Interdisciplinarity: rhetoric or the latest promising new field?

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Abstract: *The widespread interest in interdisciplinarity is justified by a number of drivers, for example complex research which requires an integrated theoretical approach and complex problems whose solution is likely to come from different modes of participation through the support of a team of experts with different backgrounds. However, to integrate different perspectives and establish an interdisciplinary research approach or network and, thence develop an interdisciplinary understanding requires that several barriers on at least two macro-levels - institutional barriers linked to career opportunities and practical, procedural barriers related to communication and collaboration among experts from different fields - be overcome.*
A case study is described in which artefacts for the educational field were created with the support of Artificial Intelligence (AI) elements. This project illustrates many of the problematic issues connected with the development of research in interdisciplinary areas.

Riassunto: *L'interesse crescente verso i temi dell'interdisciplinarità è alimentato da una serie di motivazioni legate alla complessità della ricerca che richiede un approccio teorico integrato. La stretta collaborazione tra ricercatori ed esperti con differenti background sembra essere la soluzione per risolvere problemi complessi. Ciò nonostante il processo di integrazione di diverse prospettive al fine di acquisire un approccio interdisciplinare e realizzare un gruppo di lavoro integrato che possa basarsi su una reciproca comprensione richiama alla necessità di superare ostacoli che si presentano a due macro livelli: barriere istituzionali, legate agli avanzamenti di carriera e barriere operative connesse alle modalità di comunicazione e interazione tra ricercatori che operano in campi differenti.*
Viene descritto un caso di studio nel quale la creazione di artefatti in ambito educativo ha visto il supporto di elementi di Intelligenza Artificale. Il progetto illustra molti dei nodi problematici connessi con lo sviluppo di ricerche in aree interdisciplinari.

Keywords: *Interdisciplinarity, research.*

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Interdisciplinarity: a brief overview

'Interdisciplinarity' is a recurring term in literature, often appearing in conjunction with 'research' and 'approach'; the first reference to interdisciplinarity dates back to 1944 (Lynch, 2006). In the definition proposed by Moran (2010, 14) interdisciplinarity is described as "any form of dialogue or interaction between two or more disciplines", and the concept of integration is not made explicit as it is in the integrationist interdisciplinarians' vision; they "believe that integration should be the goal of interdisciplinary work because integration addresses the challenge of complexity" (Repko, 2012, 4).

There is also a considerable amount of scientific literature which makes reference to 'transdisciplinarity'. Lynch reported that the term "'transdisciplinary research' first appeared in 1970, and by 2006 there were about 600 cites. It describes research that 'transcends' disciplines, that cuts across disciplinary boundaries, even including non-scientific sources of knowledge." (2006, 1120).

It is hard to determine the range of the semantic shift indicated by the varying pattern of usage of the terms multi-, inter-, and trans-disciplinarity; this is illustrated by the general discussions in seminars promoted as part of the *Interdisciplines* project supported by the Institut Nicod, Centre National de la Recherche Scientifique (Heintz, Origgi, Sperber, 2004). There is clear evidence of a shared perception of the need to overcome boundaries imposed by the formality of single disciplines.

The definition of 'a discipline' is a controversial issue, since the meaning of the term is conveyed through a series of variables. It is undeniable that the term is used to refer not only to a body of knowledge, but also to practices, frameworks, norms and tools by which knowledge is acquired; that is, to specific ways of thinking and reasoning. Disciplines are thus connected to disciplinary epistemologies even if it has been demonstrated across a range of disciplines that within the same discipline there can be different epistemological approaches (Rossi, 2011).

Boix-Mansilla (2007, 1) envisioned fours levels of disciplinary understanding: knowledge, methods, purpose and forms stating that "Individuals demonstrate disciplinary understanding when they can use knowledge and modes of thinking developed by expert communities (e.g. in history, biology, mathematics, visual arts) in order to create products, raise questions, solve problems, and offer explanations of the world around them in ways that echo expert practices in the domain."

The distinction between disciplines is mainly related to the 'institutionalisation' of discipline in the university departments; the context in which disciplines need to develop - the academic system - is tied to building the authority of a discipline and the aspect that contributes to defining a discipline's rigid borders. According to Post (2009), the value of discipline-related borders has three dimensions, related in some way to the reality of the university: accomplishing research, guaranteeing independence from external influences (Post cites political and social control) and ensuring a professional identity.

We will see that the symbiotic relationship between disciplines and universities represents the main barrier to interdisciplinarity, but before addressing barriers and challenges to interdisciplinary curricula and research we need to make explicit the driving factors behind the widespread interest in interdisciplinarity.

The literature highlights a number of plausible motivations for increasing interest in interdisciplinarity.

From the definition offered by the *National Academies Committee on Facilitating Interdisciplinary Research* (Kates, 2005) it is possible to identify one of the core aspects in fostering interdisciplinarity, namely the complexity of research, which therefore requires an integrated theoretical approach, and the complexity of problems, which are solved through a multi-modal approach, either through the participation of a team of experts with different backgrounds, or by a single investigator who masters several fields: "Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialised knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice" (26).

Repko (2012) states that the inability to apply contextual thinking to understand and solve complex problems is connected to the so-called 'silo perspective', namely a tendency to see the world through one perspective acquired in a specific discipline. The risks of having a narrow perspective can be overcome by two methods of integration, as mentioned above. A significant research problem might push a researcher to embrace new fields and widen his or her disciplinary borders as happened in cognitive science (Post, 2009); it must be emphasised that in this case the effort needed was so great as to raise doubts about whether it should be considered a success.

Wilson (1996, 201) underlines the downsides of being a "soloist" in interdisciplinary research, stating that the individual researcher faces an overload of tasks. A team which takes a collaborative and integrated approach may be the only sensible strategy for interdisciplinary research. This mode is also referred to as 'consilience' (Wilson, 1998) and would represent a departure from a "traditional manner of doing research - homogeneous, disciplinary, hierarchical - to a new approach that is heterogeneous, interdisciplinary, horizontal, and fluid." (Rhoten, 2004, 6).

Interdisciplinary community building progressed thanks to the use of new channels of scientific communication fostered by the development of the Internet. New media also led to the development of new forms of peer-review, publishing and recognition of research: "It has become much easier for individual researchers to establish and maintain communication based on common intellectual interests rather than on institutional alliance. The ever-growing free availability of scientific papers on line renders researchers less dependent on the library of their home institution (including paid online subscriptions). Discussion lists (and now web conferences) recruit over time their own rapidly evolving communities." (Sperber, 2003, 7-8).

The National Academies (2005) stated that the Internet can be interpreted as an example of 'generative technology', technology "whose novelty and power not only find applications of great value but also have the capacity to transform existing disciplines and generate new ones" (35).

Barriers to interdisciplinary understanding

Boix Mansilla (2007) stated that interdisciplinary understanding occurs when individuals "integrate knowledge and modes of thinking from two or more disciplines (or well-established fields of study) in order to "create products, raise questions, solve problems, and offer explanations of the world around them in ways that would not have been possible through single disciplinary means" (1).

Integrating different perspectives to establish an interdisciplinary research approach or network and thence developing an interdisciplinary understanding requires that several barriers on at least two macro-levels - an institutional, formal one and a practical, procedural one - be overcome:

- Communication within a team made up of researchers from different disciplines is likely to be affected by lack of mutual understanding,

perhaps related directly to use of language (e.g. giving the same word a different meaning), or to research methods (conducting, analysing and validating);
- Institutional obstacles have several different aspects: potential lack of interdisciplinary curricula at graduate and postgraduate level; choosing interdisciplinary research carries a real risk of damaging one's chance of establishing a successful career and obtained an secure institutional post (Sperber, 2003) and of the limited amount of funding reserved for interdisciplinary research.

Sperber (2003) provided a good example of mutual disappointment among researchers from different fields; the scientific communities of psychologists and anthropologists had "have different vocabularies, presuppositions, priorities, criteria, references" (4). The superficial similarities between the two disciplines did not help; instead they made communication less effective; over years of tentative collaboration "the same disagreements across and sometimes within disciplines are expressed in almost the same terms, as if disciplinary and theoretical affiliations could never be overcome" (5). The standards for research methodology in one community may be unacceptable or regarded as ineffective by another (e.g. the relevance of experimental evidence).

Educational institutions should provide suitable training to promote interdisciplinary understanding, but this might be only the first step in reorganising the way disciplines are structured within universities. Until discipline borders will manage scientific communities consensus to reward and fund researchers it will be difficult to conduct productive interdisciplinary research.

Turner provided a good account of the rationale for the relationship between disciplinary borders and academic power: "Disciplines are shotgun marriages […] and are kept together by the reality of the market and the value of the protection of the market that has been created by the employment requirements and expectations" (Turner, 2000, 55).

Should it be true that interdisciplinary research cannot develop without interdisciplinary education, the current academic system offers no prospect of progress; students are discouraged from pursuing interdisciplinary research because of the potential risks to a future research career whilst faculty staff who have already obtained a secure position relegate interdisciplinary research to the level of an additional research activity and do not devote time to acquiring the necessary competence. This situation results in what Sperber (2003) identified as a vicious circle since under this system no students get supervision in an interdisciplinary area, as a result of lack of competent supervisors and lack of interest.

Open questions

The ongoing debate about interdisciplinarity emphasises the importance of a set of open questions, this contribution focuses on two specific issues: the nature and rationale of students and practitioners training in interdisciplinary fields and the assessment of the quality of work conducted and published within an interdisciplinary framework. These two issues are strongly interconnected.

When considering training for interdisciplinary research we must consider at least two dimensions: the formal provision of dedicated graduate and postgraduate courses by academic scientific institutions e.g. the Education in Mathematics, Science and Technology programme at the School of Education, University of California, Berkeley and also the effort made by the wider scientific community to design frameworks able to reveal the core elements of a research product that make it interdisciplinary and set the parameters and methods for assessing such a product.

Eisenhart and DeHaan (2005), working as members of the National Research Council committee, which produced the report *Scientific Research in Education* (NRC, 2002), proposed a set of principles to guide the training of educational researchers: (a) diverse epistemological perspectives; (b) diverse methodological strategies; (c) the varied contexts of educational practice; (d) the principles of scientific inquiry and (e) an interdisciplinary approach to research (7). The last principle focuses on the need to break with the historical *habitus* of drawing a strong distinction between training for research in the 'hard sciences' and the 'soft sciences', offering trainee researchers in both domains the opportunity for what the authors call 'socialisation' to the 'Principles of Scientific Inquiry'. The distinction between training in hard and soft sciences is not limited to the kind of apprenticeship, but also the support available, in terms of fellowships and opportunities to travel and make contact with wider international scientific communities.

New fields of research are developing, some of them as a result of technological developments, for example the interest in artificial intelligence

(AI) in education, a field in which there has been dramatic progress in the last decade.

The Integrative Graduate Education and Research Traineeship (IGERT) programme offered by the National Science Foundation provides an example of a successful interdisciplinary graduate course. The programme aims to "catalyse a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries", to promote an interdisciplinary perspective which requires students to acquire a range of methodological approaches and collaborate with experts from different disciplines.

As stated above, offering interdisciplinary training courses also means designing tools for faculty to use to assess the quality of interdisciplinary research. Klein (2008*)* discussed the lack of shared criteria and standards for the assessment of interdisciplinary research and how this relates to concepts such as 'discipline', 'peers' and 'measurement'. Boix-Mansilla (2006) defined a set of dilemmas faced by those responsible for quality assessment in highly reputable institutions (e.g. the MIT Media Lab) when dealing with interdisciplinary research.

Boix Mansilla (2006) proposed an epistemic framework which recognised three dimensions of assessment for interdisciplinary work. The framework was based on an investigation which found that currently the most commonly used quality assessment procedures rely on indirect quality indicators e.g. the kind of journal in which a research paper is published. The framework highlights what Boix Mansilla called the "three epistemic symptoms of quality" in interdisciplinary research:

- Consistency: is the work consistent with previous findings and knowledge in multiple disciplines?
- Balance: is the tension between the different disciplinary perspectives resolved in a sensible balance?
- Effectiveness: does the work produce new insights or methods?

In considering indirect quality indicators we will focus on several issues: the difficulty of identifying scientific journals which publish interdisciplinary research and are accredited in more than one subject area; the risk that the review process is run by someone who is expert in one of the disciplines covered by a paper, but does not have the same comprehensive competence in other relevant disciplines. This second issue is directly related to the need for an effective peer-review process for publication of interdisciplinary research; what happens if there are no “peers”? We have emphasised above that it is important to offer interdisciplinary research training programmes and have supervisors able to train young researchers beginning their career in this ‘new field’. A similar vicious circle also affects the promotion and publication of interdisciplinary research in well-established journals.

Research lines

If as suggested (Sperber, 2003), the affinities between disciplines with a similar background are a problem, projects involving very different disciplines in the development of artefacts also face problems; in this case the difficulty lies in determinist and reductionist visions of the concept of application.

Below we provide a case study of the development of educational artefacts supported by AI elements. The I-Tutor project was funded by the European Commission and was a collaboration between the Departments of Information Engineering at University of Reading, UK and University of Palermo, Italy, and the Department of Education, Cultural Heritage and Tourism, University of Macerata, Italy.

AI is a mature sector, but its applications are rarely used in education for two reasons: low investment and ignorance of the potential of AI and distrust in its potential utility on the part of educational players. It is also true that figures in the field of information engineering have little interest in participating in such research because of the almost total lack of funding and the limited opportunity for innovation in educational applications in the sense that it would be interesting to apply tools already designed and created in the AI sector to the educational field.

The main difficulty relates to the model of collaboration. The educational expert and players in the target application field more generally, need to define the objectives and the characteristics of the artefact which is to be developed, whilst the AI expert has to create the prototype; a linear waterfall structure in which the two steps - identifying the objectives and creating the artefact - are not perceived as interconnected. The experience of the I-Tutor project showed that the design process and the creation process should follow a recursive path that could be characterised as a rapid prototyping approach (Tripp & Bichelmeyer, 1990; Botturi et al., 2007), in which the collaborative relationship between players in two different fields is continuous and recursive.

The quality of the final product depends on the level at which the players succeed in appreciating each other's epistemology and understanding its fundamentals.

There is an additional element to consider. Disciplines are not homogeneous in terms of epistemological framework, for example in education there exist several very different approaches: behaviourism, cognitivism, constructivism and post-constructivism. The external viewpoint of the researcher working in different fields often fails to distinguish the different approaches resulting in a tendency to consider everything from the single perspective that fits best with the researcher's approach.

In the field of education the cognitivist approach can most easily be operationalised, partly because it is often confused with a naive view of education - one which sees a direct relationship between teaching and learning, in which the purpose of teaching is to transmit knowledge - but these days a non-determinist view of the relationship between teaching and learning is prevalent; learning is viewed as an intentional student-based process and teaching aims to create an autopoietic and relational system that can foster the process.

The I-Tutor project

The I-Tutor project aimed to create artefacts that could be used in the educational context and more specifically, incorporated into a Learning Management System (LMS) used to run higher education courses. The artefacts were intended to help teachers maintain a non-determinist perspective on the relationship between teaching and learning. The artefacts are not intended to replace the teacher, but to help manage the huge amount of data generated by LMS activity tracking and support students' knowledge building processes.

This premise is already explicative to make it clear the change in most of the educational assumptions that are present in the world of Intelligent Tutoring Systems (ITS) that has a cognitivist background. Most current ITSs use artefacts which replace the teacher and guide the students through a series of activities in specific fields (usually training in basic subject matters, mainly connected to the shift from secondary school to further or higher education) in which many potential student errors are predictable and so the systems provide an effective intervention. This context notwithstanding the development process of the I-Tutor project was enriched by tackling unforeseen problems in the different sectors. For example educators had to take into account the need to operationalise their proposals whilst the computer science teachers gained insights from having to think about education in a non-cognitivist way.

The implications of the conclusion of the project are interesting. A first artefact of automated maps developed from a resource database prepared by a teacher. A bidimensional map represented the key concepts of the subject matter where they are located with an affinity rationale. The nodes of the map were not graphically linked. By clicking on the nodes it was possible to access related documents and resources in the database. The maps provided students with a comprehensive overview of course content and allowed them to access related resources. One of the main advantages of the maps was that they provided an alternative means of accessing resources. Every course has content structured in way that is related to the organisation of the course itself. The map showed the key nodes of the discipline and the spatial arrangement of nodes reflected the conceptual relationship among them. By depicting course content graphically the map provided students with a bidimensional representation of the course content that differed from that outlined in the syllabus; this promotes a re-crossing of the discipline that may improve the learning process. Students could also interact with the map to create a personal path connecting the nodes according to a personal rationale (Cannella et al., 2014).

A second artefact provided a visual representation of students' presence, operations, activities and output in the LMS. This artefact used algorithms typical of the clustering which allowed a teacher to visualise the data so as to compare them with the behaviour of the students. The organisation of data was dynamic and evolved according to the behaviour of the students involved.

Analysis showed that the development process for these two artefacts was not linear or regular. A first problem was related to the difficulty experts in the educational field had in explaining the non-cognitivist approach to the experts in information engineering. The naive vision of education as transmission of knowledge is very common among scientific communities not directly involved in the field. Understanding that the objective was to build artefacts that would support teaching and learning rather than either replacing the teacher or being used for automated learning was not trivial could not be taken for granted. Similarly, teachers in the educational field found it hard to understand the potential of AI and learn to direct the design of the artefacts.

It was immediately clear that development of a linear waterfall process would be impossible: educators proposed a black box pointing at the objectives and the outputs; engineers drew on their competence and knowledge of other relevant devices to create the box.

It was important that both the design and implementation processes be shared by the whole research group; conceiving and constructing the artefacts meant thinking about the potential of AI and the operational possibilities. Had the engineers assumed an overly prescriptive approach to the design process it is likely that artefacts based on a cognitivist vision, similar to existing AI applications would have been developed; the elements would have been structured and based on a clearly defined knowledge base, students would have been led step by step through a planned process.

The group had several preliminary meetings during which all the researchers explained the premises of their fields, this led to the decision to use a rapid prototyping path. Rapid prototyping guaranteed that the risk of drift was limited at each step, and that in every decision, particularly those taken in the intermediate steps, the group could control the meaning and the consistency from the different epistemological approaches of both disciplines (AI and education) whilst also taking full advantage of the potential of the technology.

Conclusions

This case study has illustrated many of the problematic issues associated with research in interdisciplinary areas, some of which were outlined briefly in earlier sections of this contribution. These problems are analysed below.

How to interact

This first challenge is linked to a fundamental conundrum. Although the importance of research which crosses disciplinary boundaries is now recognised, it is not possible as a researcher to maintain high level competence in several disciplines; however collaborative projects are not possible if the researchers involved have only a rudimentary knowledge of the epistemology of the other disciplines. This poses an apparently insoluble problem.

Blanchard-Laville (2000) has written about co-disciplinarity and proposed a solution connected to the context, that is, the project that is being developed and founded on the constitution of a research team available to interact and based on a mutual trust. It is suggested that this will activate an empathic process that allows all participants to appreciate the epistemology of the others even without a deep understanding of the foundations and global arguments in a specific field. Trust is an important premise. In the I-Tutor project engineers moved from a cognitivist vision to a vision closer to that of the expert in the educational field; that shift was the result of discussions about general issues and was predicated on reciprocal trust among the various teams in the research group. The experts in education had to think about how to convert their theories into an operational process; to do so they had to understand the potential of AI in order to participate in group discussion and negotiation of the design and creation of the artefacts.

The process was not linear. The most complex step was related to the need to make explicit the implicit epistemologies researchers had developed during the process, the engineers' educational model and the educational expert's AI model. If co-disciplinary process often seems to be based on the contribution that researchers made based on competence in their own domains, the I-Tutor project has demonstrated that collaborators' conceptualisation of each other's fields is as relevant. At the beginning of a project it is necessary to make explicit the naïve ideas that the researchers have about the fields of their colleagues in order to develop a shared epistemological background, even this is at a very basic level. The shared background enables the different players to use a shared language and understand some basic discriminating factors, to grasp the particularities of the choices to be made. A researcher cannot expect to acquire instantly comprehensive knowledge of another field different, so this knowledge should be enriched step by step throughout the process. This knowledge is also based on empathic processes, on trust built within the research group, and it is connected to the context.

Development of reciprocal understanding must be monitored throughout the project, during both design and implementation. The rapid prototyping design model is a recursive model for the design and creation of artefacts and seems most appropriate to this objective. Both teams in the group project should be involved at every step so that even in the intermediate phase, when apparently secondary choices are made, decisions are overseen by the whole group in order to maintain consistency with the general approach. The difference between two approaches is often more visible in decisions on specific options than in decisions about the broad direction of a project. Too often projects built on a firm epistemological basis produce artefacts of limited value because of inconsistencies between macro and micro levels of design.

Research and its relationship with the community

There were problems with research conducted for the I-Tutor project, both during its development and with the application of the artefacts and the implementation of pilot courses. These problems are connected to the relationship between the research group and the external scientific communities.

Many of the elements used in the artefacts did not represent progress in the field of AI. The interest from an AI perspective was the application choices and procedural hypotheses which had not been explored previously. This consideration affected the work of the project's AI expert as it was not always clear how the output would be useful academically and professionally. An additional downside was the lack of investment in technology in the educational field: is it appropriate to begin research that will not be developed further?

Another problem is tied to the presentation of the results of the project. When a scientific paper was submitted to an international ITS conference the reviews received were mostly from referees in information technology who had a cognitivist background. Of the three referees, two admitted to having difficulty in understanding the theoretical premises, stating that they were not familiar with the references given and that even if they had been able to evaluate the novelty of the research they could not fully appreciate it.

Any research group that is interested in interdisciplinary projects needs to develop its relationship with outside communities by participating in calls for proposals run by journals in the different fields represented in the research group in order to deepen reciprocal knowledge, particularly of theoretical premises, and make contact with areas in which might hold interest for the group as a whole. Collaborative participation in publishing and conferences demands that researchers move beyond a naïve view of their colleagues' fields.

In conclusion, research at disciplinary boundaries will become more important. In education technology will become more and more important and neither ideological prejudices against certain forms of innovation nor the use of obsolete technologies in school will continue to be tolerated; similarly the introduction of technology unsupported by an educational rationale will cease to be acceptable (Laurillard, 2012).

Empathic processes should be activated among the different sectors to promote communication and links at micro and macro level. The creation of research teams in which individual researchers adopt recursive rather than linear approaches and develop an affinity for their collaborators' fields is one way of achieving this. At macro level this kind of research depends on publishing in journals and maintaining an active presence at conferences for the different communities in order to foster an exchange of viewpoints.

Paradigmatic aspects (Khun, 1969) are also present; they affect the emergence of concepts and transversal and tangency metaphors in different disciplines; perhaps such elements should be highlighted and used as Trojan horses in the debate on interdisciplinary research?

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