapa conceptual: Un texto a interpretar*. *1st InternationalConference on Concept Mapping*, Pamplona: Direccion de publicaciones de la Universidad Publica de Navarra.

Trentin, G. (2004). *Apprendimento in rete e condivisione delle conoscenze*, Milano: Franco Angeli.

Varzi, A. (2005). *Ontologia*, Roma-Bari: Editori Laterza.

Vertecchi, B., (1993). *Decisione didattica e valutazione*. Firenze: La Nuova Italia editrice.

Williams, C. G., (1998). Using concept maps to assess conceptual knowledge of function. *Journal of Research in Mathematical Education, 29* (4), 414-421.

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