Why AIED Needs Marriage Counselling by Cognitive Science (to Live Happily Ever After)

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Abstract. In this position paper, I reflect upon the question "Should AI stay married to Ed?", specifically referring to how research in AI and Education should cross-fertilize to define AIED as an independent practice, beyond its composite fields. In my view, a mix of approaches, inspired by cognitive science, should serve to formulate characteristic research questions for the AIED community. Such questions may be derived from considering the social context of learning and how it is applied in artificial systems, as exemplified by educational games and ITS with Teachable Agents. I conclude by suggesting two discussion points of emergent interest to AIED research: (1) How can we formulate scientifically based guidelines for the use and evaluation of educational software? (2) Is there anything such as "unique AIED competence" and, if so, what does this imply for the AIED identity?

Keywords: AIED, marriage, multidisciplinary research, educational games, ITS, Teachable Agents.

1 Introduction

What *is* and what *should be* the role of AI in Education and conversely of Education in AI?

For all its successes, the very need to reassert AIED's position as a research field after 25 years may reflect two critical shortcomings: a failure to appreciate its relative independence from both AI and education, on the one hand, and an underused and conservative application of AI for educational purposes that has not been fully embraced by educators, on the other. One might compare to fields like HCI or interaction design, which have successfully defined and built research communities around cross-disciplinary domains that focus on people's use of technology.

A stumbling-block to AIED practitioners might be that the field has no obvious "core", that is, it has no clearly defined subject of investigation, such as "computers" or "interactive systems" or even an abstract topic like "instructional strategies". The most concise, official description of the field appears in operational terms, with respect to the scope of the AIED journal, as "the application of artificial intelligence techniques and concepts to the design of systems that support learning" (from ijaied.org). This leaves room for a great variety of research and different approaches – which is good – but the field seems to lack a common conceptual framework for relating advances in AI to advances in education research that would inform characteristic AIED research questions. Is it at all clear for the field's different practitioners what the common denominator of AIED research is?

I posit that it means something to be knowledgeable in AIED and being skilled in AIED research as such, beyond having expertise in AI and Education as distinct fields. The identity of the AIED field is then formed by the content of this "AIED competence", its unique contributions and necessary limitations to other areas. In effect, other considerations become important for AIED than in traditional AI research that does not necessarily apply to education. For example, the AIED researcher with an AI background might be more concerned with "weak AI" as a means to make students learn better or pay more effort, while having to take into account what can be realistically implemented and evaluated in a school or classroom setting, on different technical platforms (tablets, smart phones, laptops etc.) and for different groups of students. Likewise, an AIED researcher with an education or pedagogy background would look to how the use of technology can add to present pedagogical strategies and teaching methods as a means to achieve the same goals. Eventually, as research from both ends cross-fertilize, they may transform educational practices by setting new learning goals defined by the use of technology (e.g. "21st century skills") [1].

In this text, I present a view of AIED that develops from practical considerations for a functioning relationship between AI and Ed, but also forms a new area of research for educational purposes. The educational context both constrains and opens up a largely unexplored scene for novel applications of AI techniques that further motivates the growth of AIED as an independent field. As such, I argue that AIED should aspire to achieve two overarching goals: (1) Improve human learning, and (2) Inform and expand the scientific basis of education. (Notably, the AIED Society has set as its aims to promote knowledge and research in AIED but does not explicate the aims of the field itself.)

As a field of empirical, scientific inquiry (and not just the pragmatic "application of AI techniques"), AIED may be fruitfully compared to Cognitive science. The success of cognitive science as an academic discipline shows how intrinsically different fields – among those psychology, biology, computer science, anthropology and philosophy – have found a common identity in the pursuit of certain well-recognized research questions under the multidisciplinary banner of "cognition". Notably, one does not have to be an expert in all these fields to become an expert cognitive scientist, and it is possible to work within any of these fields without doing research of intrinsic interest to cognitive science. Thus, cognitive science found an identity of its own from combining perspectives and methods from various disciplines, in principle not different from how AIED can develop from merging aspects of AI and education research.

The first question then becomes how the multidisciplinary AIED field should be conceptualized in relation to its history and previous accounts. Second, we need to know what the content of the practice is – the research outcomes and applications – that motivates AI and Ed's relationship. By setting the example, cognitive science might be just the marriage counsellor that AI and Ed need to develop their common interests and secure the future well-being of AIED.

2 Reconceptualizing AIED as a multidisciplinary field

Looking back, Cumming and McDougall [2] already in 2000 speculated how AIED might be "mainstreaming into education" in the (then) future of 2010. They argued both for relabeling the field ("especially the 'AI'", p. 204, which they considered does not communicate the field well) and its crucial need for "AI expertise of the highest order" in order to "keep at the forefront of all of the contributing disciplines" (p. 205). This appears, to express it mildly, as a tall order for AIED to take. Above all, it seems to indicate that the field has long had an unclear identity, particularly when it comes to defining the kind of AI expertise needed for being an AIED, rather than an AI or educational, researcher.

I will not propose a new label for AIED research, but perhaps its identity should not be formed on basis of its historical, composite fields, but rather from what motivates AIED research as a multidisciplinary practice in the present and for the future. As to the topics of research, there is a vast array of educational technologies available today that did not exist at the field's inception 25 years ago. In short, things have changed, and besides emerging new technologies, there is an emerging new generation of AIED researchers.

Looking forward, I approach this question from the perspective of a beginning researcher in the field, who needs to define his future area of expertise. While being actively involved in the AIED community [e.g. 3, 4, 5, 6], I do not see myself as belonging either to the "AI field" or the "Education field" or at least not exclusively so. Rather, and for reasons outlined in the introduction, I would attest to Cumming and McDougall's [2] observation that "Many AIED researchers would be happy to be described as cognitive scientists." (p. 198) and their suggestion that AIED "should overlap with cognitive science" (p. 205).

Like cognitive science, albeit on a smaller scale, AIED may play a crucial role for bringing computer science-oriented (AI) and psychology/pedagogy-oriented (Education) research together. Figure 1 illustrates how this view of an emerging AIED field differs from previous conceptions of bringing AI and Ed together.

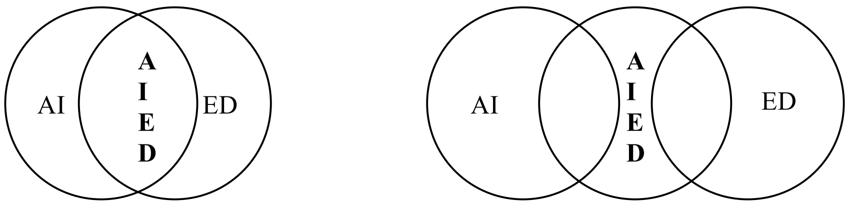

Fig. 1. Two alternative conceptions of AI + Ed: (left) AIED as the combinatory interests of AI and Education research; (right) AIED as an independent, multidisciplinary field, defining its own aims and scope in between the respective fields of AI and Education.

The emancipation of AIED research from its surrounding disciplinary boundaries (Fig. 1, left) would make room for its own defining research questions (Fig. 1, right). Whereas AI puts machine learning and human-like intelligence in focus, Education focuses on fostering human learning and intelligence. AIED knowledge should then serve to bridge this gap by informing techniques to promote more efficient and intelligent interactions with humans that improve educational outcomes (rather than, say, aiming to reproduce human abilities or solving computational problems that do not feed back to students). A combination of methodological approaches is likely needed, as every method carries with it implicit assumptions about what knowledge it can produce (from an AI as well as an education perspective).

Often multidisciplinary knowledge is needed to appreciate the educational applications of different technologies. A classic example would be how computers in school are most often used as word processing and communication tools, whereas the sophistication of the underlying technology would make the computer the obvious arena for students to learn from and by AI technologies in any school subject. However, just like book not read, the computer becomes meaningless as an educational tool unless it is engaging enough for students to actually use it. Student engagement puts the interactive qualities of the system in the forefront, not in terms of superficial "usability", but rather as to "learnability" and "teachability". This poses an array of non-trivial AIED research questions as to how the technology functions in the educational context and how AI may serve to improve the scientific basis of education. Next, I consider some of these challenges in greater detail and how they are dealt with in two types of AIED applications that exemplify the present and future potential of the field.

3 What AIED Brings to Artificial intelligence for Authentic Learning

Education is a social process characterized by learning in interaction: between teachers and students, among students, and, if AIED has a say, between "intelligent" artefacts and both teachers and students. As extensively demonstrated by Reeves and Nass' "media equation" [7], adding interactivity to a system naturally invites social behavior. Accordingly, as computerized learning environments become increasingly interactive and adaptive, they can be said to expand upon the social dimension that affects the learning process. This has important implications for AIED, first for distinguishing AIED applications from other, "static" learning material such as text books; second, for which methods should be used to study learning outcomes (e.g. some would take this as an argument for a situated perspective on learning, or against "media comparison studies" that undervalue the instructional process as such [e.g. 8, 9]). Stressing the interactivity aspect also brings forth the "social intelligence" of the system as an important consideration for new AI techniques.

With the more advanced interactivity that comes with technical development, it makes sense for a field like AIED to take social motivations for learning with artificial systems to the core of its interest. Considering that students may vary as much in what keeps them motivated and engaged as they do in cognitive abilities, AI techniques devoted to exercise social influence (e.g. by virtual agents and feedback) that adapt to the individual student would allow for unique educational arrangements. More specifically, AIED may serve to dissolve previous conceptions of "education", noted also by Cumming and McDougall, as something that takes place in groups (e.g. in schools and classes) versus "learning" as something that happens in an individual (sometimes with a book or a computer).

Schwartz and colleagues [10] argue for a specific form of computer interactivity that generates a "learning sweet spot" of both high motivation and high learning from students' social motivations. This "sweet spot" is achieved through designing an environment that encourages shared initiative and engagement in interaction, in their case with a teachable pedagogical agent. The researchers make the important point that the technology is not used with the goal to "perfectly" model human traits, conversation or intelligence, but only to be *sufficient* to elicit the social schemas (e.g. that of teacher/student) that engage students in productive interactions for learning.

Notably, the research question and goal of making a human-like functioning, artificial system (e.g. "How can we model human intelligence and learning?") are essentially different from those of making a system designed to help students organize and reason with their own concepts (e.g. "How can we visualize students' knowledge?", "What level of prompting from the system is optimal for triggering students to contribute with their own knowledge?"). One can also say that the goal of the former is to produce an *autonomously* intelligent system, whereas the goal of the latter is to produce a *jointly* (with the student and to the advantage of the student) intelligent system.

The perspective on "joint intelligence" takes more of the social context into account, which brings AIED closer to traditional educational research, drawing from established pedagogical strategies such as peer tutoring and learning-by-teaching. However, what makes AIED unique as a research field is that it deals with variables known to have an impact on learning but that have never before been possible to manipulate independently and systematically, such as social roles (including altering avatar representations of gender or ethnicity), others' skills or knowledge level (using virtual peers), and parameters for individually adapting material for teaching in groups. The educational impact of such manipulations makes a prominent subject for AIED research.

In sum, the social nature of interaction points to a range of issues crucial to understanding the impact of AI techniques when employed in real-world educational settings, which AIED should serve to make explicit for both the AI and education community:

First, it is essential to understand which social factors drive students' learning, since technical functions, even when used, may turn out to be used in unintended ways that diverge from the original pedagogical principles [6].

Second, it is important to realize that employing AI techniques may bring "added value" to traditional teaching but possibly also "reduced value", if it takes time and resources from educational needs that are better met by human teachers or other means [11]. It should be a concern of educators to determine when and for what purpose to use AI-based systems for students' learning, and it should be a primary concern of AIED research to distinguish between the "added" and the "reduced" values for different knowledge needs.

Third, and arguably the most crucial point for positioning the AIED research field, the shortcomings of technology, as well as the shortcomings of educational practices for predicting successful learning, leave space for new and original research on what forms students' learning experience in their interaction with technology. I take two examples to show how our expectations of how AI techniques "should" work can be as important for the outcome of the interaction as the underlying technology itself. This also shows that even if the social context cannot be fully controlled or predicted, a careful design can devote AI techniques to create certain "illusions" of intelligent behavior that promote students' learning.

3.1 Example 1: "Educational" games

Many computer games make use of some AI; however, AI techniques appear strikingly underused in the subcategory of so-called "educational games". However, there is an ambiguity in the term "educational games" that both confuses researchers and confounds educational practices. This confusion is mirrored in the debate of whether or not "computer games" as such are effective for learning (for contrasting accounts, see [12, 13]).

In short, the "educational" in games might refer to the educational *subject content* in terms of topics relevant to the curriculum (such as "a math game training fractions"[1] or "a political strategy game that models the global economy"[2]), or it might refer to the (intended) educational *use* of the game in a school context (such as playing a commercial game in the *Halo* or *Assassin's Creed* series that employ AI techniques and that some teachers may use for training "strategy thinking" or "problem-solving" skills, though these are not explicit aims of the game). Games with subject-relevant content typically include explicit exercises or "game tasks" for the intended skill (e.g. counting, spelling tasks) whereas the educational use of other games typically assumes that relevant skills are learned implicitly, through the practice of other kinds of overarching "game goals".

As to the vast offer of games that claim educational content, there is rarely any advanced AI to direct or scaffold the learning process. For example, several AIED-relevant review- and development articles have remarked that the vast majority of math games in the open market (e.g. in AppStore) do not adhere to even basic, cognitive design principles and they seem to contain little more than simple 'drilling' exercises with limited feedback [14, 15, 16].

Using other, commercial computer games for educational purposes, may have great effects on student engagement but little or no effect on learning [13]. This is because game-players may utilize the affordances in a game in a relatively superficial way, learning only "what to press when" to achieve certain results, such that good game performance and progression do not necessarily require the deeper cognitive processing wished for good education. Linderoth reaches the thought-provoking conclusion that the educational appeal of computer games may come from maintaining an "*illusion of learning"* (ibid, p. 59).

The task for the educator is further complicated by the fact that some commercial games might indeed require great skill (e.g. for solving puzzles) but it is hard to determine how much of these abilities are trained by the game itself and, if so, to what extent they transfer to school-relevant tasks (e.g. solving physics problems or mathematical equations).

Nevertheless, it seems safe to say that the education industry has failed to take on board the creative application of the relatively sophisticated "game AI" techniques used in the commercial gaming industry. Rather than the "illusion of learning" on

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[1] http://www.mathsgames.com/fraction-games.html

[2] http://www.positech.co.uk/democracy3/index.php

behalf of the student, an alternative and productive use of "game AI" (or "weak AI") would be to maintain an "illusion of intelligence" [17] on behalf of the software that keeps the student engaged in intellectual activities for actual learning, just like the game-player is kept engaged in playing for entertainment. In other words, a game might not need cognition-like computational power to have educational value in terms of meaningful learning, but the resources it does use should be dedicated to educationally relevant goals. It is to the latter point commercial games often cut short.

Whereas the above may be bad news to educational games, it is good news to the AIED research field, because it shows that there are both *potentially* effective AI techniques already in place and an enormous interest from the education community to employ them (e.g. Education apps being the second largest category in AppStore after Games, both in numbers of 100.000+). Games appear as a domain where AI and Educational interests merge but where AI techniques have been underemployed *for learning*. This makes "educational games" a primary topic for AIED research, a brain child still in its infancy, which calls for more attention and better interdisciplinary upbringing by AI and Ed.

3.2 Example 2: ITS including Teachable Agents

Intelligent Tutoring Systems (ITS) might represent the most dedicated and successful use of AI for student-centered learning, since it actively employs AI techniques not only to structure and present material but also for communication purposes that (more or less) model that of a human teacher. I chose this example (and to include Teachable Agents, or TA, as a "reversed" model of tutoring) because it clearly illuminates how AI-based system can make use of familiar social schemas [e.g. 18, 19].

ITS and TA exploit and benefit from social learning mechanisms (most visibly so when represented by a visual character on screen although the system could be entirely text-based) derived from the student-teacher relationship. As these systems become increasingly advanced, the knowledge needs about people's social motivations and social psychology in general become of greater importance to the AIED field.

But is it a realistic, or even wanted aspiration, for AIED purposes (i.e. for use in teaching and learning) to develop virtual agents that are as life-like or sociable as a real person? This is an important question for the future of AIED because it poses where resources are better spent; for instance, how should the overwhelming task of producing human-like AI be balanced against working out effective instructional strategies that can be formalized and computed?

Importantly, artificial systems can invoke social responses to improve learning without having to employ AI. For example, Okita et al [20] showed that the mere belief in "real" social interaction when interacting with a computer agent had positive effects on learning, again an effect exploited in the TA metaphor [18]. Some of my own AIED research [3, 4] suggests that social effects of interacting with a Teachable Agents might also transfer from the learning situation to being tested on one's knowledge; students took on harder problems and performed better on those problems if tested "in company" with the TA they had previously worked with in a learning game. In short, remarkably simple social stimuli may trigger complex and beneficial learning behaviors.

As an interesting contrasting example, some researchers have employed AI techniques to create an "illusion of teachability", by making an agent appear more socially sensitive to the student's input than it actually is [21]. In this case, the system construes a mental model of the human student that informs the agent's responses so it appears as "teachable", though it actually only reflects the kind of knowledge gaps and mistakes that the student has displayed. In effect, the student has to "teach" exactly the things needed to improve his/her own shortcomings (and not necessarily those of a third-party agent). This adds to the power of the social schema by showing that not only the intentional belief of teaching drives the effect, but also the belief in how the tutee (the agent) responds.

My point here is that an important topic of AIED research is to disentangle the social and cognitive mechanisms underlying the effects of ITS and TA, both for the general understanding of such systems and for developing resource-effective systems. For example, the "teachability" features of a TA may be theoretically divided into the underlying (AI-governed) mechanisms that direct the information processing, and its social appearance, as constituted by its visual looks, the things it says, and the types of choices it offers. A key contribution of technology is to offer means to control and regulate these factors through digitalized and personalized "social" responses that can avoid the pitfalls of human socializing (such as distraction from the task and negative stereotyping) while maintaining and even adding to the benefits (such as constructive feedback and active engagement).

In sum, ITS and TA represent a case of true cross-fertilization of the AI and Education domains that produce some unique results, never before seen in human history: semi-independent, virtual beings whose sociable qualities place them somewhere in between artificial and human agents, more like active "educational peers" than passive information systems. In this sense, AIED breaks up the traditional teacher/student dichotomy and includes a third party in the educational design. Students' social motivations to engage in interaction with this party might be more a matter of the effective representation of social features as learned and recognized from the outside world, than how its knowledge is represented inside the system. For use in the social context of a classroom, this makes a strong argument for bringing in more of the educator's experience of "what works" into the design of AI systems.

4 Moving On

Taking the example of cognitive science, I aimed to illustrate AIED as a multidisciplinary practice that forms its identity in relation to technical development as well as pedagogical methods and social learning theories. To the extent that "AI" and "Education" hold separate identities as distinct fields that do not seamlessly combine or "marry", it might be more productive to focus on what they can form together, as a common theme for their future. Educational games and ITS with TA provide example domains that cannot be said to be either "AI" or "Ed" but very much AIED. Relating to those examples, I conclude by suggesting two further discussion points that AIED should take into consideration when moving on together:

1. As to educational software (including games, ITS, simulations and other digital learning environments), AIED still seems predominantly concerned with development and design aspects, whereas little has been done to serve educators' need for sound evaluation and scientifically based, qualitative assessment of existing applications. How do design criteria for learning-effective software translate to evaluation criteria? Considering the vast selection of educational apps to date, perhaps the best way to guide teachers is to formulate meta-criteria that help inform their own selection and recognize well-designed content? How can AIED assist in making this judgment scientifically informed?

2. Considering the range of issues an AIED researcher may have to confront, as exemplified in this text, what is the essence of the "AIED competence" – what does an AIED researcher (need to) know that others don't? Is there anything such as "interdisciplinary expertise" in its own right and then, how does this show, and how is it applied, within AIED research? Is the explication of specific AIED knowledge areas required (or just helpful) for forming a unique identity of the field?

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