Applying Interactive Open Learner Models to Learning Technical Terminology

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Abstract. Our work explores an interactive open learner modelling (IOLM) approach where learner diagnosis is considered as an interactive process involving both a computer system and a learner that play symmetrical (to a certain extent) roles and construct together the learner model. The paper presents an application of IOLM for diagnosing and fostering a learner's conceptual understanding in a terminological domain. Based on an experimental study, we discuss computational and educational benefits of IOLM in terms of improving the quality of the obtained learner model and fostering reflective thinking.

Keywords. Intelligent tutoring systems, student modelling, meta-cognitive skills.

1 Introduction

A recent trend in student modelling has focused on overt approaches that envisage the diagnostic process open for inspection, discussion and direct influence from the learner [12]. Involving the learner in diagnosis originated from ideas of decreasing the complexity of learner model (LM) maintenance and tackling dynamics of student's behaviour [14]. Furthermore, overt diagnostic methods are expected to yield pedagogic gains in providing the means for reflective learning [4].

Our work explores an interactive open learner modelling (IOLM) approach and conceives diagnosis as an interactive process involving both a computer system and a learner that play symmetrical (to a certain extent) roles and construct together the LM. IOLM goes beyond open learner modelling [10,11,13] and elaborates the notion of interaction, which allows challenging the robustness of the learners' knowledge and provoking the users' active engagement in diagnosis (while learners may happen to browse passively through open learner models). We have expanded the idea of LM negotiation [4] where the interaction is triggered chiefly by conflicts between the computer and the student's views. Instead, IOLM manifests a constructive dialogue guided by the computer that flexibly switches between different diagnostic tactics.

A framework for IOLM has been presented elsewhere [8,9]. It includes distinctive components: a discourse model manages diagnostic interactions providing both a diagnoser and diagnosee a common communication method and symmetrical power in dialogue maintenance [8] while a formally defined mechanism maintains a jointly constructed LM [9]. To validate the framework we have developed STyLE-OLM - an IOLM system in a terminology domain. This paper presents an experiment with

STyLE-OLM and discusses computational and educational benefits of IOLM in terms of improving the quality of the LM and engaging the learners in reflective activities.

In the next two sections, we present the task (conceptual understanding in learning technical terminology) and outline the system. An application of STyLE-OLM for diagnosing and fostering conceptual understanding is demonstrated in section 4. Section 5 and 6 discuss some advantages of the approach, based on which we draw conclusions about a possible utilisation of IOLM in intelligent learning environments.

2 The Task: Conceptual Understanding in Terminology Learning

We have explored the task of learning technical terminology in a foreign language, particularly non-English speakers studying Finance terminology in English. Learning environments concerned with terminology, see e.g. [5, 16], suffer from the lack of adaptability. It may well be the case that the provided information contains terms a user is not familiar with. A major obstacle is the scarce attention paid to modelling a learner's cognition in this domain, which requires a sophisticated LM embracing diverse aspects of terminology competence.

Understanding term meanings is important for comprehension and production of terminological texts. This follows a more general argument about the importance of word meanings in language learning [15]. Most linguists believe that the meaning of the words is decomposed in concepts whose understanding entails acquiring a large system of knowledge where concepts are related to each other. Generally, concept learning research refers to acquiring a domain conceptualisation by applying *correctly* corresponding methods, such as generalisation (inferring from examples), explanation (justifying certain properties), deduction (inferring specific knowledge about category exemplars), and analogy (reasoning using similarities) [17]. This is often not the case with learners who may *misapply* or *fail to apply* the correct classification rule. In educational contexts, both finding possible explanations for learners' conceptual errors and fostering learners' conceptual understanding play an essential role. STyLE-OLM addresses these tasks as outlined in the following sections.

3 The STyLE-OLM[1] system

STyLE-OLM is an environment for interactive diagnosis where a learner can inspect and discuss aspects of his domain knowledge and influence the content of the LM. The architecture of the system is presented in Fig. 1.

STyLE-OLM imports a domain knowledge base (KB) built with conceptual graphs (CGs). The instantiation presented here is in a Finance domain[2]. The experiment described below was carried out with a preliminary KB, which at that time included a

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[1] STyLE-OLM is the Open Learner Modelling component in STyLE (Scientific Terminology Learning Environment) being developed in the framework of the EU funded Larflast project.

[2] The STyLE-OLM architecture does not depend on the subject area. Another instantiation of the system, which is in a Computer Science domain, has been utilised in [8] and [9].

type hierarchy with 96 concept types, and 19 CGs. The KB is being developed by a Bulgarian team [1] and used in the Larflast project. STyLE-OLM elicits the domain knowledge needed for IOLM utilising type hierarchy operations, basic CG operations (copy, join, restrict, and simplify), and some advanced operations (e.g. generalisation, specialisation, common generalisation).

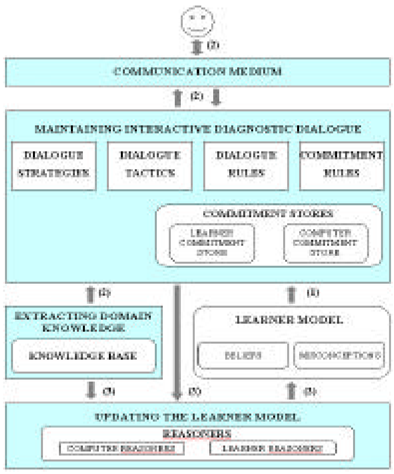

Fig. 1. The STyLE-OLM architecture. There are three main interaction stages: (1) - Initialisation, (2) - Discussion, and (3) - Learner model update.

The LM incorporates *beliefs* and *misconceptions* (Fig. 2). The beliefs, which can be correct, erroneous and incomplete, are encoded with CGs. The beliefs in the LM are open for inspection and discussion. Misconceptions are defined in our work as explanations for the learner's errors at conceptual level. At present, we consider several misclassifications and misattributions.

The communication medium in STyLE-OLM combines text and graphics. There are two modes - DISCUSS and BROWSE. In DISCUSS mode (Fig. 3), a learner discusses his domain knowledge with the system. Both the learner and the system construct dialogue utterances by creating a CG that represents the proposition of their communicative act and adding some illocutionary force to this proposition. In BROWSE mode (Fig. 4), a learner inspects the LM beliefs, elicited from the interaction and assigned a level of correctness by the system. At any time, the learner can switch between the two modes.

```
know(student1,money_market,[203]).
know(student1,money_market,[502]).
know_wrongly(student1,financial_market,[200]).
not_know(student1,capital_market,[501]).

misconception(misattribution(financial_market,200),
                misattribution_1,[203,502]).
% Error: The learner believes wrongly that
%         "On financial markets securities are converted into cash" (graph 200)
% Explanation: Because the learner believes that
%         "Money markets are financial markets" (graph 502) and
%         "On money markets securities are converted into cash" (graph 203).
```

Fig. 2. Beliefs and a misconception from a LM in STyLE-OLM, the numbers indicate graph IDs.

The LM discussion is maintained in a dialogue game manner [8]. Dialogue moves are used to indicate the illocutionary force of the agents' communicative acts (see Fig. 3). Dialogue rules define when the moves are permitted. Beliefs the agents have committed to in the dialogue are accumulated in commitment stores. The learner's commitment store contains his beliefs about the domain, while the computer's store includes its beliefs about the beliefs of the learner (see Fig. 5). Commitment rules define changes to the commitment stores as results of the dialogue moves.

We consider interactive diagnostic dialogue to consist of dialogue games that represent the interaction episodes and correspond to certain diagnostic goals. The goals define game tactics, e.g. *explore* aspects of the learner's knowledge, *explain* a learner's error by discovering a possible misconception, or *negotiate* a different view. Tactics define sequences of communicative acts to be address in the dialogue. CG schemata are used to obtain domain content for the tactics. To select a game to 'play' at each time of the dialogue, STyLE-OLM consults dialogue strategies - rules that suggest which dialogue game should be active in the current situation. The strategies may require that the current game is interrupted and a new or an interrupted one is activated.

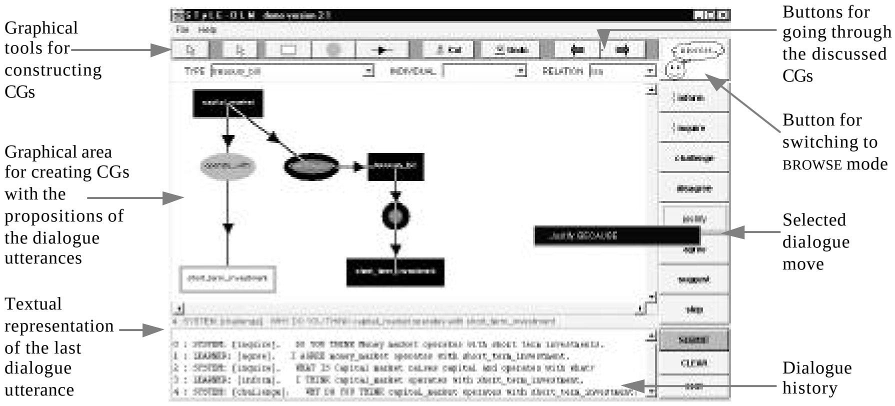

Fig. 3. STyLE-OLM in DISCUSS mode - a learner's justification after a system's challenge.

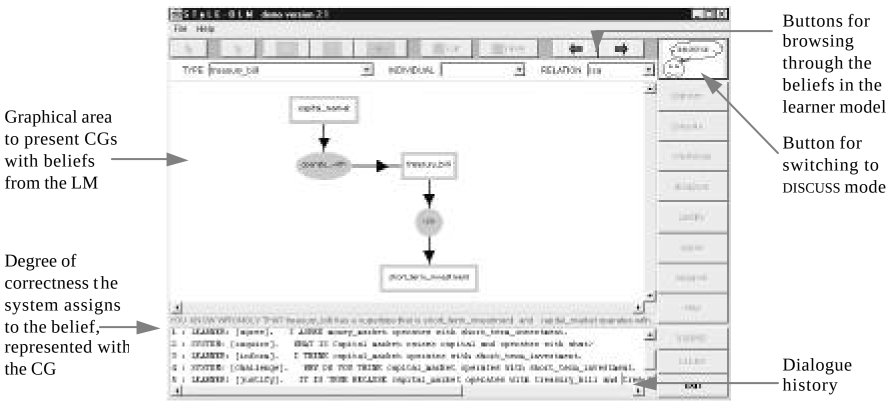

Fig. 4. STyLE-OLM in BROWSE mode where the learner can inspect the learner model.

```
   from the system commitment store
believe(system,believe(learner,502).
believe(system,believe(learner,203)->believe(learner,502)).
believe(system,notbelieve(learner,501).
not_believe(system,believe(learner,201).

   from the learner commitment store
believe(learner,200).
believe(learner,200->203).
not_believe(learner,501).
```

Fig. 5. Example beliefs from the commitment stores. The numbers present IDs of CGs.

A modal logic operator maintains the changes in the commitment stores and extracts what the agents have agreed about the student's beliefs [9]. When a belief contradicts with a commitment store, STyLE-OLM removes the beliefs inconsistent with the one stated last and initiates a confirmation dialogue. Having the agents' explicit commitments represented in the commitment stores, STyLE-OLM applies reasoners to infer potential consequences of these commitments. It elicits agreements and conflicts in the system and learner's views about the learner, e.g. an agreement that `believe(learner,203)` can be inferred from the commitment stores presented in Fig. 5 assuming that the learner might apply a modus ponens reasoner and the computer applies a default reasoner over its beliefs about the learner. The agreements are used as a source for updating the LM. The conflicts are to be addressed in following negotiative dialogues.

As shown in Fig. 1, the interaction with STyLE-OLM comprises three main stages:

(1) *Initialisation* - an initial LM (built by traditional diagnostic methods) is imported and converted into commitment stores. It is assumed that both agents support the initial LM and corresponding beliefs are added to both commitment stores.

(2) *Discussion* - a loop that involves the agents' turns taken in a sequential order - each learner's turn is analysed by the system and a system's response is generated.

(3) *Learner model update* - after the interaction is terminated (the learner quits the session) or suspended (the learner switches to BROWSE mode for inspecting the LM), the agreements and conflicts between the commitment stores are extracted and the beliefs in the LM are updated. Possible learner's misconceptions may be assigned.

4 Diagnosing and Fostering Conceptual Understanding

4.1 The experiment

An experiment with seven subjects, postgraduate students at the authors' department, was conducted primarily to examine the behaviour of STyLE-OLM, specifically the use of the communication medium, the dialogue management, and the LM maintenance. The experiment also allowed us to examine some advantages of IOLM.

Each learner attended an individual session. Prior to the session, a learner was given an introductory text with target Finance terms to study for a while and then asked to answer several drill questions about these terms without using the text. The learners' drill performance was assessed and initial LMs obtained (by hand). The learners were given some training to get acquainted with the communication medium.

In a session with STyLE-OLM, the learners were asked to help the computer system to obtain a better model of their domain conceptualisations, which would facilitate adaptability in pedagogical situations like generating explanations, providing feedback, selecting instructional materials. The learners were encouraged to inspect the LM, discuss their domain knowledge, and influence the content of the learner model. Generally, the interactions lasted about half an hour and were terminated by the learners. The sessions with STyLE-OLM were observed and monitored by the experimenter. Log files were recorded to study aspects of the system's behaviour.

4.2 An example: articulating aspects of a learner's conceptual knowledge

The excerpt here is from a session with a learner whose initial LM showed a reasonably strong knowledge in FINANCIAL MARKETS, the topic in the evaluative study. We use textual form to represent to represent the dialogue, although all communication is actually done graphically (see Figs. 3 and 4). At particular places we give learner's comments, experimenter's observations and details about the behaviour of the system.

The initial LM contains information that the learner **`knows`** the domain facts:

"MONEY MARKET `operates with` SHORT TERM INVESTMENTS",

"CAPITAL MARKET `operates with` LONG TERM INVESTMENTS",

"CAPITAL MARKET `supports` BUILDING NEW HOMES, FACTORIES, SCHOOLS, HIGHWAYS AND SHOPS".

The learner **`does not know`** that

"`On the` MONEY MARKET SECURITIES `are converted into` CASH".

The initial situation is that the learner confuses the terms CAPITAL MARKET and MONEY MARKET. STyLE-OLM initiates a dialogue game to explore the similarity and the difference between both terms. The system starts with the definitions of these terms and tries to confirm the beliefs in the learner model (so it uses `inform` moves).

0. STyLE-OLM$_{[inform]}$ YOU THINK that CAPITAL MARKET operates with LONG TERM INVESTMENTS.

1. Learner$_{[agree]}$I AGREE that CAPITAL MARKET operates with LONG TERM INVESTMENTS.

2. STyLE-OLM$_{[inform]}$ YOU THINK that MONEY MARKET operates with SHORT TERM INVESTMENTS.

3. Learner$_{[disagree]}$ I DISAGREE that MONEY MARKET operates with SHORT TERM INVESTMENTS.

STyLE-OLM continues with the comparison of the terms and addresses a situation about CAPITAL MARKET that was included in the initial LM.

4. STyLE-OLM$_{[inform]}$ YOU THINK that CAPITAL MARKET supports BUILDING NEW HOMES, FACTORIES, SCHOOLS, HIGHWAYS and SHOPS.

5. Learner$_{[inform]}$ I THINK that CAPITAL MARKET supports BUILDING NEW HOMES, FACTORIES, SCHOOLS, HIGHWAYS and SHOPS.

The system continues by exploring the type hierarchy.

6. STyLE-OLM$_{[inquire]}$ DO YOU THINK CAPITAL MARKET is a FINANCIAL MARKET?

7. Learner$_{[agree]}$ I AGREE that CAPITAL MARKET is a FINANCIAL MARKET.

To further explore the domain about CAPITAL MARKET, STyLE-OLM generates CGs that specialise the definition of the term by using exemplars of LONG TERM INVESTMENTS. As these beliefs are not in the commitment stores, the system uses `inquire` moves.

8. STyLE-OLM$_{[inquire]}$ DO YOU THINK CAPITAL MARKET operates with CORPORATE STOCKS?

9. Learner$_{[disagree]}$ I DISAGREE that CAPITAL MARKET operates with CORPORATE STOCKS.

10. STyLE-OLM$_{[inquire]}$ DO YOU THINK CAPITAL MARKET operates with TAX EXEMPT BONDS.

Learner's comments: *"I see, it's asking me about tax exempt bond now… It might be true if tax exempt bond is a kind of long term investment. I can ask the system this."*

At this point, the robustness of the learner's domain expertise is challenged. In searching for clarifications of domain aspects, he inquires the system.

11. Learner$_{[inquire]}$ IS IT TRUE that TAX EXEMPT BOND is a LONG TERM INVESTMENT.

STyLE-OLM now changes the current plan to include an answer to the question.

12. STyLE-OLM$_{[inform]}$ I KNOW that TAX EXEMPT BOND is a LONG TERM INVESTMENT.

Learner's comments: *"I see. Then I can answer the question it asked me earlier… "*

13. Learner$_{[inform]}$ I THINK that CAPITAL MARKET operates with TAX EXEMPT BONDS.

STyLE-OLM continues the game exploring exemplars of LONG TERM INVESTMENTS.

14. STyLE-OLM$_{[inquire]}$ DO YOU THINK CAPITAL MARKET operates with MORTGAGE LOANS.

Learner's comments: *"Perhaps, I shall change the topic… I shall think of which market operates with mortgage loans…"*

The learner reads through the Finance terms. He does not seem to find the term he is looking for. He decides to see his model and goes to BROWSE mode. The learner browses through the graphs presenting beliefs from the LM. He seems happy with the information in the LM, goes back to DISCUSS mode, and continues the dialogue.

15. Learner$_{[inform]}$ I THINK that NEGOTIATED MARKET operates with MORTGAGE LOANS.

The strategies accept the focus change suggested by the learner. The current game is suspended, a game that explores domain aspects with the new focus is initiated. The dialogue continues with MORTGAGE LOAN as it is more relevant to the preceding discourse.

16. STyLE-OLM$_{[inquire]}$ DO YOU THINK MORTGAGE LOAN is a LONG TERM INVESTMENT?

In the dialogue follow up, MORTGAGE LOAN is to be further elaborated.

After the session, the LM is updated. The interaction revealed facts that the learner **`does not know:`**

"MONEY MARKET `operates with` SHORT TERM INVESTMENTS" (which was presented as known before the interaction)

"CAPITAL MARKET `operates with` CORPORATE STOCKS, CONSUMER LOANS, `and` NEGOTIABLE CERTIFICATES OF DEPOSIT".

In addition to the explicitly stated beliefs, the system makes a plausible inference that the learner **`does not know`** that

"CORPORATE STOCKS `and` TAX EXEMPT BONDS `are` LONG TERM INVESTMENTS".

The following belief is erroneous, i.e. marked as **`known wrongly`**, because the domain knowledge base does not support it.

"NEGOTIATED MARKET `operates with` MORTGAGE LOANS".

The experiment is presented in more detail in [7]. Next, we discuss the results in respect to some computational and educational advantages of IOLM.

5 On the Quality of the Updated Learner Model

In order to analyse the quality of the LM we need criteria for comparing the initial and the updated LMs. We will define that a LM L_{new} is of a *better quality* than a LM L if: (1) L_{new} removes the inconsistencies in L if such exist; (2) L_{new} presents a larger scope of learner's beliefs; (3) L_{new} provides more explanations of the learner's errors; (4) L_{new} includes a higher proportion of valid assertions about the learner's knowledge; (5) L_{new} minimises the number of not valid assertions about the learner's knowledge.

The first criterion refers to problems with LM consistency often experienced by observational diagnosis, e.g. a belief contradicting the previous beliefs needs to be added. The inconsistencies were addressed in confirmation episodes. Few conflicting beliefs were left due to limitations in the CG inference, e.g. it did not recognise that two CGs represented propositions which were rephrasing one another.

The second criterion concerns articulating learner's beliefs and expanding the LM. The mean number of added beliefs to the LMs was 7 (S.D.=4). Some beliefs were deleted from the LMs as a result of the interactions with STyLE-OLM.

The third criterion refers to finding possible learner's misconceptions, addressed in some dialogue tactics. Although several misconception searches were initiated, few misconceptions were added to the LMs. Users often discovered their errors and made claims that changed LMs. Thus, potential misconceptions were not confirmed.

The last two criteria refer to validating the changes in the LM. We consider that a LM obtained from a computer diagnoser is *valid* if it satisfies the diagnosee, the student who has been diagnosed, and a human diagnoser, a teacher who can perform the diagnosis instead of the computer. We gave each learner questions concerning the resulting LM. Five learners considered that the LM corresponded to their domain knowledge, one was neutral, and one disagreed with the LM because it had facts presented as 'known' which he did not actually know. These facts were not discussed with STyLE-OLM but were present in the initial LM of the user. While such cases fortify the benefits of IOLM, they also show potential pitfalls for missing necessary discussion topics (and leaving invalid pieces in the LM) because either dialogue tactics may not capture them or a learner could terminate the session before their discovering.

The dialogue transcripts, the initial and the obtained LMs from some sessions were given for validation to a human diagnoser - a foreign language teacher in a Finance domain. Differently from the diagnosees, the teacher was rather neutral validating (on the basis of the observed interactions) the LMs she inspected. She questioned principally the approach of assigning correctness to someone's knowledge when a deficient system's expertise was employed. The teacher pointed at inadequacies in strategies that may have hindered the articulation of students' knowledge, e.g. when a learner made a wrong claim the system did not initiate a game to explore the error (see 3 in the excerpt above) and thus relevant beliefs might have been missed.

6 Fostering Reflective Conceptual Understanding

Involving learners in situations where they can inspect and discuss their models is a reflective activity which leads learners to think about their knowledge, to articulate, validate, and challenge the robustness of their own domain competence.

Predominantly, we observed that the learners were fostered to render statements about their domain beliefs, which caused recalling and reconsidering domain aspects [2]. The *more knowledgeable* students tended to make more claims about their beliefs. The mean percentage of this reflective activity calculated in respect to all reflective activities each learner experienced is 79% (S.D.=12) for the *more knowledgeable* group and 53% (S.D.=7) for the *less knowledgeable* group. The difference in the means was found to be significant (Mann-Whitney for very small samples, n_1=3, n_2=4, U=0, p=0.028). The discussions with the *more knowledgeable* learners contained relatively varied types of exchanges where participants made claims about their beliefs, while typically the *less knowledgeable* learners made claims about their domain beliefs challenging aspects of the LM after inspecting it in BROWSE mode.

Students went back to claims about their beliefs and (at times) changed these claims, i.e. they were recalling and reconsidering domain aspects [2] and validating their domain beliefs [6]. These reflective activities were usually observed in situations where learners were challenged by STyLE-OLM and looked back at their claims both in the dialogue history and the obtained LM. *Less knowledgeable* learners experienced such situations more often (mean 27%, S.D.=9) since their claims were more frequently challenged by the system. These participants tend to browse their LMs in order to check the correctness of the claims they had made. Two *more knowledgeable learners* did not go back to claims they had made (mean 9%, S.D.=13).

The students investigated arguments to support their beliefs, i.e. they were searching for grounds of their beliefs [6]. The users grounded their domain beliefs by asking questions to clarify aspects of the domain relying on the system's domain expertise (mean for the *more knowledgeable* 12%, S.D.=5; mean for the *less knowledgeable* 21%, S.D.=6). While *more knowledgeable* learners constructed questions exploring aspects not discussed yet but following the preceding discourse (as in 11 in the dialogue above), the *less knowledgeable* students often asked questions after browsing the LM. Sometimes, these users 'answered' a question by posing it back to the system (the reflectiveness of such inquiries is dubious).

The occurrence of the above situations in interactions with STyLE-OLM has allowed us to argue about the presence of reflection. As a whole, the *more knowledgeable* users were relatively well-engaged in discussions about the LMs. They experienced on average a total of 12.5 (S.D.=4) reflective activities in a session. While the interactions with the *less knowledgeable* students were shorter and had frequent focus changes, these users browsed their models more often when provoked by system's inquiries or challenges. The mean total number of reflective activities that the *less knowledgeable* users were involved in was slightly lower: 11.3 (S.D.=1). We argue that STyLE-OLM is capable of engaging both groups of learner in reflective activities.

The study showed that the scope of articulated domain beliefs was extending in a coherent manner so that learners had not only recalled aspects of the domain but been able to build a consistent picture connecting related domain facts. We also found that in each session different alternatives related to one piece of knowledge were explored, e.g. the excerpt above shows term definitions, situations with domain terms; hierarchical relations, and exemplars of generic terms. These factors address the effectiveness of the reflection. They are by no means comprehensive and further investigations of this issue, e.g. considering the learning effect, are required.

7 Conclusions

This paper has elaborated on the potential of interactive open learner modelling, illustrated in a terminological domain. We have presented a system that exemplifies the approach. Based on an experiment with the system, we have shown that IOLM can both improve the quality of the LM and provide means for engaging the learners in reflective activities. STyLE-OLM is based on a fairly general framework for IOLM. Generalisation of the approach shown here to other declarative domains is likely [7].

The benefits of the approach allow us to argue about the *twofold role* of IOLM in intelligent learning environments. On the one hand, IOLM can be part of the diagnostic component to target problems with traditional, observational, diagnosis. On the other hand, IOLM may well be included in the learning activities of an educational system and approached as a pedagogical activity by an instructional planner. These issues have been addressed in the integration of STyLE-OLM in STyLE [3] - a learning environment that supports non-native speakers to learn English Finance terminology.

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