

# The Missing Peer, Artificial Peers and the Enhancement of Human-Human Collaborative Student Modelling

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**Abstract:** We present peerISM, a domain-independent collaborative student modelling system to support two students in critiquing each other's work in distributed and face-to-face mode. It has an artificial peer to provide additional support, and to enable interaction to continue with a single learner when one partner 'goes missing'.

## 1 Introduction

Much ongoing research focuses on the value of human-human collaboration in which one human peer interacts with another. The value of synchronous and asynchronous forms of collaboration have been examined with results that need careful interpretation [1]. Another strand of research applies the notion of collaboration to the issue of building a shared model of a learner [2,3,4]. Such collaborative student modelling minimally requires that an individual interacts with a computer system to negotiate the contents of an 'open' student model.

While there is a plethora of environments notionally designed to support collaborative work, there are relatively few environments in which the system both supports and enhances the activities of two human students in critiquing each other's work in a detailed manner. We describe such a system: peerISM. PeerISM extends the notion of collaborative student modelling by seeking to utilise the strengths of human-human collaboration together with a system designed to support and enhance the quality of the interaction.

This paper explains why peerISM was extended to include an artificial peer. The work is distinct from many other approaches to incorporating an artificial learning companion into an environment, for example: research on learning companions sometimes stresses the scarcity of suitable human resources requested by an individual [5]; or assumes that benefits of face-to-face communication will automatically transfer to human/artificial learner pairs. Work with peerISM emphasises *human-human interaction*, with *additional* support from an artificial peer. This artificial peer assumes a more central role when a human peer 'goes missing'.

## 2 Rationale

Artificial Learners (AL) have been investigated as a way of helping students by providing a computational peer with whom a human student may learn. The aim of integrating an AL into an intelligent learning environment (ILE) is to take advantage of benefits of face-to-face collaboration settings, in particular: the potential for encouraging learner reflection, and combining this with the benefits that an ILE can offer. Early implementations examining the potential of ALs were described by Chan & Baskin [6], and Dillenbourg & Self [7]. Interest in ALs continues, as current systems build on previous findings, to try to define the most efficient kinds of AL to interact with a student. For example, Dillenbourg & Self found that human learners (HL) became disinterested when their AL could not offer sufficient useful

suggestions. This problem is now being addressed in systems focussing on ALs with knowledge levels aimed at maximising the effectiveness of interactions for the human student [8,9].

Inevitably there will be differences between AL-HL, and HL-HL interactions, and some systems are designed for use purely with collaborating HL pairs [10,11]. Another possibility is distributed HL pairs [12]. The choice of approach is likely to depend on the particular learning context. For example, it has been suggested that face-to-face collaboration might be useful in situations where HLs have already developed mature social skills, and also possess similar knowledge levels; and distributed HL pairs might be more appropriate for tasks which require time to reflect [13]. Another issue to consider is the collaboration skills of HLs interacting in some way via computers [14]. A potential problem for HL-HL pairs is coordinating the presence of two learners—an issue which is irrelevant to AL-HL pairs [5].

It would be useful to develop an approach to computer based, or computer mediated pair interaction, which could be more widely applicable than most implemented to date. MIST [11] has the advantage that it is independent from content knowledge, within the task of learning from texts. This is beneficial not only because it can be used across courses, by different students, but also is advantageous in that individuals may become accustomed to using the system repeatedly, in different situations, reducing the need for them to learn a new program. This is particularly important where students are unaccustomed to computer use.

It is important to maintain the aim of promoting reflection in a domain independent system, and the literature on self and peer assessment offers a useful direction. Both types of assessment can benefit learning, and can be usefully employed formatively, in a range of subjects [15,16,17]. In the case of peer assessment, a time delay is implied between initial completion of a task and self evaluation by one student, and the evaluation by the other, allowing the giver of feedback time to reflect. If this feedback is on the same task that the student performed themselves, they will be interacting with the material for a second time, and will be likely to obtain greater benefit since they have already considered their own self evaluation before being confronted with another student's responses to the task. This might help combat the problem noted by Dillenbourg, that "the availability of reflection tools does not guarantee that users do indeed reflect on their learning experiences" [18].

Another way to promote learner reflection is to encourage learner/system collaborative student modelling [2,3,4]. This involves student/system interaction about student model contents. An accessible student model is in some sense similar to a learning companion, as expressed by Chan of the AL in Integration-Kid: "...the companion's behaviour can be viewed as a form of active student model...it interacts explicitly with the student and reflects to the student an image close to him" [19]. An additional advantage of collaborative student modelling is that the image reflected to the student is intended to be *of* him, rather than close to him. Thus, if this image does not correspond to how the student evaluates their beliefs, they should recognise the differences between their beliefs and the contents of their student model, focusing reflection more specifically onto their own knowledge and misconceptions.

Combining self and peer assessment with collaborative student modelling suggests a student model with contributions from the student modelled, and from a peer, in addition to representations of the student's beliefs inferred by the system. Thus the notion of collaborative student modelling is extended beyond student/system negotiation of model contents, to include information from peers: human (HP) and/or artificial (AP)<sup>1</sup>. PeerISM is an Inspectable Student Model comprising representations from the learner modelled, an HP and/or AP, and the system itself. The aim of promoting learner reflection is maintained. PeerISM is flexible with regard to its context of use, as it is domain independent. As student contributions are in the form of 'assessment', different skills are required than for HP-HP collaboration, where collaboration is often expected to occur from scratch. For example, if assessment criteria are provided, learners have a focus from which they may develop their individual and joint interaction, making the question of knowledge level of each member of a pair less crucial. Face-to-face interaction can then occur, when partners already have a focus

for their discussion [see 10]. The problem of peer availability can be overcome by acting only with the AP.

### 3 Promoting reflection with peerISM

PeerISM is designed to help students learn by promoting reflection in the following manner:

- by requiring users to provide a self-assessment;
- by exposing students to the work of others;
- by requiring students to give peer feedback, and evaluate the feedback that they give;
- by providing an inspectable student model derived from self evaluation, peer evaluation (HP and/or AP), and system inference;
- by admitting students into their model to offer amendments to representations of their beliefs; to comment to a peer about their evaluation; or to comment on the system's remarks;
- by giving a starting point for human-human interaction (at or away from the computer).

Three versions of peerISM have been implemented: one which allows short one-word answers that can be evaluated by the system [20]; one which permits only text as input; and a third, a variant of the second, which includes an AP. The second and third versions are the focus of this paper, and are domain independent. The system is used as follows:

- 1 Students individually input their textual answers to questions provided by their tutor, into the edit fields shown in *answers and self evaluation* in Fig. 1. They then click on a button to give a quantitative self evaluation for each answer, on a four point scale (very good; good; variable; problematic). Qualitative evaluations can also be noted.
- 2 Students view their partner's work in a separate section (not shown), or on a printout.
- 3 Peer assessment is given in the *peer feedback* section. Qualitative feedback is given in edit fields, allowing commentary on any aspects of the work the evaluator wishes. A quantitative evaluation is also provided for each answer, on the same four point scale. Evaluators also indicate their confidence in their feedback and evaluation (sure or unsure).
- 4 Students view their respective *student models*, created from self, HP and/or AP, and system comments (see Fig. 2). The student's own answers are also available. The self and HP evaluations are taken from the assessments provided by each partner; in the case of the HP, also taking into account their confidence in their evaluation. AP evaluations are inferred from the system's checking of the answer edit fields for keywords provided previously, by the tutor. This may not lead to an accurate assessment: e.g. a student might use an alternative acceptable word. However, since the AP is giving a *peer* evaluation, the recipient of inaccurate comments will be aware of the possibility of inaccuracy. The model of the learner inferred by the AP is presented as textual feedback. The system evaluation is inferred from the combination of quantitative self evaluations and all available quantitative peer evaluations [see also 21,22]. Again none of the information sources are guaranteed accurate. If all evaluations are similar, peerISM assumes these to be *probably* true. If there are differences, these are noted. The system's model is also presented textually.
- 5 When viewing their student model, students may make comments for themselves, to their HP and to peerISM. Comments to HPs are designed to remain as HP-HP interactions unless a problem cannot be resolved. Such interactions may be on- or off-line. Comments may also be sent to the tutor. This facility is intended for difficulties that are not resolved to the learner's satisfaction. Encouraging student written explanations as questions to their tutor, in cases of disagreement, is designed to promote self explanation of beliefs and domain knowledge—which may result in students resolving difficulties for themselves [23].
- 6 Viewing paired student models has been suggested to lead to intense face-to-face peer (HP-HP) interaction, including self- and other-explanation, and spontaneous peer tutoring [10]. The inspectable student models of peerISM are intended to fulfil a similar function—learners will have completed the task and reflected on their views before meeting face-to-face, where intensive interaction may then develop, based around the contents of their

respective models. This should help address the observation of Teasley and Roschelle that "collaboration does not just happen because individuals are co-present" [24].

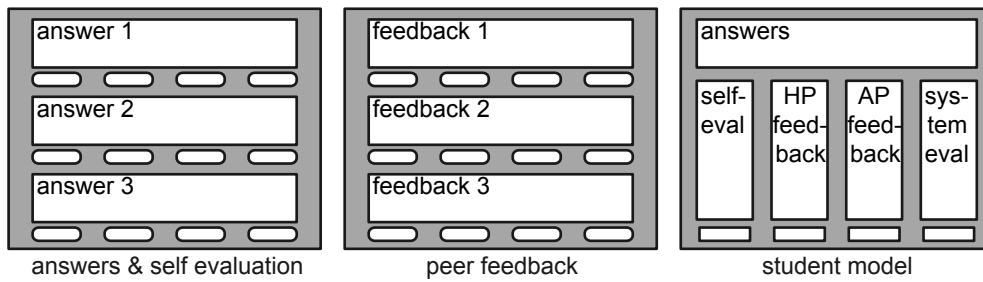


Fig. 1: the peerISM screens

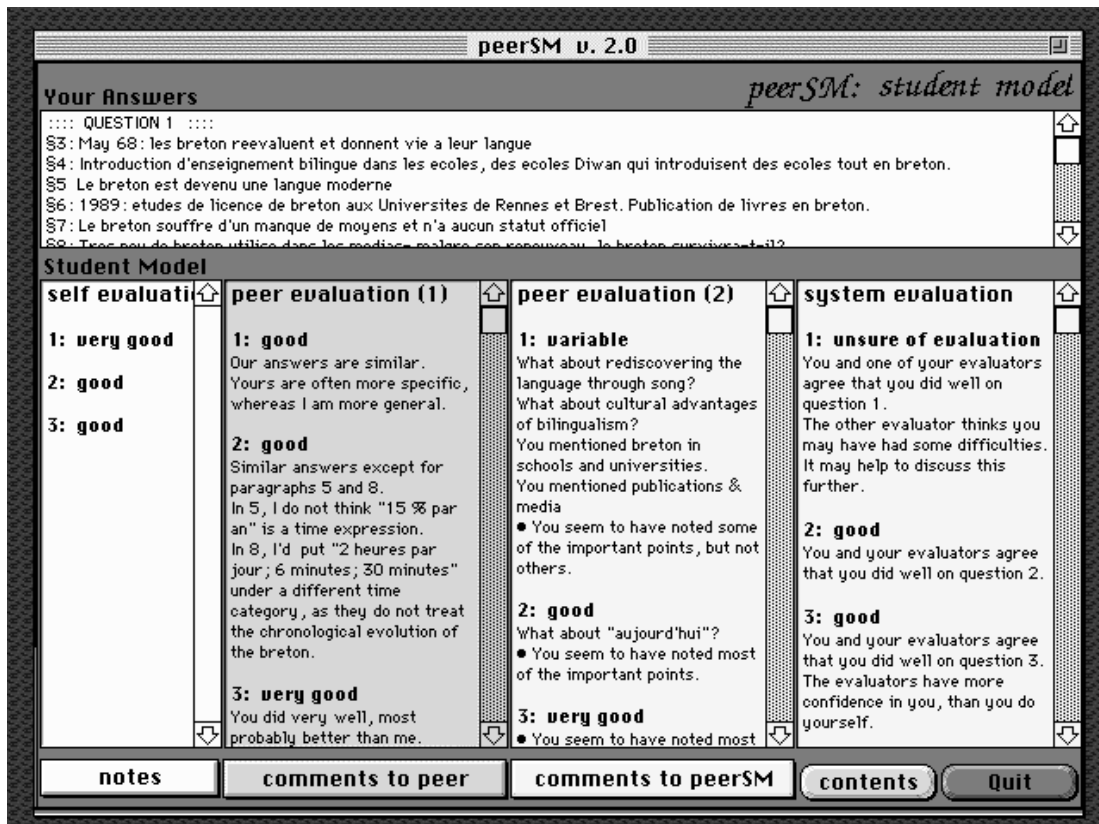


Fig. 2: the student model showing self, HP, AP and system contributions

This human-human collaborative student modelling may result 'only' in modified mental models, or may also lead to explicit changes in the peerISM models, if learners choose to interact with the system again. In the latter case, students may find further changes occurring in their mental models. The kinds of interaction between students at this stage should be determined by the students themselves, according to the approaches that *they* find useful.

Because the multiple agents involved in peerISM interact about the evaluation of a piece of work, initially in asynchronous mode, selection amongst available peers based on student models is not such an issue as in other contexts [e.g. 21,25]. However, if more than two HPs become involved in the peer feedback context, this must be considered [see 26].

## 4 An example context of peerISM

### 4.1 *The domain*

Halliday states "Talking and writing...are different ways of saying. They are different modes for expressing linguistic meanings" [27]. Although some of the claims for differences between oral and written language may be oversimplified [see 28], students do experience difficulties in writing which arise to some extent from gaps in their understanding of the function of genres. Writers must also appreciate the perspectives of both author and audience as, in contrast to conversation, the target readership is usually absent during composition [29].

It is suggested that there can be a relationship between the development of effective reading and writing skills [30]; and the analysis of texts by learners can be a useful way of facilitating their appreciation of what constitutes a good text, in a certain genre [31]. In accordance with these views, undergraduate students taking a French Language module as part of an Applied Language degree were encouraged to analyse texts, to empower them to attempt similar documents themselves. Texts were studied as follows: a general overview was gained from the title, first and last paragraphs. Students then independently summarised the main ideas in each paragraph, and highlighted key structuring features, e.g. time phrases and connectors. The use of tense and lexis was considered, with reference to the part played in the cohesive development of the content. Finally, a summary of the text was produced in pairs.

PeerISM was introduced to promote interaction between pairs of students to help them develop familiarity with text structure and organisation of content, by having to discuss their accounts of these aspects of the text with a partner. Such deliberation aims to raise awareness of document structure, to then serve as an example for the organisation and structuring of writing. Self and peer evaluations focussed on the independently written summaries, with the aim of this leading to subsequent face-to-face interaction about the learners' respective student models. The final co-written summary was a means to link discussion about the student models with the task of understanding the structure of the text.

A second reason to use peerISM in this context is the feeling of isolation faced by many, when writing. Introducing peer interaction in reading and summarising was designed to make it easier to overcome this remoteness amongst students, by getting them accustomed to working together, and then continuing peer feedback and interaction into the writing process. A further benefit is that peer discussion of writing can lead to the development of more effective writing techniques, resulting ultimately in the production of better texts [32].

### 4.2 *PeerISM in use*

The use of peerISM described below was undertaken before the AP was available. Hence all peers were HPs. The group comprised 12 students. All pairs were self-selecting. Students were assigned the task described above, and shown how to use peerISM. Written instructions were also distributed. Help is also available from within the peerISM program.

Only 6 of the 12 students attempted to use peerISM. Of those learners who used it, there was only one pair who completed all steps as a pair. This was because 4 of the users were partnered with people who did not attempt to use the system. From their class participation, it appeared that the non-users did little preparation in any form (i.e. their lack of participation seemed to be general, rather than directed specifically at the peerISM component of the task). The pair who did work together suggested that they would like to use the system again. Thus they completed their assignment for the following week in the same manner. They provided useful information about their experiences with peerISM, and on the basis of this were invited to be co-authors on this paper. Some of their comments are reproduced in Fig. 3.

As was the case for most of the group, neither KD nor CH were habitual computer users. Nevertheless, they found peerISM useful for learning. It enabled them to work at a

pace which suited, a feature considered important by each of them. Both students also described the benefits of reflection facilitated by peerISM. Peer interaction had a positive effect for both: each made changes after viewing their partner's work, and each reflected further on returning to the work a second time. In addition, both felt the need to discuss their work and the feedback. CH also felt that although conventional (face-to-face) peer work can be very helpful, with peerISM this can be taken further by providing a focal point for reflection.

KD felt that peerISM might not be so effective for pairs who are at different levels, an issue raised also by Jehng et al [13]. It has been suggested that if there are differences between the cognitive abilities of individuals, a collaborative interaction will change into one of tutor-tutee [33]. If this occurs with peerISM, this kind of interaction may also be beneficial: the tutee will receive explanations, and the tutor will be reinforcing their own knowledge by making it explicit [see 10]. KD was subsequently asked to comment on how she felt about the potential of peer tutoring in such a situation (see Fig. 3). KD clearly felt that had she found herself in either role of a peer tutoring situation, it would have been useful for her own learning. However, she was very sensitive to the possibility that this may not apply to other learners—some may not wish to assume the role of tutor only. Further investigation is required to determine the relative benefits of peer tutoring and peer collaboration in the context of peerISM, and how much these may vary amongst individuals.

As well as its role of enhancing reflection on the domain, for CH inspection of her student model served as a trigger to realising how she might further improve, by more detailed self evaluation. However, she also raised the question of whether more comprehensive self evaluation might result in less peer interaction. This possibility merits further consideration. If it is found to be the case for some partners, the benefits gained from additional self evaluation need to be weighed against effects of reduced peer interaction, for those pairs. CH felt that in their case, increased self assessment would not have led to reduced peer discussion.

<p><i>KD:</i> I enjoyed doing the exercise and found it useful. Many times I have done some work and I have wondered how good my answers were, and how someone else would have tackled the questions. I could have asked of course, but it is not always easy, as some people lose interest once they have done the work. Sometimes I felt I would be taking someone's valuable time, and also it is at times embarrassing to ask 'how did you write...'</p> <p>Comparing my own work with someone else's can help me learn new ways of building constructions, how to summarise, etc., especially as I cannot ask the tutor every time I have a question, otherwise he would not have time left to teach! Learning through a system like peerISM means that I can learn at my pace without my partner being present. I can read her answers as many times as I like. Assessing her work makes me contribute to her work as well as making me think.</p> <p>In order to give feedback, I read my partner's answers, which I found impressive: a very good summary, well chosen words, no unnecessary details. I then went back to my answers and compared them with C's and saw how I could improve my work, but I felt I had to ask my partner a few questions first. Our feedback led to a discussion between us, for example, C had used 'par rapport à' and we talked about when to use the expression. We also talked about how to find the main idea in a paragraph, etc.</p> <p>I feel that peerISM has enhanced my learning. For example, my summaries were too long, too detailed, and looking at C's was a good model to follow. If I had spent the same total time working alone, I would not have benefitted as much because I could only have compared my work to what I already know instead of learning new skills.</p> <p>My only reservation is that students assessing each other should be of roughly similar ability.</p> <p><i>Response when asked about tutoring:</i></p> <p><i>KD:</i> If I had tutored a partner, it would have been useful to me in more than one way. It would have allowed me to reflect on my work more than I usually do so that I could explain it to my partner. It would encourage communication between us and I would enjoy helping her. If my partner was the stronger, I would welcome tutoring, as for me the best way to learn is by example and comparison. PeerISM allows me to do just that. But I still feel I should also be able to help her, as she might otherwise lose interest.</p>	<p><i>CH:</i> I think that pair-work can be very fruitful, yet often the problem seems to be that the partners do not get enough time for reflection. There is usually time pressure. Working with somebody face-to-face one is also more hesitant with criticism perhaps: whilst one would not dare to 'offend' somebody face-to-face, one can write a more critical comment on the computer. In this way peerISM does in my opinion bring down unhelpful barriers on the one hand (i.e. being too polite), and contributes towards constructive criticism on the other. PeerISM made me type my answers, gave me time to view my partner's answers when it was convenient for me, and took away immediate time and peer pressure. This proved positive. Giving feedback meant that I generally reconsidered the questions, which consolidated my learning. I also had to evaluate my own answers at least semi-consciously, compare them with my partner's and make a judgement accordingly. I made amendments to at least one of my answers on coming back to the work.</p> <p>To look at somebody else's work in this formal way was a good experience. One can, of course, talk to people about the work, and this is usually done in conventional pair work. PeerISM seems to give the starting point of taking an informal discussion a little further: one has the work on paper first, i.e. everything is very conscious and ordered, but perhaps not detailed enough. One can then discuss each other's work in a more informed, and at the same time, informal, way. It really makes one work that bit harder than in conventional pair work.</p> <p>I am a strong believer in 'real communication between humans', and I realise that peerISM in no way excludes this. K and I both felt the need to discuss our input, especially where discrepancies arose. We did this partly formally in front of the computer, and partly informally over a cup of coffee. I think it was in part writing the feedback, and partly receiving it, which triggered our questions.</p> <p>Working alone would not have been as useful: one would not spend so much time on the work, i.e. one would answer the questions once and not go back and reconsider them. I think having a second opinion is always helpful, even if only to reconfirm our own.</p> <p>When I looked at my student model I realised I could perhaps have used more self evaluation. When I write an answer which is not a straightforward yes or no response, and which is intended for someone else's consumption, I often want to explain the 'hows' and the 'whys'. I think this could be contained in a more detailed self evaluation and might help subsequent communication between partners. On the other hand, it might make that very communication superfluous. In our case, I think more detailed self evaluation would have helped us make our argument more explicit, and assisted our partner in giving feedback.</p>
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Fig. 3: comments from an HP-HP pair

## 5 The artificial peer

Chan [34] discusses roles for APs and HPs in combination, in Social Learning Systems. Because of the situation which occurred in the above student group, where four individuals used peerISM, but their partner did not, an AP as an additional peer evaluator might be useful

to help overcome the peer availability problem. This could, in fact, be described here as an *uncooperative peer problem*, since the non-users avoided the work in general: they did not complete the initial individual stage (even on paper), thus there was no work for their partners to give feedback on; neither did they provide feedback to their partners, who had done the initial work. With an AP, the four students with non-user partners may have been able to gain some benefit from peerISM without the need for a reliable HP.

The problem of non-users remains. It may be the case that some students gain less from peer interaction, working better independently. The question then arises as to whether there is any reason to try to enforce HP-HP interaction for such individuals [33]. However, the 6 non-users in this group did not perform the final task at an adequate level. For such students it might be helpful to encourage AP-HP interaction, as their motivation may increase if they are able to benefit from giving and receiving feedback without having to interact with an HP.

The AP, although less central in this context, may also be useful for HP-HP pairs as an additional resource. Fig. 2 shows how differences between HP and AP feedback to an individual might prompt learners to think about different issues<sup>2</sup>.

## 6 Discussion and further work

This paper described peerISM, a domain independent system to encourage learner reflection by collaborative peer modelling and self and peer evaluation. PeerISM may be used with a human and/or computational peer. The AP differs from APs in most other systems in the same way that the HP contributions to the student model differ from traditional HP-HP collaboration: the HP and AP are not trying to collaboratively learn domain content provided through the system, but are carrying out peer evaluations.

In the empirical work reported here, the student population split into those who participated as HP-HP pairs and found the experience rewarding; those that were let down because their partner did not participate; and those who were not highly motivated. From these observations, we propose further research to investigate both the ways in which the use of a simple AP affects the HP-HP interaction; the ways in which the AP influences an HP in a situation where another HP cannot—or will not—participate; and the possible motivational value of an AP for those who are poorly motivated to do even the off-line work.

An important issue to consider is the minimum necessary functionality of the AP. The functionality could reasonably include: performing the tasks; commenting on HP performance including generation of confidence values; negotiating a new assessment based on HP response; changing the AP's own solution. The present AP can comment based on keywords the teacher believes necessary for a successful answer, but this will not permit much negotiation to occur, and such an AP cannot do the task. Current work is investigating the potential for this additional role, to enable an HP to offer feedback when no HP partner is available.

## Notes

1. AP is an artificial peer: it may or may not itself be capable of learning.
2. Fig. 2 shows the model comprising self, HP, AP and system contributions. It was amended from one of the models of the successful pair, with AP evaluations added, and system comments accordingly altered.

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