Sharing knowledge and promoting reflection through the learner model

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Abstract. In this paper, we discuss how externalising learners' interaction behaviour may support learners' explorations in an adaptive educational hypermedia environment that provides activity-oriented content. In particular, we collect raw data from learners' interaction, model the state of interaction using a set of indicators and contextual information, and visualize this information alongside with comparative information coming from the instructor or colleagues. This way we provide learners with a mirror of their behaviour and relative measures such as instructor's proposals or peers' behaviour, aiming (a) to promote learners' reflection on their learning and support them self-diagnose the efficacy of their interaction; (b) to help learners to plan their learning; (c) to facilitate collaboration because learners can improve understanding of themselves and each other, and select appropriate partners; (d) to support tutors in providing personalised guidance and instruction and evaluate the available educational content.

1 Introduction

INSPIRE [1] is an adaptive educational hypermedia environment that allows learners to freely explore the available content offering them individual advices. The content consists of a variety of modules for learners, ranging from expository examples to open problems that promote learners to explore the underlying concepts. Several activities embed microworlds developed with MicroworldsPro (LCSI: http://www.microworlds.com/) or involve tools available on the Internet such as simulations, aiming to increase interactivity and enhance learner control. Activities are usually based on a specific scenario that promotes observation, exploration, and hypothesis testing. Currently the data available from learners' interaction with the microworlds are their answers and explanations to particular questions embedded in the activity-scenario.

INSPIRE supports learners to improve the effectiveness of their explorations, mainly at content level, providing adaptive support based on learners' individual characteristics, i.e. structuring the content around specific learning goals augmented with visual queues that inform learners about the content that they are ready to study based on their knowledge level (adaptive navigation support technique), or providing individualized versions of the educational material pages with alternative sequencing of the modules involved based on learners' learning style (adaptive presentation support technique). Learners are free to follow or not these advices on how and what to study. Another type of support that we elaborate on is modelling the learners' interaction with the system and visualizing this information to the learner and tutor in a meaningful way through the learner model. Opening the learner model to learners and using a variety of strategies to support interaction with the learner model provide learners with opportunities for reflection [2, 3, 4].

Especially, in an educational hypermedia environment such as INSPIRE, learners make explicit decisions repeatedly during interaction usually resulting in complex interaction protocols. These protocols refer to the series of events which occur during hypermedia usage with corresponding time stamps [5]. However, collecting learner actions is the first step for re-constructing a view of learners' activity able to promote learners' reflection on their explorations. Additionally, heterogeneous data included in interaction protocols must be carefully handled in order to yield meaningful information and build a thorough view of learners' activity. To this end, contextual information about the learner, the content, the available tools, the adaptive guidance offered is necessary.

Our proposal for designing support for learners' explorations combines and expands ideas coming form the areas of open learner modelling, interaction analysis [5,6,7] and computer supported collaborative learning [8]. In particular, we collect raw data from learners' interaction, model the state of interaction using a set of indicators and contextual information, and visualize this information alongside with comparative information coming from the instructor or colleagues. This way we aim to provide learners with a mirror of their behaviour and relative measures such as instructor's proposals or peers' behaviour, to support learners self-diagnose the efficacy of their interaction. In this context, challenging research goals are modelling learners' behaviour and the 'context' that affects learners' actions, and visualizing this information in a meaningful way for both learners and tutors. In particular we aim to design an open learner model that supports (a) learners observe and self-reflect on their behaviour - i.e. think about consequences and implications of their own actions -, and change it if necessary -i.e. consider the consequences and efficacy of their actions-, (b) the system in putting an interpretation on learners' actions, (c) tutors in acquiring a comprehensive image of learners' work useful to assess learners' performance, interests and needs, and evaluate the content.

2 Modelling the content

INSPIRE provides learners with structured *content* which is comprised of units, such as learning goals, concepts and educational material modules that can be reused by learners of different profiles. The notion of *learning goals* is used in order to build a hypermedia structure that provides learners with an overview of how all the relevant information fits together. In particular, each goal is associated with a conceptual structure that includes all the necessary domain concepts and their relationships – outcomes, prerequisites, related concepts. Each outcome concept is accompanied by educational material pages that consist of a variety of content modules of different interactivity levels, usually focus on learners' misunderstandings/false beliefs, and support specific levels of performance. For example, a page for the ‘loop construct’ concept (Learning goal: ‘How to use loop constructs’) may focus on the condition terminating the loop or the infinite loop, topics quite difficult for novice programmers. The design of the educational material is activity-oriented aiming to promote learners to use tools, generate and test hypothesis in a real context, solve open problems exploring alternative options. To this end, microworlds have been developed, and several tools have been located on the Internet.

Different types of content modules have been developed such as (i) modules that visualise specific internal processes along with appropriate explanations aiming to stimulate learners observe important parameters that affect the evolution of the process, (ii) modules that simulate a guided exploratory environment and usually incorporate a microworld, promoting learners to explore specific issues following a scenario (see Fig. 1), (iii) modules that pose open problems for investigation.

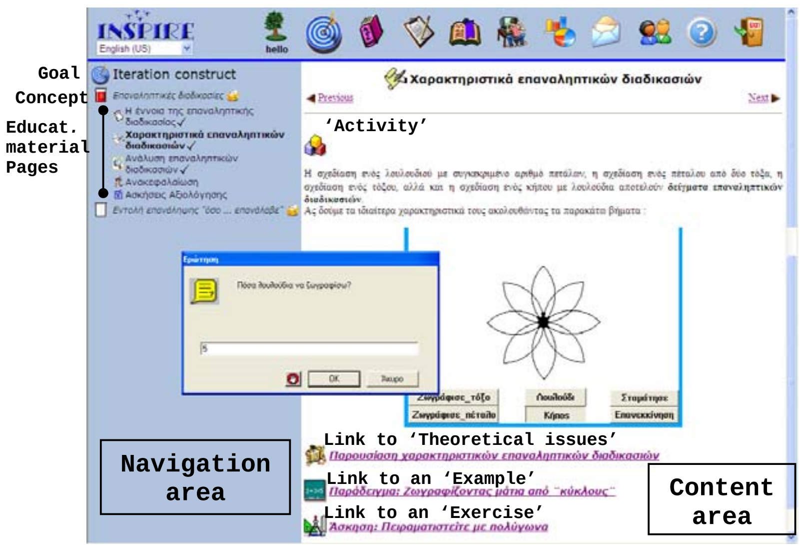

Fig.1: Educational material page of the ‘Use’ level of performance appears at the Content area of INSPIRE including multiple types of modules: an exploratory activity that embeds a microworld, theoretical tips, an expository example, an experimental activity.

Content modules are combined in educational material pages of different performance levels (‘Remember’ level: focusing on understanding, ‘Use’ level: focusing on the use of the underlying concepts, ‘Find’ level: focusing on generating new generalities). For instance, an educational material page of the ‘Use’ level that aims to gradually introduce the loop construct to learners includes the following modules: (a) an example that visualises the instruction flow in the loop construct in a real program and explain the main parameters involved and the evolution of the process through the execution of the program, (b) a guided exploratory environment in which learners are expected to investigate specific parameters of the loop construct following a specific scenario, such as the role of the counter in the evolution and termination of the loop construct, and (c) an open problem involving the loop construct.

Each educational material page is currently described by a set of metadata consisted of three types of descriptors based on the ARIADNE Educational metadata recommendation (see Table 1): (a) General: groups the general information that describes the learning object such as document title, document language, etc., (b) Semantics: groups elements that describe the semantic classification of the learning object, (c) Pedagogical: groups elements that describe the pedagogic and educational characteristics of the learning object, (d) Technical: groups elements that describe the technical requirements and characteristics of the learning object.

Table 1: A sample of the metadata information of the educational material page {Edxx}. The page is entitled “The main parameters of the loop construct” and belongs to the outcome concept “Loop construct” of the learning goal “How to define a loop construct”.

General Information	**Semantics of the resource**	**Pedagogical attributes**
Identifier: Edxx *Title*: “The main parameters of the loop construct” *Authors*: 'K. Papanikolaou, K.Maragos, K.Glezou' *Date*: '19/01/2006' *Publisher*: 'Dept. of Informatics & Telecommu-nications, Univ. of Athens' *Sources*: 'Computer Programming’ textbook	*Discipline*: 'Computer Programming' *Sub-discipline*: 'Programming constructs' *Main Concept*: ‘Loop construct’ *Learning Goal*: “How to define a loop construct” *Main Concept Synonyms*: *Other Concepts*:	*End User Type*: 'Learner' *Doc. Format*: 'Text' & ‘microworlds’ *Usage Remarks*: ‘get MicroworldsPro plugin’ *Didactical Context*: 'High School’ *Interactivity level*: ‘High’ *Difficulty Level*: 'Use' *Semantic Density:* 'High' *Pedagogical Duration:* 20

We currently work on a typology of the content (at module and page level), available tools, and tasks involved aiming to extent the above metadescription and support the production of more interpretative views of learners’ interaction. An interesting direction is also to extend *descriptive metadata* with ‘*usage information’* representing information about how the learner interacted with the content, including observed metrics such as study time, number of learner hits, submissions, along with patterns of access, explorations etc [9]. This type of information may come from individual learners by recording their experiences through the interaction and inspecting these interaction instances for meaningful patterns of success or failure for learners with particular profiles.

3 Enabling shared decision making through the learner model

While learners working with INSPIRE, the system maintains information about learners’ interaction, selections, and submissions. This information is shared with learners through their learner model. Especially, the learner model of INSPIRE has been extended to provide learners with appropriate tools and information, allowing them to intervene to the adaptive behaviour of the system, see and contribute to their profile, and acquire an image of their interaction behaviour. In particular, the learner model of INSPIRE is divided in 4 sub-areas, whilst learners are currently allowed to update the first three areas: (a) the '*Learning Style*' area which shows learners' current learning style category used for system adaptation as well as the whole pattern of learners' learning style (i.e. learners' preference on all the different styles is shown), and provides them the opportunity to manually change it or resubmit the learning style (questionnaire of Honey and Mumford); (b) the '*Adaptive Navigation Mode*' area which allows learners to select the type of adaptive navigation technique among Hiding (hides non-suggested content), Disabling (disables non-suggested content), and Visual Commenting (graphically augments links to non-suggested content) since there are pros and cons for all the three techniques depending on the learners' knowledge level and level of expertise in using computers; (c) '*Knowledge Level'* area shows learners' knowledge level on the domain concepts and information about their performance, objectives they have attained; (d) '*Interaction Analysis*' area providing a mirror of learners' interaction compared to a model suggested by the tutor.

Below we focus on the externalisation of interaction analysis which is a main challenge in opening the learner model of INSPIRE [10] to learners and tutors. INSPIRE gathers data from learner's interaction with the system and visualises it augmented with contextual information, in order to support learners gather evidence to evaluate the efficacy of their moves. Key issues in this process are the selection of the appropriate data (learners' actions and contextual information) and the production of interpretative views along with a meaningful way for conveying them to the learner.

Selection of appropriate data. A set of indicators from learners' interaction with the content and tools of the educational environment have been selected that represent the state of interaction. In particular, we use *navigational indicators* such as number of hits, frequency of visits, *temporal indicators* such as time spent on different types of resources and assessment - cases of long intervals of learners' work are marked -, and *performance indicators* such as attempts on assessment questions, performance on multiple types of questions, *indicators* of learner's interaction. Indicators are recorded at three levels of *observation grain*, coarse, intermediate, fine, in order to provide a comprehensive view of learners' activity (see below for a detailed description). The above information is provided along with *contextual information* about the *content* that the learner encounters during the interaction such as type, semantic density, and the *tools* they use such as the learner model, note keeping, adaptation controls.

Producing interpretative views of learners' activity. Interpretative views of learners' activity may support the investigation of purposeful chunks of actions in learners' interaction protocols taking into account that the key to finding meaningful patterns is the purpose for which the patterns are sought. Such views aim to be used as reflection-support mechanisms by learners and evaluation tools by tutors. A first step towards this direction is to combine the indicators of learners' interaction with contextual information, and design appropriate visualizations. The indicators are illustrated along with the currently available semantic information of the content such as type and semantic density. Semantic density is proposed by the tutor but we intend to alternatively evaluate it based on peers' interaction e.g. reflect mean time spent on specific resources by selected peers. For example, the time that the learner has spent on specific resources, is presented aside the semantic density of the resources as proposed by the tutor filling the corresponding line– when this time exceeds the tutor's proposal it turns to red (see Fig.2, area (a)).

A critical issue in representing the interaction indicators is the definition of the appropriate *observation grain*, which relates to the precision of the events considered as units in the analysis of the interaction protocols [5]. Three different levels of observation grain have been considered for learners' interaction, ranging from global activity patterns (*coarse grain*) when studying a goal, to specific aspects of the interaction at an *intermediate grain*, that relate to specific events of interest useful when testing specific hypotheses about the cognitive processes at work, and at a *fine grain* where all the observable actions are taken into account and the analysis focuses on meaningful patterns.

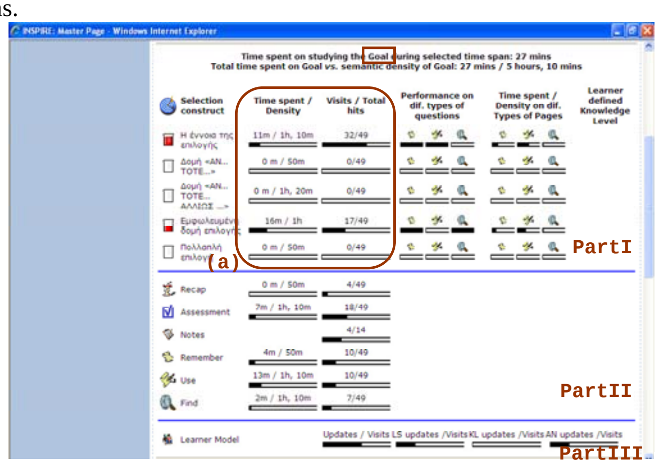

Fig.2: Mirroring learner's interaction at the coarse observation grain. The screenshot illustrates learners' interaction with the content of a learning goal during a time span of 27 minutes. The data available is divided in three subareas reflecting learners' activity on: (i) the content of the domain concepts (Part I), (ii) the different types of pages and keeping notes (Part II), (iii) the Learner model and adaptation controls (Part III).

In more detail, at the *coarse level*, information about learners' global activity is captured as a means to evaluate learners' involvement in a learning goal. For instance, information provided includes the total time they spent on the goal (at particular sessions or total study time) as well as learners' activity with the content of the domain concepts including for each concept, the time spent along with the semantic density of the resource, visits along with total number hits on the content, level of performance on different types of questions and the way this was evaluated (automatically by the system or learner defined) (see Fig.2, Part I). Moreover, learners' activity with the relevant educational material pages of different types is represented (see Fig.2, Part II), as well as the use of tools like the learner model, note keeping and adaptation controls (see Fig.2, Part II & III).

Information at the coarse observation grain may support learners plan their work, manage their time, organize materials and resources, and schedule the procedures *necessary to complete a task. Moreover, tutors may acquire an image for the learners' global activity and level of performance on the domain concepts.*

The information at the *intermediate* grain permits a more detailed observation of learners' actions that reflect learners' work with different types of resources –related to learner's style preferences - and the impact on their performance. For instance, information provided reflects (a) learners' global activity (see Fig.3, Part I) with the educational material pages of a concept (time spent along with the semantic density of the resource, visits along with total number hits on the content), and the content modules of different types involved (for each type of module, time spent is presented along with the semantic density of the module), (b) learners' activity with all the different types of content such as educational material pages (see Fig.3, in Part II pages of multiple types), and knowledge modules (see Fig.3, in Part III modules of multiple types) including time spent, visits, information about learners' performance.

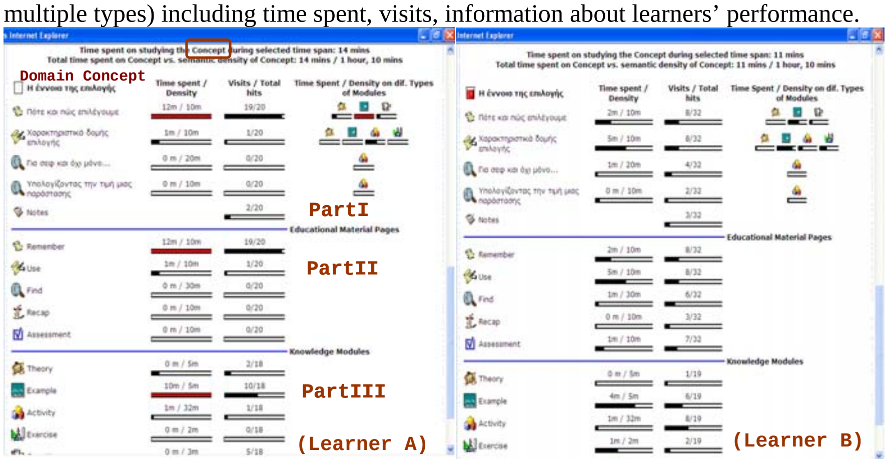

Fig.3: Mirroring learner's interaction at the intermediate observation grain. These screenshots illustrate interaction of two learners (Learners A and B) with the educational content of a particular domain concept. The data available is divided in three subareas reflecting learners' activity on: (i) the particular educational material pages of the concept and on keeping notes (Part I), (b) the different types of pages (Part II), (c) the different types of content modules included in the pages (Part III).

For instance, information about the time a learner spent on specific resources combined with the semantic density of the resources and the learners' knowledge level could provide a means to evaluate learners' progress as well as the adequacy of the content for particular learners. In Fig. 3, Learners A and B have spent almost the same time on the domain concept, 14 and 11 minutes respectively. During this session, Learner A concentrated on pages of the 'Remember' level working with examples (time spent exceeds the proposed one) but without submitting the relevant assessment questions, whilst Learner B concentrated on 'Use' pages (although s/he also visited the 'Remember' pages) working mostly with examples and answered successfully questions of the 'Remember' and 'Use' levels of performance. Both learners seem to prefer working with ‘examples’, although their progress and the type of pages they seem to prefer differ. However, more information about the particular resources, tasks involved and learners’ submissions is necessary for a deeper view to their activity.

Information at the intermediate observation grain reflects learners’ current activity with the content of a concept, their progress, as well as their preferences on specific types of resources. This information may support learners plan their work and cultivate their style awareness. Moreover, sharing this information with peers may support learners seeking for help. It may also support tutors acquire an image for the learners’ global activity, progress and needs as well as for the adequacy of the resources offered to learners with particular profiles.

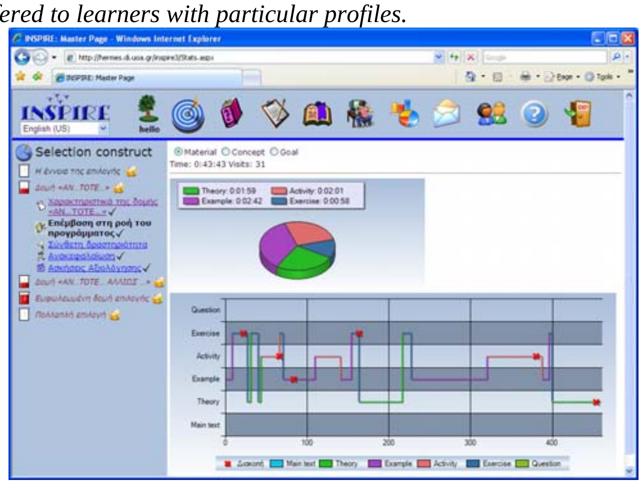

Fig.4: Mirroring learner’s interaction with the content modules of a ‘Use’ page at a *fine observation grain*. In this screenshot, the learner’s navigation pattern at a particular educational material page is illustrated. Note that ‘x’ illustrates long intervals.

The information at the *fine* grain regards learner’s activity on particular tasks allowing the investigation of purposeful chunks of actions, the identification of repetitive patterns of learners’ behaviour, and may provide a deeper view on the way learners use the resources and available tools. Content and tasks metadescriptions as discussed in Section 2 will provide a framework for interpreting learners’ actual use and submissions. Valuable information at this grain may come also from learners’ interaction with embedded microworlds – a direction that we intend to investigate. In any case, the information at this grain allows the investigation of the evolution of learners’ activity. To this end, a record of learners’ interaction with the content over time is necessary including a sequence of interaction instances for subsequent time periods. This sequence forms a “learning trail” through the content for a learner, and this trail may reveal learners’ preferences, strategies and interesting patterns of success and failure. Furthermore, by comparing learners’ trails, we may result in interaction patterns for learners with particular profiles.

For instance, information about the resources or tools that a learner uses when undertaking specific tasks combined with self-explanations and evaluations submitted by the learners may provide a view of learner strategies and/or a valuable resource for evaluating the content. Thus, a possible interpretation of the pattern of Fig. 4 depicting the sequencing of modules that a learner adopted, is that the focus of the interaction is on the 'Activity' since the learner revisits the 'Activity' module and in the meantime s/he frequently visits the modules 'Example' and 'Theory' in order to get information and complete the activity. Contextual information about the tasks that learners undertake through the activity and modules used, may provide a deeper insight in learners' goals and the purpose of the interaction. Moreover, involving learners in the interpretation of their interaction patterns is necessary for minimising arbitrariness in the identification of meaningful patterns.

Information at the fine observation grain may promote learners' awareness on their learning and reflection on the efficiency of their learning strategies. Sharing this information with colleagues may give them new ideas and encourages deeper thought about the implications of their own ideas and strategies. Moreover, this information may support tutors evaluate the difficulties that a learner faces when working with specific resources as well as the quality and adequacy of the content.

3 Discussion and future plans

Intelligent and Adaptive Educational Systems usually integrate adaptive and adaptable components that are based on shared decision making between the learner and the system. Sharing knowledge that the system maintains through the interaction promotes transparency in communication with the learner and involves learners in decision making cultivating meta-cognitive skills. In this paper we discussed the open learner model of INSPIRE as a means for sharing system internal knowledge about learners and their interaction behaviour, with learners and tutors. Opening the learner model and specifically visualizing the interaction aims to provide a meaningful mirror promoting learners reflect on their activity considering efficacy of their actions to their objectives. Interaction patterns if related to learners' profiles may also support content evaluation, as well as adaptation of tasks, tools or study advices to learners' individual characteristics. Moreover, it may support social interaction providing a basis for learners to share their experiences or for group formation purposes.

Especially in Exploratory Learning Environments which encourage the learner to create their own solutions to problems, the provision of a meaningful mirror of their activity may support self-reflection, and knowledge sharing. However, there are an enormous number of patterns that can be found when inspecting actual learner behaviour. As key issues that should be taken into account in producing interpretative views of meaningful patterns useful to learners and their peers are the purpose for which the patterns are sought, and contextual information relating for instance to the learner (profile and personal view), the content, the available tools. Purpose and appropriate contextual information about the learning environment, place their own particular constraints on *what* patterns are meaningful, *how to look for* these patterns, and *how to use* what these patterns reveal in order to achieve the purpose. However, the interpretative views of learners' interaction produced by system designers and their expressive power of learners' cognitive processes is important to be evaluated by the learners themselves. Learners' personal views on their interaction patterns or of their peers will prove what actually these patterns reveal.

Currently the evaluation of the learner model of INSPIRE (http://hermes.di.uoa.gr/inspire3) is in progress. In particular we investigate the expressiveness of the indicators and contextual information selected and the visualisations used. Preliminary results show that learners want to have access to their model and to information maintained by the system, but most of them do not feel safe to intervene to the information provided. They need support in order to interpret the contents of their model and be able to creatively use them. They suggest that the combination of temporal and performance indicators may support them in changing their studying behaviour, whilst navigational indicators increase their awareness of the way they use different types of resources. We investigate what the interaction patterns of themselves or their peers reveal to them and how they might use them. We also intend to further work on building interpretative views of the fine level of observation grain for learners' interaction based on specific purposes and learners' profiles and on the way these may augment the learner model of individual or groups of learners.

4 References

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