

# Collaborative E-Learning through Open Social Student Modeling and Progressive Zoom Navigation

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**Abstract**—Students usually do not study individually; instead, they tend to study collaboratively. The “power of known peers” can be embraced to provide implicit navigation support for collaborative social e-learning environments. In this paper, we present a novel approach to collaborative e-learning through open social student modeling with Progressive Zoom navigation support. Progressive Zoom is a Google-Maps paradigm which seeks to address information overload issues. It enables students to zoom in or out in a multi-layer fashion, so students can reflect on their individual and peer progress based on the knowledge and pedagogical context. In our initial survey, all students were satisfied with the navigation interface and would recommend the interface to their classmates.

**Keywords**- Collaborative E-Learning, Social Navigation, Open Social Student Modeling, Multi-layer Social Knowledge Maps, Progressive Zoom, Adaptive Learning, Treemaps, Google Maps API

## I. INTRODUCTION

Students usually do not learn individually; instead, they tend to work collaboratively. According to [39], *collaborative learning* is a situation in which two or more students learn or attempt to learn something together [15]. Unlike individual learning, students engaged in collaborative learning capitalize on one another’s knowledge and skills, for example, asking one another’s for information, evaluating each other’s ideas, and monitoring one another’s work [10-11]. More specifically, collaborative learning is based on the model that knowledge can be created within a population where members actively interact by sharing experiences and take on asymmetry roles [31]. Traditional classroom study can usually promote collaborative learning with the help of face-to-face teacher and student interaction.

However, due to the asynchronous nature of e-learning, students often experience a lack of collaboration. Social navigation has been used to address this issue in a collaborative e-learning environment [25]. *Social navigation* was first introduced as “navigation because other people have looked at something” [17]. The main purpose of social navigation [13-14, 29-30] is to help students to follow the “footprints” of others directly or indirectly. *Collaborative e-learning* is defined as “constructing knowledge, negotiating meanings and/or solving

problems through the mutual engagement of two or more learners in a coordinated effort using Internet and electronic communications” [32].

While “Peers can be the best teachers, because they’re the ones that remember what it’s like to not understand” (Mazur, 2011)<sup>1</sup>, “Teaching according to one’s ability” (Confucius, 551 BC)<sup>2</sup> should be also emphasized. *Open Social Student Modeling* [21] tries to further combine the power of both personalized and social learning. It allows students to see not only their own models, but also the models of their peers thus benefiting from both cognitive and social learning [9, 18, 21]. In this paper, we focus on exploring collaborative e-learning with Open Social Student Modeling.

While open and social student models have demonstrated their values, their practical application in large-scale learning is still a challenge due to the fact that the volume of information collected by a student model over a typical four-month course is too large. Visualizing a course-scale student model using traditional approaches might not be helpful: instead, students might be subjected to information overload.

On the other hand, Google Maps [20] is able to address the information overload issues by providing navigation of Geographical Information Systems (GIS) in a multi-layer fashion. For example, when travelling from Minneapolis to Pittsburgh in the U.S., Google Maps shows that you need to travel six states using the interstate highway system. As you travel, you can zoom in or out to different levels of detail depending on your local, city, state, or interstate traffic situation. Furthermore, when you turn on the traffic overlay, you can plan your route to avoid traffic jams with the help of GPS. The multi-layer zoomable interface of Google Maps provides remarkable flexibility in navigation support: on each layer, it shows those details critical for making decisions on this layer of navigation. We hypothesize that this can be generalized as *Progressive Zoom Navigation*, which

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<sup>1</sup> Harvard professor Eric Mazur, an advocate of peer learning

<sup>2</sup> Ancient Chinese Philosopher Confucius, an advocate of personalized learning

incrementally provides more details based on the context and level of abstraction.

Is it possible to build such an intuitive navigation tool for adaptive learning based on Progressive Zoom? There is a definite need for Progressive Zoom support in E-learning. When making decisions about our learning we do operate on several layers. For example, on the college education layer, students think about degrees and courses -- paying little attention to the structures below the course level. On the course level, students think about course topics, book chapters, projects and other top-level course elements. Within a specific topic or chapter, they consider sub-topics, readings and assignments and so forth. What if we can provide navigation support for students with their own “degree program knowledge maps”, so that they can reflect their own and peers’ progress based on their knowledge and pedagogical context? We hypothesize that “open social student modeling” based on Progressive Zoom can make this “collaborative social navigation support” come true, while addressing the information overload issues. In summary, in this paper we propose a novel approach to collaborative e-learning with the combination of both open social student modeling and progressive zoom navigation support.

In the next section, we provide a short review of the literature related work. The overall design of the Progressive Zooming Framework is provided in Section 3. In Section 4, we focus on open social modeling as one of the models for the multi-layer knowledge maps. We demonstrate the collaborative social navigation support component ProgressiveZoom in Section 5 and its initial evaluation in Section 6. Finally, we summarize this work and discuss future research plans.

## II. RELATED WORK

### A. Open and Social Student Modeling

The student model is a critical component for any adaptive learning system. By tracking a learner’s knowledge and progress, it allows various components of an adaptive system to deliver personalized learning experiences. Over the last 10

years, special attention was paid to Open Learner Models (OLM) [3-4, 16] that visualized student knowledge and progress. OLM demonstrated that the information about student knowledge could be useful not only for adaptive learning algorithms, but also for the students themselves. By supporting reflection, self-directed learning, and transparency, OLM made adaptive learning systems more attractive to learners. CourseVis is one of the few open user model systems that provide graphical visualization of groups to teachers and learners [5]. It helps instructors to identify problems early and prevent some of the problems associated with distance learning. Most recent research efforts in this direction focus on the Open Social Student model which provides students with benefits from both cognitive and social learning [21]. Social Visualization of student performance helps students to be more engaged in learning activities and realize better performance in self-assessment quizzes [18]. However, the visualization discussed above is based upon a single-layer knowledge map.

### B. Layered Knowledge Maps

Various efforts were devoted to build knowledge maps with more than one layer. In Knowledge See II [7], two-layer knowledge maps were developed based on Self Organized Maps (SOM) to provide adaptive navigation support. A layered thematic K-map system was proposed to tackle the issues of discovery of the hidden structure of codified knowledge and to compactly visualize the map morphology to improve effective navigation [27]. An ontology-based multi-layered knowledge framework for product lifecycle management was proposed to help knowledge engineers create, edit, and visualize product knowledge according to the framework [26]. In QuizMap [6], multi-layer knowledge maps were developed based on Treemaps to facilitate both open social student modeling and adaptive navigation support. As shown in Fig. 1, the QuizMap may become too complex to explore. In these examples above, no zoomable interface is provided to address the information overload issues, which is the primary contribution of the proposed approach.

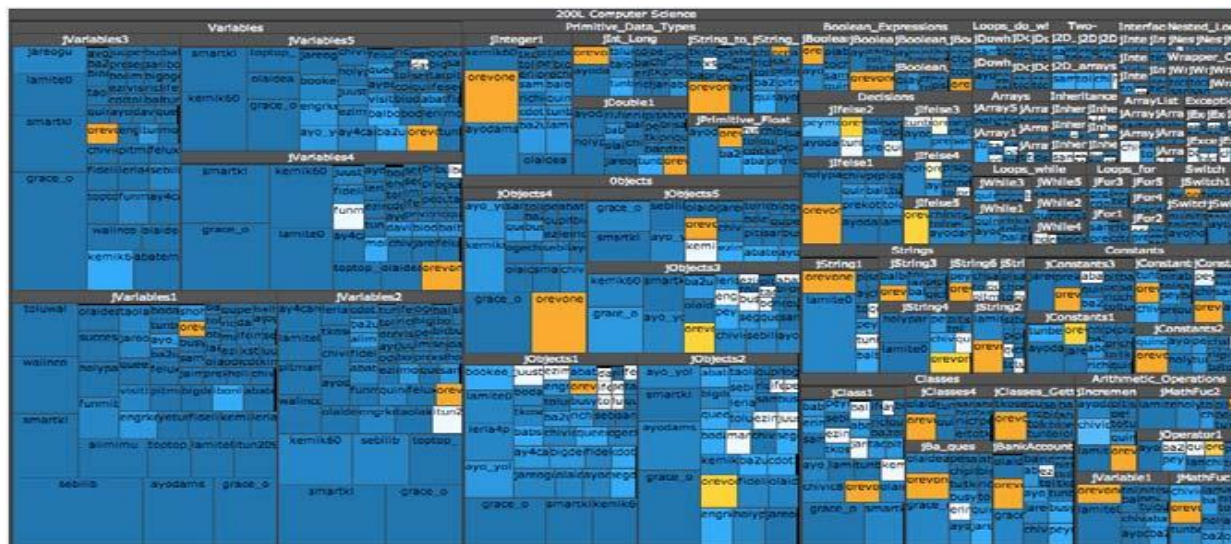


Fig. 1 An overview of QuizMap

### C. Other Applications with Google Maps API

Our approach is mainly inspired by the intuitive visualization of an online mapping service, such as Google Maps [20], which incrementally provides more detail based on the context and level of abstraction in the domain of GIS. In the domain of e-learning systems, a concept-map navigator is provided by Khan Academy [12] based on the Google Maps

API. But it fails to provide a balance of local/global view, and students may easily get lost in their learning process as shown in Fig. 2. Compared with our approach, the concept-map navigator cannot provide contextual navigation when other models are not integrated. In the domain of bioinformatics, the Google Maps API is used to visualize multi-scale structures, e.g. Genome Projector, Protein Interactive Network, Gene Co-expression, Pathway Projector [2, 22-24].



Fig. 2 Concept Map Navigator Presented by Khan Academy

### III. THE PROGRESSIVE ZOOMING FRAMEWORK

While it seems straight forward to zoom in or out in Google Maps based on the scope of geography, it is not the case for an e-learning environment. There are two specific issues to address: 1) how to build multi-layer knowledge maps and 2) the suitable dimensions of zooming in or out in the knowledge maps. These two issues can be coupled and can be specified as “how to build zoomable multi-layer knowledge maps?”

For the first issue, the problem is that there are two conflicting approaches for knowledge organization, both being popular in knowledge modeling and personalized learning: cognitively-oriented concept based modeling [8] that treats a body of knowledge as a network of relatively fine-grained concepts, and pedagogically-oriented topic based modeling [35] that represents knowledge as a taxonomy of relatively coarse-grained topics. What is the right approach to building multi-layer knowledge maps to bridge these two approaches? The good news is that the integrated hierarchical structure of pedagogical models, knowledge models and student models is usually captured in the Adaptive Courseware Environment as a web-based tutoring framework [36]. We hypothesize that it is possible to build multi-layer knowledge maps based on these three models as illustrated in Fig. 3. For the *Pedagogical Modeling*, the course is organized in hierarchical layers which provide the meaningful context, for example, lectures, topics and sub-topics. It is constructed from the syllabus and textbooks. This structure can be extended to include other courses and degree programs. For the *Knowledge Modeling*,

some concepts are more important than others. As a result, key concepts are extracted from general to specific along the hierarchical pedagogical structure. For the student modeling, *Open Social Student Modeling* is used in order to embrace both cognitive and social learning perspectives. It keeps track of the students’ individual and peer performance progress along the hierarchical pedagogical structure. It is important to propagate and aggregate the progress from two directions respectively: top-down (from the lecture to topic to sub-topic levels) and bottom-up (from the sub-topic to topic to lecture levels). More details on building the multi-layer social knowledge maps can be found in our work [28].

The second issue is: how to zoom in or out in these knowledge maps in a meaningful dimension. In other words, how should we capture the navigation in a “multi-layer” fashion? As the knowledge maps are constructed from three models, we could consider the knowledge maps as three layers. In other words, we could explore across the different models, for example, from pedagogical model, knowledge model, to student model, or the other way around. The point is that: there are different options, but they may not always work. From our experiences, it seems to work well when students zoom in or out along the pedagogical hierarchical structure with the knowledge model and open social student model as overlays on it. This is confirmed by our initial survey which will be reported in Section 6. Furthermore, our approach is similar to the Google Maps navigation paradigm, and it is also possible to scale up to other layers in the future.

In brief, the Progressive Zooming Framework is proposed to respond to the two issues above. As shown in Fig. 4, the corner-stone of the Progressive Zooming Framework is the integration of a pedagogical model, a knowledge model and an open social student model for adaptive learning systems, while the cap-stone is the Treemaps as a scalable layout for hierarchical structure visualization [34]. The Multi-layer Social Knowledge Maps are built from the three integrated models

and they are further visualized as Treemaps [6] with a Zoomable interface, which provides the progressive zoom navigation support. In this section, we focus on the framework’s overall design. The open social student model will be explained in detail in next section. In Section 5, we will explain the progressive zoom navigation support in more detail.

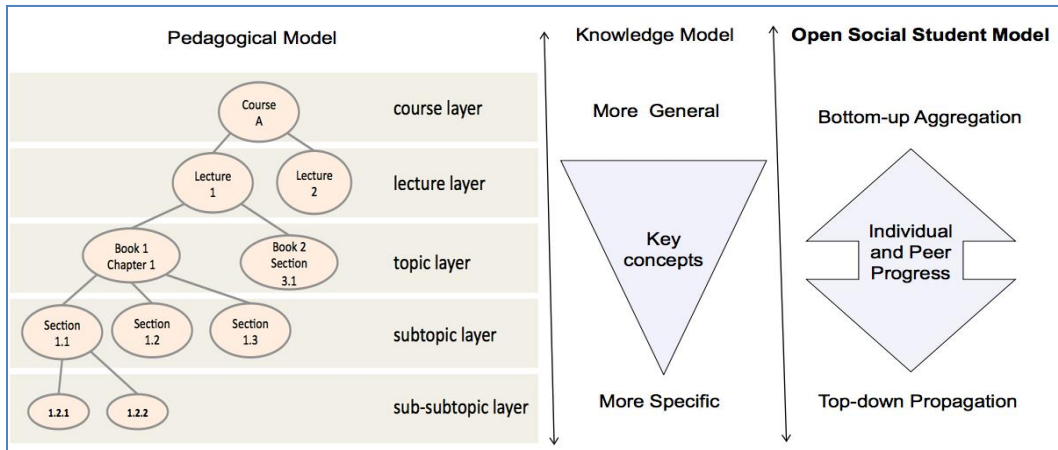


Fig. 3 Knowledge Maps Integrated with Three Models

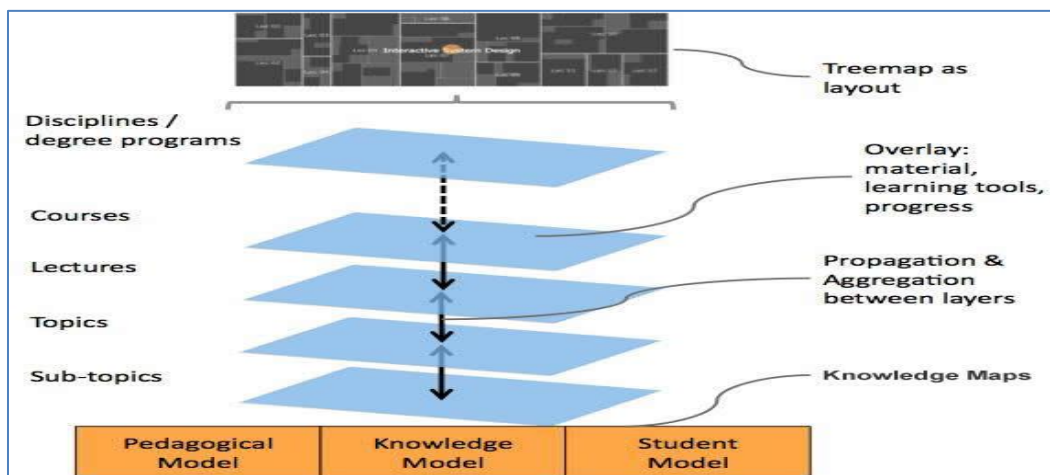


Fig. 4 The Progressive Zooming Framework

There is one important feature about our framework: it is not a closed framework, instead, it is ready to embrace more facilities and services from the knowledge modeling and open social student modeling when they are available. For example, the related learning materials, tools, and student’s learning progress can be captured as overlays along the hierarchical structures, highlighted by the key concepts (as shown in the knowledge model in Fig. 3). To illustrate using metaphor of Google Maps, the pedagogical model defines the “geographical” structure of a course, the knowledge model and open social student model define the “highway/road systems” and “traffic” of a course, respectively. And this course is always open to include more “construction inputs and measurements” when available. For example, Google Maps has directions by car and

public transportation, but new services such as directions for walking or biking are in beta testing.

Through the ProgressiveZoom interface, students can zoom in or out to different contexts and levels of abstraction in e-learning environments, for example, courses, lectures, topics and sub-topics. Again, to illustrate with the Google Maps metaphor, we can zoom in or out in different layers, for example, the state layer, city layer, and local layer. We hypothesize that this approach will help students to increase their awareness and engagement in their learning process.

Currently, we focus on building the knowledge maps for one course, the Interactive System Design (ISD) course at the School of Information Sciences, University of Pittsburgh, US.

Nevertheless the Multi-layer Social Knowledge Maps can be extended to include other courses and disciplines or degree programs (connected with dashed arrows in the multi-layer structure in Fig. 4), similar to how Google Maps can include other countries and continents. This addresses the scalability and global/local view challenges in visualization.

#### IV. OPEN SOCIAL STUDENT MODELING

As explained in the previous section, the Open Social Student Model is the dynamic “positioning” measurement of the framework. It keeps track of the students’ individual and peer progress by propagating the progress from higher to lower layers and by aggregating from the lower to higher layers along the pedagogical hierarchical structure as shown in the knowledge maps (see Fig. 3). Varied measurements or “footprints” in social navigation can be used, from simple textbook reading to complex self-assessments. Even simple textbook reading can be measured in different ways, for example, number of visits, annotations, tags, and eye tracking to determine attention. However, these integrated measurements are not the selling-point of this paper; instead, we focus on exploring collaborative e-learning through open social student modeling. And, we start from the simplest measurement.

Currently, the open social student model is simplified to reflect the progress of the student in reading the documents for the course. The student model is stored in the CUMULATE User Model Infrastructure [37]. In this approach, the individual progress of the student in one specific node is recursively calculated by aggregating the progress in its child nodes. In other words, the progress of a specific node is simplified as the average of the current progress in that node and the sum of progress in its child nodes as specified in Equation 1.

$$p_{u,e} = \frac{v_{u,e} + \sum_{c \in C} p_{u,c}}{|C| + 1} \quad (1)$$

Here  $p_{u,e}$  is the progress of the student  $u$  in the node  $e$ . The notation  $v_{u,e}$  takes value 1 if the student  $u$  has read at least once the documents in the node  $e$ ; the value of 0 otherwise.  $C$  represents the set of all direct child nodes of  $e$ . The value  $p_{u,c}$  is the progress of the student  $u$  in the child node  $c$ .

In order to promote collaborative social learning, we also present the peer progress along the pedagogical structure. Currently we use the aggregated popularity as a simple peer progress indicator. Similar to the node progress, the popularity of a specific node is simplified as the average of the current popularity in that node and the sum of popularity in its child nodes as specified in Equation 2.

$$pop_{g,e} = \frac{w_{g,e} + \sum_{c \in C} pop_{g,c}}{|C| + 1} \quad (2)$$

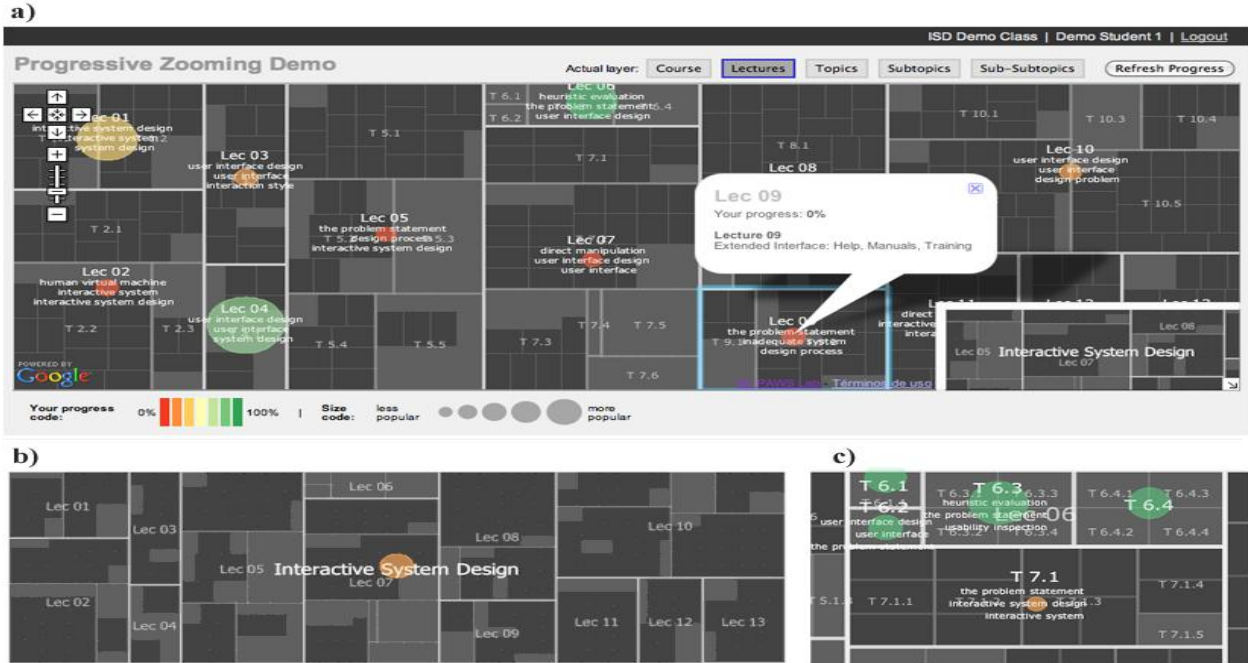
Here  $pop_{g,e}$  is the popularity level of the node  $e$  for the group (class)  $g$ . The value  $w_{g,e}$  is the number of times the document in the node  $e$  has been visited.  $C$  is the set of all the direct child nodes of  $e$ . The value  $pop_{g,c}$  is the popularity of the child node  $c$ .

In our current approach, a Progress Manager [28] computes only the aggregated individual and group progress from bottom to top, and updates the student model with the actions captured in the interface. Nevertheless, it is also possible to propagate the progress from top to bottom. For example, key concepts are usually introduced from general to specific from top to bottom. If students have learned some more general key concepts at the topic level, they should be able to learn the more specific related key concepts at the sub-topic level. In other words, if the students make some progress at the higher level, they should have made some progress at the lower level accordingly, and the corresponding progress should be propagated down to the lower level.

Furthermore, if we extend the knowledge maps to include different courses and degree programs, we should also make special considerations/extension to the open social student model. For example, 1) if students have taken some courses, they may be able to learn other courses more easily. For example, a Java programming course should help students to learn C++ more efficiently. 2) Prerequisite courses should be considered. For example, the prerequisite course for “Adaptive Information Systems” at iSchool at Pitt is either the “Interactive System Design” course or the “Database” course. 3) When students decide which courses to take, they may be influenced by students from similar background and/or with related career goals. For example, if students have difficulty in deciding which degree program they should take, the overlapping of the different degree programs should be provided to students, as well as an explanation of how the different degree programs meet different career goals. 4) If students have different schedules or timelines to work on the degree program, a potential set of courses may be recommended based on the activity of peers and time conflict information. These are some potential measurements that the open social student model for the degree program layer can provide to the students. And the potential is unlimited!

#### V. PROGRESSIVE ZOOM NAVIGATION SUPPORT: A ZOOMABLE INTERFACE WITH GOOGLE MAPS API

As its name suggests, ProgressiveZoom (Fig. 5) is an interactive visualization interface to provide students with Progressive Zoom navigation support to interact with learning resources and to reflect on their personalized and social learning progress based on the multi-layer social knowledge maps. Our current implementation is based on Google Maps API since our work is mainly inspired by Google Maps. For our demo course, the pedagogical structure is constructed from the ISD (Interactive System Design) course and five textbooks. The key concepts from the knowledge model are extracted using Yahoo Content Analysis API [40]. In our demo, the knowledge maps are pre-generated as layered base maps with the Treemaps layout using a visualization toolkit Prefuse [38]. The layered base maps are cut into tiles with G-Language API [19]. Progress and popularity level indicators from the open social student model are shown as overlays on the base maps. Finally the interface is implemented with the Google Maps API. Currently the interface is only linked to an external textbook reader, which has already been implemented in KnowledgeSeaII [7]. But it will be possible to link to other available assessment tools in the future.



**Fig. 5: ProgressiveZoom interface.** The navigation through the course hierarchy of topics (lectures, topics, and subtopics) is performed using the semantic zooming paradigm: for example, by zooming in or out from the level of the lectures (shown in this fig. 5-a), the next level of topics and the associated information are shown. At each level, key concepts are presented to help students monitor their progresses. The feedback is presented in the form of multi-color and varied size bubbles. The size of the bubble represents the group popularity from less popular to more popular. The color code represents the individual progress diverging from Red (0%) to Green (100%). Each instruction unit can be clicked, which leads to additional learning materials and tools.

### A. Visual encoding

Visual coding is used to guide students' attention. Bubbles of different colors and sizes (Fig.6) represent the progress of the student and the popularity of the node respectively. Color represents progress from red (0%) to green (100%) in a seven step scale (each step represents 1/7 of 100% progress). Students can easily identify their own progress according to the bubble color. The size of the bubbles represents group popularity. Students can easily identify where the hot topics according to the bubble size. We hypothesize that students will be guided by bigger red bubbles to tackle hot topics when they realize that they do not make good progress on those popular topics.



**Fig. 6** Individual progress marked with diverging color scheme and peer popularity noted by different bubble sizes. It is intuitive to guide students to pay attention to bigger red bubbles.

In order to accommodate the scale used in Google Maps API, the radius of a bubble is measured in kilometers (see Equation 3.)

$$r = \frac{50000gp + 300000}{\text{zoomlevel}} \quad (3)$$

Where  $gp$  is the group popularity calculated as described in Equation 2, above. In the level of zoom 1, Null visits (null popularity) in a node is represented as a 300 km radius bubble. Each point in the level of popularity increases the bubble radius by 50 km. The value is divided by the level of zoom to keep the size representations consistent, regardless of the zoom level. The value of the two coefficients were chosen by taking into considerations that bubbles should be visible when no visit occurs (popularity = 0) and should not clutter up the visualization when high number of visits occurs.

### B. Interactive Interface

We follow the visual-information-seeking-mantra: "Overview, zoom, filter, then details on demand" [33]. The default perspective is an overview of a course level. Then, Semantic Zooming is used to show different layers at different zoom levels, for example, lecture layer, topic layer and subtopic layer. A filter is applied to the corresponding layer. Details on demand are also implemented. For example, the click event triggers an overlay balloon window containing data about the node. By clicking on the link that appears on the balloon, a textbook reader (external application) is loaded in a new browser window and the activity is recorded in the

database. By pressing the *refresh progress* button, the new progress can be observed by a change of the color and size on the corresponding bubbles.

To provide a scenario, students can navigate through the course material without information overloading. For example, as shown in Fig. 5, when Student-one first accesses the ISD course, his individual progress is shown in light red bubble in the overview of the course. Then he zooms in to the lecture level, and checks out his progress of each lecture by the bubble colors. Now he clicks on Lecture 9 to diagnose the problem. He can see that he has not made progress in this lecture. He can continue to zoom into the topics level and read the textbook through the reader. After he has worked on the material, the progress is aggregated and reflected on the higher levels, for example the lecture and course level. He can also compare the different bubble sizes, which gives him a hint regarding the

popularity of that learning unit. This provides implicit social navigation support for collaborative e-learning, in which students can have a sense of peers' activity.

## VI. EVALUATION

We conducted a survey-based initial evaluation. Nine students from a previous offering of the ISD course participated. Overall, at least 70% of the students gave positive feedback (agree or strongly agree) regarding the interface features. Moreover, at least 60% of the students gave positive feedback about social learning. All students were satisfied with the interface and would recommend the interface to their classmates. Although this implementation is a prototype, the design is promising to the students.

<b>A. Your background knowledge</b>	
A1	I am familiar using Google Maps. ( __Yes. __No.)
A2	I am familiar with Treemap as a layout for hierarchical visualization. ( __Yes. __No.)
<b>B. Your perception of the interface (See Fig. 5)</b>	
B1	The layout (Treemap) of the base images helps me to keep track of the course structure on different level, for example, course level, lecture level, topic level. (1 2 3 4 5)
B2	The Zoomable interface helps me to navigate through different level without confusion. ( __Yes. __No.)
B3	The feature of combined color and size of the bubbles helps me to identify my strength and weakness, while keeping track of group activities in class. (1 2 3 4 5)
B4	The bubbles on each level help me to focus on most critical tasks on that level. (1 2 3 4 5)
B5	The layer buttons help me to navigate through the multi-layer content. (1 2 3 4 5)
B6	The pop-up information window helps to look for more course material further. (1 2 3 4 5)
<b>C. Your preference about the interface</b>	
C1	The interface is intuitive to use. (1 2 3 4 5)
C2	I am satisfied with the interface. (1 2 3 4 5)
C3	I would recommend the interface to my classmates. (1 2 3 4 5)
C4	I will use this interface if provided in similar classes. (1 2 3 4 5)
C5	I feel comfortable sharing my progress with others. (1 2 3 4 5)
C6	I do not mind that my progress is displayed anonymously in the average progress of the entire class. (1 2 3 4 5)
<b>D. Additional comments about the interface</b>	

Table 1. Questionnaire

### A. Survey Design

Since ProgressiveZoom is a new Zoomable interface design, it has not been compared to other existing tools. It is inspired by Google Maps, and it uses Treemaps as the layout for the base map. We hypothesize that students who are familiar with Google Maps and Treemaps should feel more comfortable with ProgressiveZoom. Therefore, we divided the questionnaires into four parts: user background, perception, preference and free-form comments (Table 1). The scale is 1 to 5 from strongly disagree to strongly agree.

We asked the students to watch the video at: <http://youtu.be/56T94jJFma8> and explore the demo at: <http://adapt2.sis.pitt.edu/pz/test.jsp>, then answer the questions as shown in Table 1.

### B. Findings

For the positive perspective (yes, agree or strongly agree), as shown in Fig. 7, all 9 students were familiar with Google Maps (A1) and they all agreed that the Zoomable interface helped them to navigate through the course structure without confusion (B2). This provides us with evidence that the Progressive Zoom navigation can be extended to support learning. Figures 7 and 8 also show that 7 out of 9 students were familiar with the Treemap layout (A2), and they indicated that the Treemaps layout for the base maps helped them to navigate the course on different levels (B1). This finding exceeded our expectations, which supports our assertion that the hierarchical course structure is straight-forward enough for students. All students were satisfied with the interface (C2) and would recommend the interface to their classmates (C3).

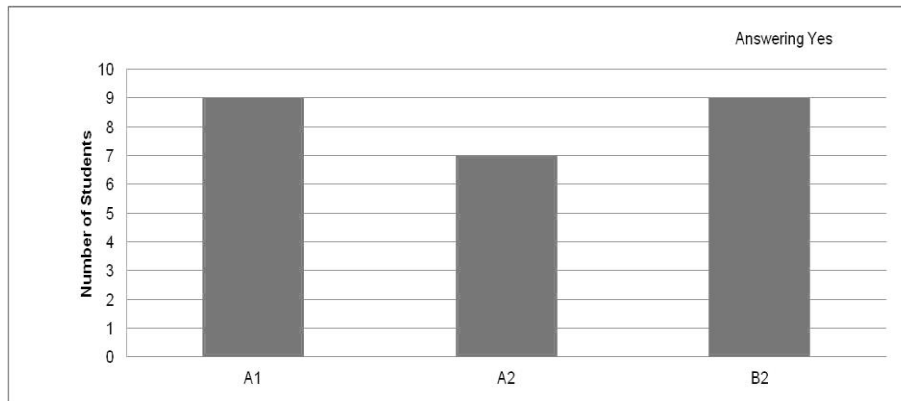


Fig. 7 Evaluation: A-Background and B2-Zoomable Interface

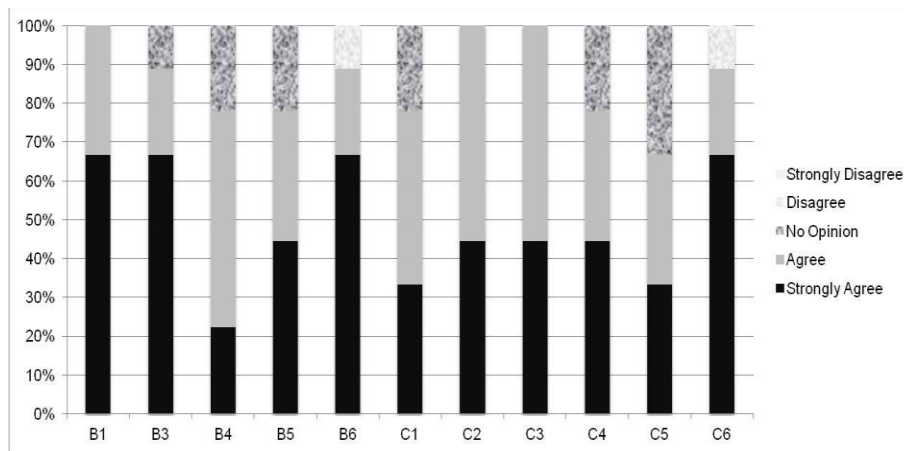


Fig. 8 Evaluation: B-Perception and C-Preferences

From the negative perspective (no opinion or disagree), one out of nine students indicated having no opinion about using the combined color and size features of bubbles to represent the individual and peer progress (B3). This is also better than we expected because this is an over simplified version to visualize the open social student model. Two students noted no opinion of the bubbles on each level (B4) and the layer buttons (B5), as they thought the interaction were not fully functional as Google Maps. We think these are issues caused by some technical challenges in the implementation. For example, the zoom-start event is not captured by the zoom control in Google Maps API v2. We cannot remove the bubbles on each layer when using the Google Zoom control. As a result, the students can zoom in with a double-click mouse event and can only zoom out with layer buttons. One student indicated that the pop-up information window did not help in finding more related course materials (B6): he opined that the system should provide more related information other than those in the bubbles. We think this details-on-demand feature is just a starting point, and we are happy to see that students are asking for more helpful information in this feature. Two students had no opinion of the intuitive interface (C1). And one of the two students mentioned that similar materials were spread over many lectures. We think this is caused by the primitive functioning of the knowledge modeling. Two of the nine students indicated no opinion if they

will use this interface as provided in other similar courses (C4), but we are not certain of the reasons yet. Finally, as for the social learning feature, three students had no opinion regarding whether or not they feel comfortable sharing their progress with others (C5). One student indicated that she does mind that her progress is displayed anonymously in the average progress of the entire class (C6).

The verbatim comments also provide insight from the students; they provide a balanced view of both positive and negative perspectives:

“The interface is quite innovative and attractive. The Treemap layout makes the course structure very straightforward. I can easily understand the proportion of each section in the course and the relationship between them. This goal is relatively hard to reach in nowadays e-learning systems. The colorful bubbles are also really helpful. I can focus on my weakness and get encouraged when color changes. Another thing I like is the display of previous layer keywords and next layer keywords at the same time. It prevents the user from getting lost while navigating. With different font size, I can easily distinguish the previous layer from the next layer. The only small issue is that currently I need to double-click on a portion of the course to zoom-in or out. If in the future I can also use mouse wheel to zoom-in and out, like Google Maps



does, that might be more perfect. On the whole, the design is really fascinating and I would definitely recommend to others.”

“Based on the demo, I realized that when I first use it, I can easily know how to operate it without instruction. It is very good thing. However, maybe the structure in the demo a little bit mass for user to figure out different classes. I mean maybe we can make the shape more organized. I have not realized that the size of the shape is based on the child nodes or the number of pages. And I think this kind of method to arrange the size is very interesting and useful. Because the bigger size means more important or more content, so it is better that let user to see it more clear.”

“The interface is well-designed to me. It provides a new way for students to learn. However, I find two shortcomings. First, the bubble in the first layer has continuous duplicates like the following picture. Second, it is always dynamic zooming without physical zooming. Third, it doesn’t allow mouse to roll to zoom in or zoom out. It requires user to click on the zoom in/out button to change from layers.

“It would be better if the interface can change the progress immediately and user can use the mouse scroll to zoom in or zoom out the interface.”

“Less grid in first sight and when user click it, then zoom in and show more grids.”

“Interface looks great and professional; the most important part is that it’s easy to use. But when loading the Treemap, it’s some sort of slow. Besides the interface part, I think there is one thing you may think more about. When you click and get the pop-up info, if the progress shows 0% and you click the article to enter the article page, whether you read it or just open the window, when you refresh the Treemap page, the progress will increase, like to 100%. It’s some kind of improper.”

“Some of subtopics contain no materials related to study topics or, topics just display one material for one topic, it is enough to calculate how much you have completed in the study process.”

## VII. SUMMARY AND FUTURE WORK

In this paper, we have presented a novel approach to collaborative e-learning through open social student modeling and Progressive Zoom navigation. Progressive Zoom is inspired by Google Maps in order to address information overload issues. It enables students to zoom in or out in a multi-layer fashion, so students can reflect on their individual and group progress based on the knowledge and pedagogical context. In our initial survey, all nine students were satisfied with the overall interface and would recommend the interface to their classmates. Based on a smaller portion of students having a negative opinion of some specific features or preferences, they confirm that we should strive for more in depth research in this direction.

Since currently we only include a simple “number of visits” to an external textbook reader, one of the future efforts will be to provide better textbook reading support for collaborative e-learning. It is a strategy introduced by “Cognitive Psychology and Its Implications” [1]:

A variant of the PQ4R (Preview, Question, Read, Reflect, Recite, and Review):

- 1) Preview the chapter.
- 2) Make up a study question.
- 3) Read the section and understand it and answer your question.
- 4) At the end of each section, read the summary and ask yourself if that is the main point you got out of the section and why it is the main point.
- 5) Go through the text, mentally reviewing the main points.

When applying this strategy, people usually make notes on the textbooks. We think the Progressive Zoom navigation will help to reinforce this strategy. For example, it would be easier to skim through the topic/chapter layer in order to have a preview of the subject, making notes of study questions for that layer. It would be easier to *zoom in* on the sub-topic/section layer to get more details and work on the questions, then *zoom out* again to reflect on the overall picture and main points. Furthermore, these activities would become valuable “footprints” for the peer readers: imagine that we can read notes and reflections from a professor/author years later. Again, this will further facilitate the collaborative e-learning.

Other future work revolves around how to extend the open social model to provide adaptive social knowledge maps for students from different degree programs as discussed in Section 4. From the interface perspective, we plan to provide explicitly support for self-guided learning [41] through dynamic query, overviews and details on demand, and linked view. These tasks include diagnose learning needs, formulate learning goals, identify learning resources, select and implement learning strategies and evaluate learning outcomes. We also plan to conduct a semester-long classroom user-study to investigate if this tool will help students to increase their awareness and engagement in the learning process.

## ACKNOWLEDGMENT

This research was supported in part by the National Science Foundation under Grant No. 0447083

MinEr Liang is currently a Visiting Scholar at the School of Information Science, University of Pittsburgh. She would like to thank the Faculty, Staff, and Colleagues of the school for their support during the work reported in this paper. This work was supported by a grant from the National Natural Science Foundation of China (No. 60973026), the Shanghai Leading Academic Discipline Project (project number B114), and the Shanghai Committee of Science and Technology (nos. 08DZ2271800 and 09DZ2272800).

Julio Guerra is supported by a Chilean Scholarship (Becas Chile) from the National Commission for Science Research and Technology (CONICYT, Chile) and the Universidad Austral de Chile.

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