REFINING THE ROLE OF THE SCIENCE TEACHER IN THE IT EPOQUE

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Abstract

The use of computer-based educational tools is increasing fast and it can be predicted to become extensive or even dominant for a number of functions. On the other hand, there are functions that can never be replaced by multimedia tools, and can only pertain to a teacher. In the case of science education, these functions relate to the building of the perception of what science is and how it proceeds, to the stimulation of fundamental curiosity attitudes, to the development of logical reasoning (including inherent language-of-science aspects). This implies a refining of the role of the science teacher to emphasize these functions and interface and balance them with the functions that are increasingly delegated to computer-based options. The paper includes reflections on the features of this "refining", substantiated by the consideration/analysis of concrete examples from current classroom practices and from diagnosed students' difficulties specifically concerning the functions that are inherently human-pertaining. It is expected to contribute to the educational investigation for the design of approaches aimed at maximising both the benefits of computer-based tools and the fundamental roles of the science teacher.
Key words: *development of reflection abilities, IT in science education, teacher's role in science education.*

Introduction

The use of IT-based/computer-based teaching activities is expanding rapidly, with the fast increase both of computer power and of cost-affordability. It has added tools that are both extremely useful and fascinating, like many forms of visualisation. It enables new options both for classroom activities and for (earners' personal study. It has radically changed the way of searching for information, and the amount of information that can be accessed in a short time. It adds possibilities like that of following courses taught in far away places, listening and viewing the lecturer in real time.

It appears natural to pose the question as to whether computer-based teaching/learning can replace the human teacher and the classroom activities associated with the presence of a human teacher, and, if not, what can be the role of the teacher in coexistence with IT-based educational options. The current work develops a series of reflections with specific focus on science teaching, attempting to identify the educational components that are so deeply inherent to human-pertaining abilities that they can only be developed through direct learner-teacher interactions, and to outline the main characteristics of the new roles of the science teacher, in view of a full utilisation of the advantages/benefits offered by IT technology, without diminishing or renouncing those human-pertaining aspects that constitute the backbone of the ability “to do science” and, therefore, of science development. Among these, the aspects associated with the ability to complex thought, in all its forms, appear those that more exclusively require the guidance of a teacher.

The nature of science and science teaching

The nature of science, of the scientific method, of the discovery process, of the validity extent (or truth-ness probability) of the information/knowledge it generates, is an issue of such fundamental character that it has been the object of investigation and reflection through centuries, by scientists as well as by philosophers. Discussing it would go beyond the scope of the current work. Attention will be here given to those aspects that can be integrated into science teaching, both as part of the overall education of a human being – like, e.g., the development of an inquiring mind – and as part of a more focused familiarisation with science and its approaches.

Two major streams can be identified in the current approaches to science teaching: an approach that could be viewed as pertaining to an empiricist-type domain, favouring the learning of individual facts/bits of information, and an approach that can be viewed as more closely linked to the core of the Galilean method, giving importance to the links between facts and to the building of frameworks through the continuous interplay between experimental information and conceptual reflection (Mammino, 1998). The values of the latter approach require full utilization and fostering of the thought-abilities typical of the human mind. The refining of the science teacher’s role envisaged in the current discussion is mostly referred to this type of approach.

The practical/implementation aspects of science teaching

The values of the adopted educational approach permeate all the implementation aspects of the teaching process, from explanations to classroom interactions to assessment criteria. The way IT is utilised falls within it. If the objective is the simultaneous and integrated development of observation, analysis, interpretation and reflection abilities, active teaching/learning perspectives are the most apt (Pinto Cañon, 2007) and IT-based options become tools that can be beneficially integrated into interactive-teaching/active-learning, with full awareness of their advantages and their limits. Careful consideration of the major components of classroom activities, and of the major features determining the level of acquisition of scientific knowledge by students, can clearly highlight the distinction between what can be “delegated” to IT and what remains typically human-pertaining (i.e., teacher-pertaining).

Explanation is the fundamental activity of the teaching process. In the stage when a new topic is first encountered in a course, the learner’s active involvement can be realised through aptly selected questions stimulating students to reflect on what they already know, and to use it as a basis on which to gradually build the frameworks corresponding to the new information (Mammino, 2006-a). This requires suitably tuned responses by the teacher to individual answers by individual students (and the high variety of possible answers, in relation to the individual students’ backgrounds, is not apt for forms of standardisation that might be turned into programming). In this stage, IT can serve as a tool to illustrate information (both from the teacher and from students’ answers) by selecting suitable examples, simulations, visualization etc.

Explanation is not limited to the stage when a new topic is first presented – it is an integral component of all the activities, which actually become diverse explanation vehicles. One of the most powerful activities/tools is error analysis (Mammino, 1996 & 2002; Love & Mammino, 1997), that can be ideally turned into a tool for classroom interactions and collective search for correct answers, with gradual optimisation of the answers until a satisfactory one is achieved (Mammino, 2008). To maximise its benefits, the analysis requires continuous *in situ* tuning to the characteristics of each error analysed and to the needs of each individual student, as they surface through interactions. This, in turn, requires extensive knowledge and high flexibility from the teacher, to find the best (often creative) ways to guide students to identify and understand the nature of each analysed error, thus attaining better understanding of the concepts involved. The task is highly demanding because of the very high, probably limitless number of different errors that students may invent on a specific issue (as the experience of every teacher who has been teaching the same course/topics over many years can confirm). The task largely exceeds the possibilities of computer-based options, as a computer programme can incorporate explanations of an ensemble of "simple" errors and activate links when those errors appear, but cannot respond to the variety of possible errors, or the complexity of the explanations needed for the analysis of most errors concerning science concepts.

Visualisation has fundamental roles in science teaching/learning (Gilbert, 2008). IT has enormously expanded the possibility of visualising objects and events, thus enormously increasing the effectiveness of visualisation as well as its ability to attract attention. On the other hand, the development of visual literacy, of the ability to read/interpret images and to communicate through images (models, diagrams) is developed through teacher-guided interactive options like the collaborative building of images, the use of images for error analysis, or the reading of diagrams in terms of language and in terms of mathematics (Mammino, 1999 & 2008).

The ability to understand and generate science requires high levels of reflection abilities and, therefore:

- the ability to identify links and combine pieces of information from different sources (even from different fields) not as a mere sum (A + B + C + ...), but as a sum including interaction terms (A + B + C + d AB + e AC + f BC + g ABC + ...).
- the ability to logical thinking
- the ability to abstract thinking
- the ability of drawing on acquired/internalised knowledge to perform sets of mental processes in an immediate way (a type of ability that is often included in the term *intuition*).

All these abilities require careful nurturing through gradual training and guidance in order to develop to full potentialities.

The ability to abstract thinking appears the one that may be more seriously jeopardised by the tendency to emphasize only concrete, individual examples – as currently dominant in most computer-based options. The problem is clearly explained in (Russo, 1998), symbolised by the difference between restricting mathematics teaching/learning to an approach where playing with sticks replaces the conceptual work with the abstract *segment* concept and an approach where abstract thinking is nurtured as the essence of mathematics, and sticks might just have the role of occasional auxiliary tools. Continuous decrease in abstract thinking abilities is already diagnosed in many contexts by educators. An example is offered by the increasing number of students experiencing difficulties in solving problems that do not require algorithms (or solution pathways) that they have already encountered and often memorised, but different algorithms – though these can usually be derived quite easily from the already encountered ones. Many other abilities fundamental for science understanding, like the ability to distinguish between what has general validity and what refers to particular instances (Mammino, 2001-a), are closely dependent on the ability to abstract thinking.

Thinking abilities are closely linked to a fundamental tool whose importance is often underestimated or not sufficiently emphasised – the language mastering. Language is not only the principal vehicle for communication; it is also an essential instrument of thought (Bruner, 1975). When science is concerned, the language requirements respond to what is termed the *language-of-science*, a mode of expression that maintains full consistence with the nature and characteristics of the object or event concerned, as well as with method-related aspects like the way and extent to which we know them (Mammino, 1995, 2001-b & 2006-b). Familiarity with the language of science is essential for science understanding and learning (Lahore, 1993; Mammino, 2006-b). The experience of disadvantaged contexts, where instruction occurs through a second language that students do not master adequately, provides enlightening evidence about the impacts of poor language-mastering on the acquisition of scientific knowledge (Rubanza, 2002; Mammino, 2005, 2006-c & 2007). The development/acquisition of language-mastering can only be fostered and nurtured by a teacher, simultaneously guiding the acquisition of increasingly sophisticated language abilities and thought abilities. An adequate sophistication level is necessary for the ability to utilise complex language, incorporating complex logical relationships, to enable the development of complex thought (sets of thoughts that generate one from the other, that explore and evaluate possibilities, that establish and distinguish what is real, what is possible and what is impossible). Complex thought is a fundamentally human-pertaining ability.

Writing is one of the fundamental activities that can simultaneously foster the development of reflection abilities and the acquisition of knowledge (Beall & Trimbur, 1993; Cooper, 1993; Castro, 1995), as it demands careful reflection on what one already knows, or is in the process of learning, in order to verify the correctness/clarity of each piece of information and to organise and express them according to a logical thread. It can also provide valuable diagnostic information to the teacher, apt for real-time responses and interventions (Mammino, 2008). This activity pertains to the domain of what requires active guidance by a teacher, as only a teacher can have the ability to follow and asses the content and organisation logic of the texts written by students, and to discuss them with the students. The increasing resort to multiple-choice (closed) questions – also in view of the possibility of time-saving machine-marking that they offer – may jeopardise students' ability to written expression, unless adequate space is maintained for options in which students have to organise texts. The search for optimal combinations of closed and open questions – combinations that may be substantially different for different topics/themes – becomes a challenge for the teacher who wishes to maximise the benefits of both. Multiple-choice questions (basically requiring responses of the YES/NO type) may be designed in such a way as to stimulate the types of reflections that are needed to distinguish between the concepts expressed by different statements, and to choose the correct one/s. But they cannot replace the role of open questions, which require the type of reflection needed to organise information on the basis of the identification of relationships between the different information-pieces available.

Other limits to the possible roles of IT-based options are inherent in their nature. The search for relationships between the information discussed in the class and the students' everyday experience, whose role is fundamental for effective science education (Pinto Cañon, 2003), requires the participation and guidance of a teacher. The same is true for the attention or response to important features of the human nature, like diversity. Each individual is different from the others, and diversity is a source of richness, essential for the development of new knowledge. A teacher can appreciate diversity and tune the approach to the needs, requirements and expectations of individual students or groups. A computer cannot take into account the individuality of students or groups, or the specific needs of groups that are – for one reason or another – more disadvantaged. It cannot refine/tune the approach on the basis of the students' needs, or of their responses to each stage or detail of the course progress.

The roles of the science teacher in the IT époque

The brief overview of the previous section clearly highlights the challenges of the new roles of the science teacher in the IT époque, as the tasks that pertain to his/her direct activity are the more challenging ones, those that respond to the more sophisticated components of science teaching/learning – nurturing the development of abilities that imply complexity as their inherent characteristic, or border on it, and devoting attention to individual students in such a way as to respond to their individual needs. The importance of interactive teaching/learning options, already broadly recognised (Brewer, 1985; Forman & Cazden, 1985), increases sharply in front of these tasks.

The use of interactive teaching/learning options requires deep content knowledge from the teacher, for him/her to feel comfortable at guiding interactions. Promptness in identifying students' needs and responses, and continuous tuning of explanations and interventions to them, require a mental availability and creative attitudes. Designing the overall educational project in such a way as to maximise the benefits from the utilisation of IT-based resources (visualisation, simulations, answers to multiple-choice questions, etc) while simultaneously underlying the importance of the human-pertaining components (reflection/thinking abilities, expression abilities, creativity, etc) and developing them through the interactions, requires extensive knowledge as well as creativity. In summary, the role of the science teacher in the IT époque is bound to be more active and creative than in traditional approaches, because the teacher takes charge of the more sophisticated components of the teaching process, as more routine or standardisable components can be, at least partially, delegated to computers.

Discussion and conclusions

The IT époque poses the question of the optimal balance between IT-based educational options and the teacher's role. As far as science teaching/learning is concerned, IT-based options can have the role of valuable resources, while the development of the abilities that are fundamental for the acquisition of scientific knowledge – observation, analysis, reflection and critical thinking abilities – pertains to the domain of what requires continuous guidance by a teacher.

Interactive teaching/learning options are fundamental for the development of these abilities, as well as for continuous verification of the correctness and clarity of they way students perceive/interpret the information pertaining to the themes that are object of attention during the progress of a course. All the components that can be utilised as interaction activities (collective search of implications, to make the presentation of new theories active; analysis of errors; discussion/interpretation of images; etc.) require the knowledge-based guidance and properly tuned responses that only a teacher can provide.

In summary, it can be said that IT has the role envisaged by its name ─ search and provision of information ─ while the development of mental abilities and attitudes pertains to the teacher's role. IT can provide a huge number of individual pieces of information, but restricting education to this would remain within the limits of an empiricist approach. The ability to find links between facts – that is the foundation of the scientific approach – can only develop with the guidance of a teacher, through interactions and dialogue. This gives new emphasis to the role of the teacher, in his/her capacity as the person who presents new information linking it to the already acquired one, guides interactions, fosters the development of scientific curiosity, reflection abilities and creativity, and integrates IT resources into the overall educational project he/she designs to pursue these objectives.

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