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GeogDL: a web-based approach to geography examination revision

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Abstract

The traditional educational approach with students as passive recipients has been the subject of criticism. A constructivist learner-centered approach towards education has been argued to produce greater internalization and application of knowledge compared to the traditional teacher-centered, transmission-oriented approach. Nevertheless, contemporary instructional design models argue for the use and integration of both approaches especially in complex learning tasks. This paper describes GeogDL, a Web-based application developed above a digital library of geographical resources for Singapore students preparing to take a national examination in geography. GeogDL is unique in that it not only provides an environment for active learning, it also adopts a pragmatic approach to learning that recognizes the importance of examinations especially in the Singapore education system. The paper discusses the components within the system that permit teachers to facilitate active student learning, to draw interconnections, and to promote knowledge sharing and collaboration. GeogDL was pilot-tested on a group of secondary school students in Singapore and the results suggested the viability of the system and also provided direction for future development.

Keywords: Applications in subject areas; Interactive learning environments; Pedagogical issues; Secondary education; Teaching/learning strategies

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1. Introduction

Students in Singapore undergo four or five years of secondary-level education (Grades 7–10) after which they take the Singapore-Cambridge General Certificate of Education 'Ordinary' (GCE 'O') level examination. This is an annual national examination covering a variety of subjects such as mathematics, the sciences, literature, and geography, among others. Students are then admitted to various higher-level educational institutions such as junior colleges and polytechnics depending on the results obtained (Ministry of Education, 2000).

The GCE 'O' Level geography examination is broadly classified into three themes – physical geography, human geography, and map reading techniques (Ministry of Education, 1998). Physical geography examines the distribution of physical features on the Earth's surface and also looks into how various weathering elements affect climate, vegetation and land formation. Human geography is concerned with the distribution of human features and their activities on the Earth's surface, and the correlation of people with the environment. Finally, map reading imparts the skills necessary for navigation as well as the interpretation of maps and physical landscapes.

Students studying geography are assessed on their ability to draw relationships between different topics. They are required to demonstrate reasoning skills, have the ability to select, organize and interpret geographical data, recognize patterns and deduce relationships. It is also expected that through the geographical training they receive, students will be able to make judgments that demonstrate sensitivity and concern for the environment (Ministry of Education, 1998). Types of questions asked are thus diverse ranging from those that require higher-order thinking skills to those that test factual content.

The instruction of geography at the secondary-level is predominantly textbook-based supplemented with resources such as Web sites, CD-ROMs, and physical models (2-D and 3-D). In addition, a popular approach to examination revision involves students working on past-year GCE 'O' level geography examination questions and perusing their solutions. With these, students are able to see examples of the types of questions typically covered in the geography examination, look at possible solutions, judge the relative importance of certain topics, and even spot "trends" in the types of questions asked.

Past-year examination solutions are currently sold as books organized by year and/or topics. While relatively popular, these solutions have several shortcomings. For example, because these solutions are produced by independent publishers, some answers may not be correct. Teachers are typically not able to discover all errors due to the range of publications available. Consequently, students who are not discerning will simply accept all solutions as correct. Further, students use these solutions to determine important areas in the examination and then focus only on them. As a result, students become "exam smart", knowing only how to answer certain questions but not necessarily demonstrating an understanding of the subject. This observation is supported by studies documenting that many students who score well on standardized tests are still unable to successfully integrate knowledge gleaned from the classrooms with real-life applications (Resnick, 1987; Yager, 1991).

Despite their shortcomings, we adopt the view that past-year examination solutions when properly used with existing teaching materials can be a useful educational resource. For example, teachers could first locate or author acceptable solutions and supplement them with related topics

for students to explore. Alternatively, students can work independently or in groups to author solutions with the teacher working as a facilitator alongside them ensuring accuracy of content. These solutions can then be shared with other students.

The remainder of this paper describes GeogDL, a Web-based application for helping students study and prepare for the GCE 'O' level geography examination (Chua, Goh, Lim, Liu, & Ang, 2002). Using GeogDL, students may attempt examination questions, peruse solutions, explore resources related to questions and share knowledge with other users. The paper begins with the philosophy behind the design of the application followed by a description of its features and usage. In particular, this paper will highlight the components within the application that were built upon learner-centered, constructivist principles, hence demonstrating how teachers can use the system to facilitate active student learning and to assist students in drawing interconnections between various aspects of geographical issues.

2. The GeogDL project: Rationale and theoretical underpinnings

Constructivism has received considerable attention in teacher preparation, education scholarship and policy formation (MacKinnon & Scarff-Seatter, 1997; Teets & Starnes, 1996). It has been heralded as an approach that is more productive and relevant for teacher training as well as for instructing elementary through high-school students (Cannella & Reiff, 1994). Constructivist approaches maintain that individuals create knowledge via active involvement with content rather than through imitation or repetition (Kroll & LaBosky, 1996). Learning activities in constructivist environments are characterized by active engagement, problem-solving, inquiry, and collaboration with others. This challenges the traditional reductionist approach to teaching and learning which are teacher-centered, memory-oriented and transmission-oriented. The traditional approach is one in which the teacher fills the students with deposits of information deemed by the teacher to be knowledge, and the students store these pieces of information intact, until needed (Oldfather, Bonds, & Bray, 1994). Constructivists argue that when information is obtained purely via transmission models, it is not always integrated with prior knowledge and is often only accessed and articulated for academic purposes such as formal tests and exams (Richardson, 1997). Teaching and learning via constructivist models have been argued to produce in-depth understanding, greater internalization and application of knowledge (Cannella & Reiff, 1994; Richardson, 1997).

Nevertheless, such arguments do not mean that traditional approaches to teaching and learning are inappropriate. In most subjects taught at secondary or primary levels, students typically require both domain knowledge and the ability to apply such knowledge to solve problems that may be ill- or well-structured. Geography is no exception, and students are required to acquire both types of knowledge (Ministry of Education, 1998). Consequently, we agree with contemporary instructional design and learning models that students involved in complex learning tasks such as the study of geography should be provided with a variety of practice task types. For example, the 4C/ID model (Van Merriënboer, Clark, & De Croock, 2002) adopts a holistic constructivist approach that integrates traditional learning techniques. In addition, the American Psychological Association (APA) Task Force on Psychology in Education (APA Task Force, 1997) examined ways in which psychology of learners and learning could inform curriculum instruction and

design. Recommendations from the Task Force report included 14 learner-centered psychological principles. Specifically, the first principle states that "the learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience" (APA Task Force, 1997, Cognitive and Metacognitive Factors Principle 1). Further, techniques involved may include "habit formation in motor learning; and learning that involves the generation of knowledge, or cognitive skills and learning strategies" (APA Task Force, 1997, Cognitive and Metacognitive Factors Principle 1).

In the context of successfully negotiating the geography examination, students should thus be exposed to a variety of question types ranging from drill and practice questions commonly used in traditional teaching approaches to those requiring active student exploration and participation used in the constructivist approaches to teaching and learning. GeogDL subscribes to this view of supporting geography education through a Web-based application providing access to a repository of past-year examination questions and solutions supplemented with additional geographical content. The latter are accessible through G-Portal (Lim et al., 2002), a digital library system providing services over geospatial Web content. GeogDL is not meant to be a replacement for textbooks and classroom education, but an alternative to printed past-year examination solutions. One of the goals of this project is to shift students' attitudes towards geography education from one that is mainly exam-oriented to one that encompasses active learning and knowledge construction. For this reason, students perusing questions and solutions in GeogDL can also access and interact with related resources via G-Portal. The two systems work in concert, with GeogDL providing focused examination preparation while G-Portal facilitates exploration of geography concepts in general.

3. GeogDL: Features and architecture

GeogDL consists of three major modules: the practice and review module, the mock exam module, and the contributions module. Together, these components provide a learning environment that fosters individual as well as group learning among users of the digital library.

3.1. Accessing individual examination resources

GeogDL's practice and review module allows users to attempt individual examination questions, review answers and explore related supplementary content. Students can either browse a hierarchically organized list of questions modeled after the geography syllabus or perform searches over the collection.

Fig. 1 shows how examination questions are accessed through the practice and review module's search interface. Students can either use a simple keyword search or opt for more advanced search features such as specifying question type (e.g., multiple choice or essay) or year ranges. Upon selection of a question in the search results listings, GeogDL displays it together with a set of possible answer choices (for multiple choice questions). When an attempt is made, GeogDL presents the solution as well as an explanation for it. At the same time, links to concepts related to the present question are also displayed as part of the solution. Selecting a link causes GeogDL to invoke G-Portal to allow exploration of the supplementary resources associated with that concept

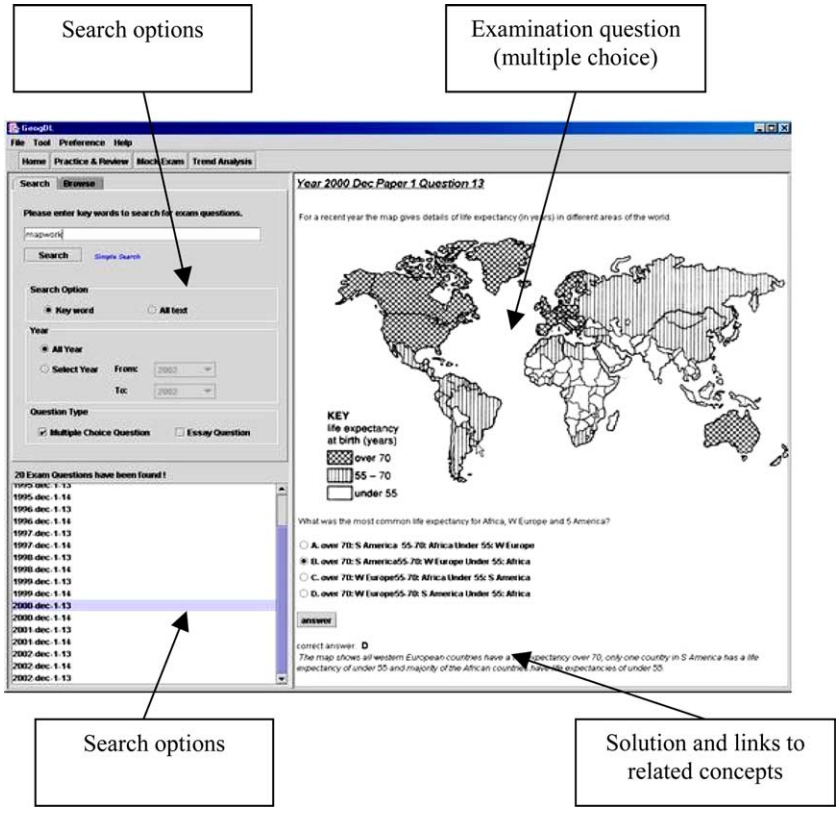


Fig. 1. Accessing examination questions and solutions in GeogDL.

(see Section 3.4). In the current implementation, resources are geography-oriented Web sites selected by teachers after a review process.

Relationships may also be drawn across examination questions. For example, a related link found in a particular solution might be a reference to another examination question. Students following that link will cause GeogDL to display that question. The ability to find related information including examination questions provides a further benefit to students over print versions of solutions. With print, students tend to study solutions in isolation. Using GeogDL however, students are able to gain a broader perspective of the geography examination as well as the subject itself.

3.2. Attempting mock exams

Fig. 2 shows GeogDL's mock exam interface. It has a deliberate minimalist design to focus users on the content. Upon reading a question, users provide an answer and proceed to the next question. Users may also revisit previous questions to modify their answers. GeogDL monitors the time taken for each question to give an indication of how difficult a particular question is to a student.

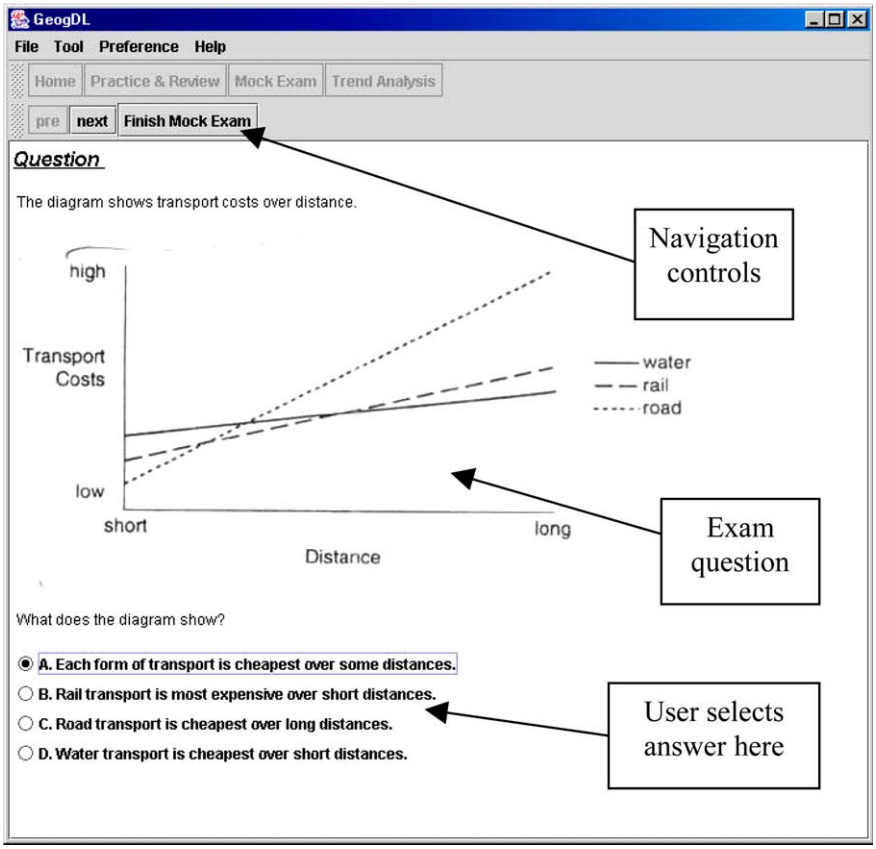
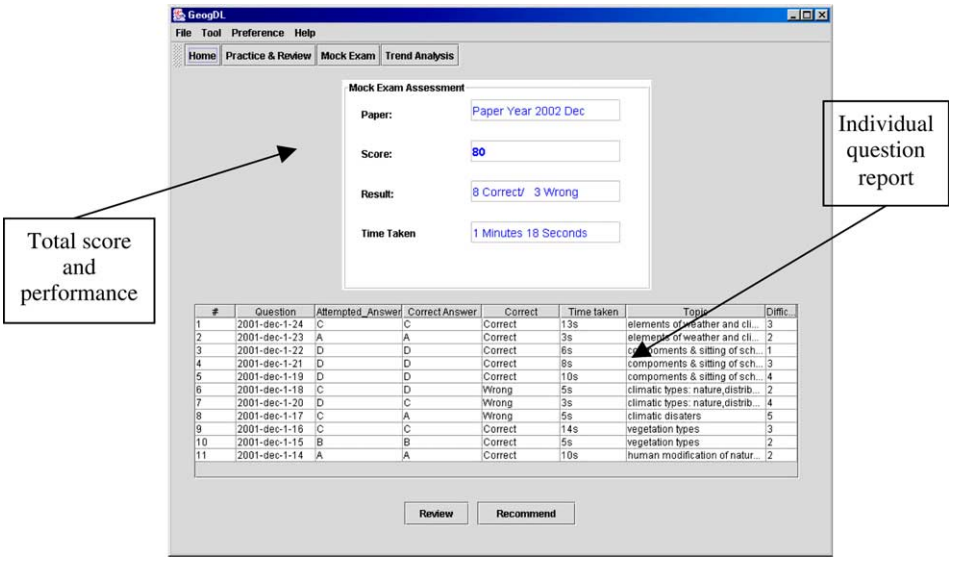


Fig. 2. GeogDL's mock exam interface.

Upon completion of the mock exam, GeogDL grades it and displays a performance report (Fig. 3). The report contains a summary of the results and includes the total score and total time taken. Performance data for individual questions are also provided. This includes the correct answer, time taken, question topic and difficulty level. Students and teachers may use the performance report to gauge mastery of geography concepts as well as areas for further improvement. Students may also review the solutions and explore supplementary resources from the report interface.

The structure and content of a mock exam is defined by a mock exam paper – a virtual collection of examination questions. The paper is virtual because questions are not predefined. Instead, an author (e.g., a teacher) indicates the characteristics of questions that should appear. These include question type (e.g., multiple choice, essay), topic area (e.g., "natural vegetation"), number of questions and level of difficulty (as indicated by the questions' metadata). When a mock exam session is initiated, GeogDL selects questions using the characteristics set in the paper. Students are thus presented with a unique exam each time a session is run, allowing them to attempt a wider variety of questions. Authors may also create static mock exam papers so that



#	Question	Attempted_Answer	Correct Answer	Correct	Time taken	Topic	Diffic.
1	2001-dec-1-24	C	C	Correct	13s	elements of weather and cli...	3
2	2001-dec-1-23	A	A	Correct	3s	elements of weather and cli...	2
3	2001-dec-1-22	D	D	Correct	6s	components & sitting of sch...	1
4	2001-dec-1-21	D	D	Correct	8s	components & sitting of sch...	3
5	2001-dec-1-19	D	D	Correct	10s	components & sitting of sch...	4
6	2001-dec-1-18	C	D	Wrong	5s	climatic types: nature,distrib...	2
7	2001-dec-1-20	D	C	Wrong	3s	climatic types: nature,distrib...	4
8	2001-dec-1-17	C	A	Wrong	5s	climatic disaters	5
9	2001-dec-1-16	C	C	Correct	14s	vegetation types	3
10	2001-dec-1-15	B	B	Correct	5s	vegetation types	2
11	2001-dec-1-14	A	A	Correct	10s	human modification of natur...	2

Fig. 3. The mock exam report.

each session results in the same set of questions. This feature would be useful in situations when a teacher wants to measure the performance of his/her class, when a teacher wants students to attempt certain questions that are deemed important in the geography examination, or to emphasize a certain topic learnt in class.

3.3. Making contributions

GeogDL provides an environment for collaboration and knowledge sharing, one in which content constantly evolves through the contribution of new information by students, teachers and other stakeholders. This is facilitated through the contributions module, and in GeogDL, contributions can be in the form of discussions about existing content in the digital library or new content (examination questions, solutions and supplementary resources).

All registered GeogDL users are able to contribute to discussion topics. This is designed to be similar to Usenet newsgroups or Web-based discussion forums that most users are familiar with. Discussion topics are associated with a particular examination question–solution pair and provide a means for users to comment about their opinions about the question/solution, to provide additional information, to seek clarification about certain issues, or simply to chat with other users. Fig. 4 shows GeogDL's interface to access and contribute to discussion topics. Upon selection of a question, the user invokes the discussions interface and browses the various topics found there. The user is also able to create a new topic or reply to an existing topic.

Unlike discussion topics, new content contributions are restricted to a limited set of authorized users in order to maintain the quality of the collection. These users are typically teachers, GeogDL administrators or other stakeholders familiar with geography and/or the examination syllabus. As a further means of ensuring quality, contributions are further subject to review. Thus,

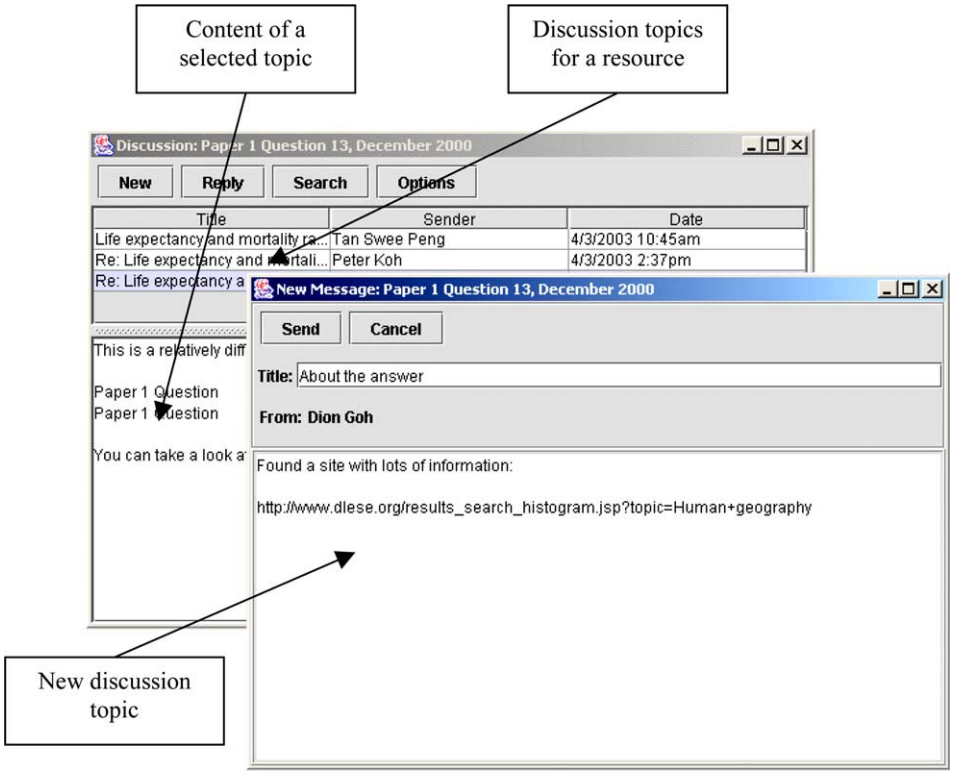


Fig. 4. Contributing discussion topics in GeogDL.

contributions are not immediately added into the digital library. Instead, they are stored in a holding area pending review either by a teacher or a stakeholder with an editorial role. If a resource is judged to be acceptable, the reviewer "publishes" it, after which it becomes available to all other GeogDL users. Contributions that are judged to be not of "publishable quality" will be returned for revision. Alternatively to facilitate student contributions, teachers could assist students with authoring of their resources to ensure that the content is accurate and acceptable.

3.4. G-Portal

As discussed previously, G-Portal is used to explore supplementary resources associated with an examination question. The system is a complementary project to GeogDL whose aims include the identification, classification and organization of geospatial content on the Web, and the provision of digital services such as searching and visualization.

G-Portal resources are defined as Web content, annotations and metadata and are organized around projects which are user-defined collections of related resources. Resources within projects are further organized into layers which allow finer grained organization of content. Resources within a project are visualized using either a map-based interface or a classification interface (see

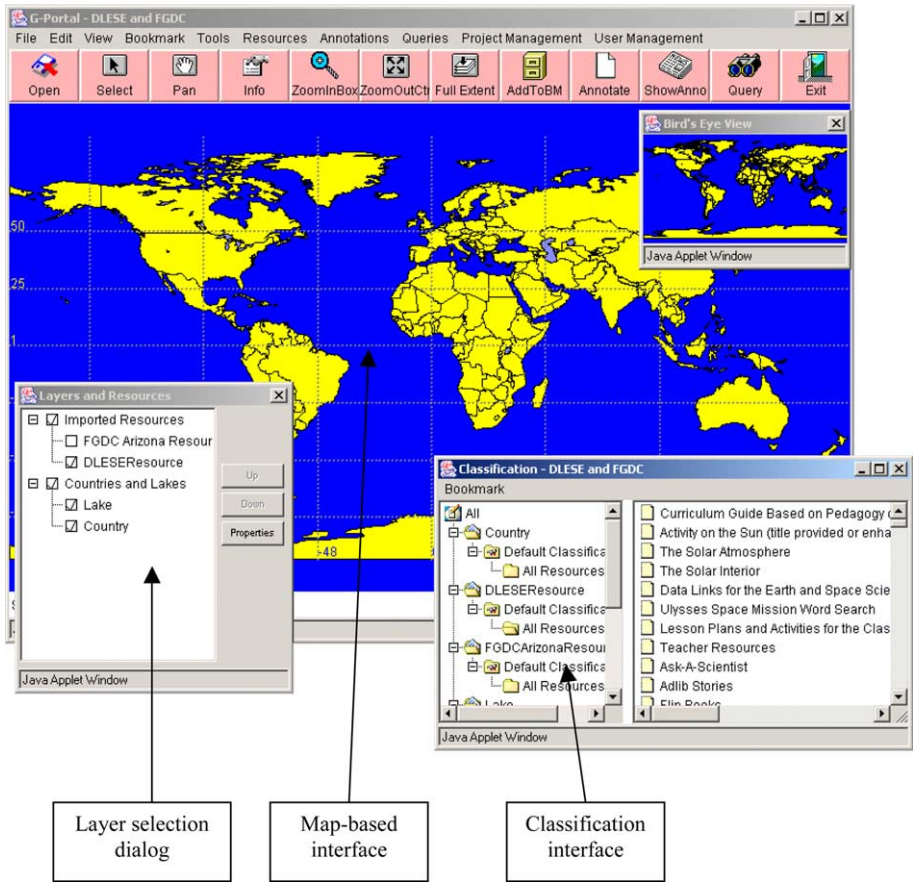


Fig. 5. Accessing supplementary resources through G-Portal.

Fig. 5). In GeogDL, supplementary resources associated with each examination question are packaged as separate projects.

The map-based interface displays resources with spatial attributes. These include countries, rivers and mountains and their associated content (for example, identifying a particular climatic region on a map). Navigation tools such as zoom and pan are provided for users to browse the map. In addition, project layers may be shown or hidden, changing the visibility of the associated resources. Resources without spatial attributes are displayed using the classification interface which categorizes and presents resources using project-specific classification criteria, and is similar in appearance and functionality to Microsoft Windows' Explorer application. Examples of such resources include general information about climate ("Why are land and sea breezes a feature of many coastal regions") and population ("What problems does the growth of squatter settlements create for large urban areas?").

The map and classification interfaces are synchronized so that when a resource on one interface is accessed, related resources on the other interface can be displayed. For example, if a user selects an equatorial region on the map interface, the classification interface may display resources

describing the characteristics of such a region. More information about G-Portal can be found in Lim et al. (2002).

3.5. Architecture

The major components of GeogDL are shown in Fig. 6. The collection of the digital library is maintained in two databases. The question database stores examination resources (questions, answers, supplementary resources and mock exam papers) while the metadata database stores metadata for these resources.

The mock exam module automatically extracts questions from the question database given a mock exam paper and presents them to the user. The practice and review module on the other hand, allows users to attempt individual questions, review answers and peruse related supplementary content. These are retrieved by the browse and search service. Using this service, users can either perform fielded searches on the metadata database or browse a hierarchically organized list of questions modeled after the geography syllabus. As users interact with these modules, access to each question is logged into the question statistics database which keeps track of overall usage patterns much like Web server access logs. This database also maintains distribution data for individual topic areas. Both sets of data are used by students and teachers to monitor individual or class performance.

The annotation module allows users (e.g., students and teachers) to contribute discussions to the digital library. Registered users may create or add to threaded discussions on any of GeogDL's resources, or rate resources according to quality and level of difficulty. This module facilitates communication between students and their peers, and between students and teachers, and

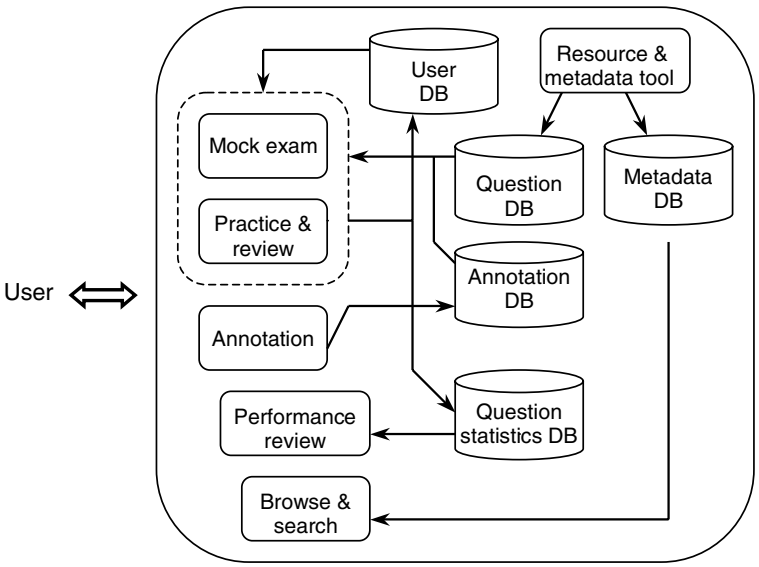


Fig. 6. GeogDL's architecture.

in the process, provides a means for sharing knowledge about topics in geography and the examination itself. Contributions are saved in the annotation database and are displayed by the practice and review module when associated resources are accessed. Finally, the resource and metadata tool allows authorized users such as teachers to add and modify resources in the digital library. As each resource must be associated with appropriate metadata, the tool also provides support for metadata entry and validation.

4. Using GeogDL

As discussed previously, GeogDL and G-Portal are not meant to be replacements for classroom instruction and textbooks but as complements to them. At the same time, we also recognize that teachers have increasing responsibilities in schools and thus, a major design goal for the two systems is that they should be simple and intuitive enough to be used by students without constant intervention by teachers. Put differently, GeogDL and G-Portal should not be viewed as additional burdens to teachers who will otherwise resist using them in their classrooms.

Thus, we envisage a practical strategy for incorporating the two systems into the classroom in which students are the main users while teachers become facilitators who provide guidance only when necessary. Consider, for example, the use of GeogDL as a drill and practice tool for examination preparation. Upon completion of a lesson, teachers could ask students to attempt related questions to assess mastery of the topic. In addition, using the virtual mock exam paper in GeogDL, a teacher might create exams with varying levels of difficulty, and then instruct students to attempt a particular exam given his/her ability level. Such approaches could conceivably help in easing a teacher's workload (Goh, Theng, Yin, & Lim, 2003). In a typical classroom setting, students would attempt print versions of mock exams and upon completion, the teacher would painstakingly go through each solution, answering any questions that might arise during the process. With GeogDL, students could independently attempt the questions and then peruse the solutions and supplementary resources (via G-Portal). The teacher now becomes a facilitator that assists students in interacting with the systems, and provides additional instruction only when students require more information than what GeogDL and G-Portal can provide.

Teachers could also use GeogDL and G-Portal as tools that assist in the development of students' metacognitive skills through techniques such as problem-based learning. Consider a scenario where a teacher completes a lesson on natural vegetation and students are presented with an activity that investigates how climate affects various species living in different types of forests found in Asia. To assist them in their work, students are asked to use GeogDL and G-Portal to study the topic further and at the same time, attempt related examination questions to reinforce what they have learnt. Once notified, students log into GeogDL and begin exploring the resources by searching and browsing for questions they wish to view, perusing the solutions, and exploring related topics using the G-Portal system through following links found in the solutions.

Knowledge construction is also supported through GeogDL's contributions module. Through the use of discussion topics, students can create communities around areas of interest and share their knowledge about the subject. This could include personal comments, snippets of information from various sources, or links to Web sites. For example, a student in the above scenario encounters the following natural vegetation question in GeogDL:

An image with two forest profiles is shown. Forest A has a dense vegetation growth, consisting of thick underground growth, trees with thick trunks, closely spaced with heights ranging from 15 to 45 m. Forest B is comparatively more open and less luxuriant, with little undergrowth and the tree trunks are more slender. The heights of the trees are between 12 and 35 m. Students are required to identify the forest types and suggest possible locations of such growth. They are also required to describe the main differences between the two profiles in terms of forest structure and tree type.

The solution to the question identifies regions such as Central and South America, Africa, and Southeast Asia as those with tropical rainforests (Forest A) and countries such as Australia, India, Bangladesh and China as those with tropical monsoon forests (Forest B). Supplementary resources associated with each region are also included in the solution. After reading the solution, the student initiates a discussion topic asking for more information about tropical rainforests and the type of flora and fauna found there. Other students (and perhaps teachers) with such knowledge might respond with this information. Due to the unstructured nature of discussion groups, topics could evolve in fascinating and unexpected ways resulting in further knowledge creation in areas other than tropical rainforests. Here, the teacher could play the role of a moderator that guides discussions, providing accurate and timely information, and ensuring at the same time, that students do not stray from the learning goals. Note also that the solution contains regions (e.g., South America and Africa) not covered in the original class assignment (Asia). However, by reading the associated supplementary resources, students will be better able to draw relationships between climate and species in various forest types by reading about similarities and differences across the world, and not just in Asia.

Finally, while GeogDL provides a mock exam module, it is meant as a tool to provide feedback on how well a student masters geography concepts and areas for further improvement rather than just another means for assessment. For this reason, the design of the entire system emphasizes content over assessment, with other features such as discussions and resource exploration playing a more central role. As a result, students are encouraged to look beyond answers and performance measures and use GeogDL as a tool for discovery and learning. However, such a mindset change requires assistance from teachers who need to stress to students that GeogDL is not just another automated testing tool to grade individual performance, but a resource for geography education.

5. Pilot study

GeogDL and G-Portal were pilot-tested on a group of secondary school students. The study sought to determine the usability of the system and to elicit feedback to guide future development and was based on by Carroll's (2000) work on the task-artifact cycle and user-centered strategies such as scenario-based design and claims analysis.

5.1. Participants and procedure

Participants (4 boys and 4 girls) came from a local secondary school in Singapore. The boys were between 13 and 14 years old, and were generally more confident Web users compared to the girls. They rated themselves as novice to intermediate in terms of library searching/browsing skills.

The girls rated themselves as novice or intermediate users of the Web. Similar to the boys, library searching/browsing skills were not good, ranging from novice to intermediate.

Since one of the goals of GeogDL is to help students revise for the GCE 'O' level geography examination, participants were presented with a scenario (Carroll, 2000) in which they had to use the system for locating and practicing examination questions and G-Portal for exploring supplementary resources. Participants were then asked to evaluate how well the two systems could fulfill the tasks required by the scenario. Each participant was assigned a usability-trained evaluator who observed how the tasks were performed, elicited feedback, and provided any necessary assistance.

5.2. Findings

Participants' responses to GeogDL were encouraging. In particular, most liked the idea of having an online tool in which they could search and browse for examination questions, attempt them and view suggested solutions. The ability to explore related questions and supplementary resources was also appealing since this feature was not available in print versions of examination questions. Two participants however did express reservations about the effectiveness of GeogDL over print. Such responses were expected since participants were new to the system and this lack of experience inevitably caused problems in using GeogDL during the pilot study. Nevertheless, GeogDL did receive unequivocal endorsement in that all participants were willing to evaluate the next version of the system if invited, and they would also recommend the system to their classmates when it became publicly available.

Participants encountered more problems while using G-Portal than GeogDL. Perhaps one of the biggest obstacles of using G-Portal was that participants were familiar with the Web-based model of interaction rather than the system's map-based, direct manipulation model. For example, all participants initially experienced some difficulty in zooming and panning within the map as well as deciding which project layers to show and hide. This required the usability-trained evaluators to intervene and provide guidance, and resulted in comments such as "I'm not sure what to do or how to proceed", "I don't know how to start using G-Portal" and "links are not designed using Web formats".

After using the system for a short period of time however, participants remarked that the navigation features (e.g., zooming) were similar to those in popular software such as Microsoft Word and no further problems in this area were encountered. One possible reason that this issue arose was that there was a divergence in participants' expectations between how G-Portal should work and how the system actually functioned. Specifically, because participants were informed that G-Portal was a Web-based application, they were conditioned through experience to expect an information access model based on navigation via hyperlinks. Thus when presented with a Java applet that offered access to examination resources through a map-based interface, they became confused and needed time to reorient themselves to interacting with G-Portal using this relatively unfamiliar metaphor.

In contrast, participants were observed to have fewer problems using GeogDL because it functioned more like a regular application. Although they too were told that GeogDL was a Web-based application, participants were better able to reorient themselves when they saw familiar user interface controls such as buttons, list boxes, text fields and menus.

5.3. Future work

Improvements under consideration for the next iteration of GeogDL and G-Portal involve the implementation of a virtual tour of the system supported with online help and proper training for users. Other features suggested by participants include a personal coach that analyzes mock exam performance and recommends questions and supplementary resources tailored to specific needs as well as collaborative tools for real-time chatting and authoring.

In addition, although the findings in this initial study proved useful, its shortcomings are also recognized due to the non-generalizability of the results because of the small number of participants. Future work will thus include two further studies. The first concerns a larger-scale usability evaluation of GeogDL and G-Portal involving several classes of geography students. A second, longitudinal study will track a group of students as they use GeogDL and G-Portal to determine whether desired learning outcomes in geography have been achieved.

6. Conclusion

This paper describes GeogDL, a Web-based application providing access to a digital library of geographical resources for students in Singapore preparing to take a national examination in geography. These resources include past-year examination questions and solutions supplemented with additional geographical content. GeogDL is unique in that it not only provides an environment for active learning, it also adopts a pragmatic approach to learning that recognizes the importance of examinations especially in the Singapore education system.

Thus, while GeogDL shares the same philosophy of constructivism as existing education-oriented geography digital libraries, the system differs it that it also incorporates elements of traditional learning methods such as drill and practice. In this sense, our view shares similarities with contemporary instructional design models (Van Merriënboer et al., 2002) in that complex learning tasks should be supported by a variety of learning strategies (both traditional and constructivist) to achieve desired outcomes. For example, the Alexandria Digital Earth Prototype System (Smith, Janee, Frew, & Coleman, 2001) provides students with "learning spaces" (Coleman, Smith, Buchel, & Mayer, 2001), personalized collections of geospatial resources relevant to one or more concepts or hypotheses. Through the process of exploring, manipulating and interacting with the resources in these learning spaces, students' scientific reasoning skills in geography may be cultivated. These skills can then be applied to solve real-word problems as well as examination questions. In contrast, GeogDL adopts a "bottom-up" approach in which students are first assisted with examination preparation. As students explore examination questions and solutions, GeogDL provides related higher-level concepts for them to investigate, allowing them to draw associations between various geographical issues and developing their reasoning skills.

Important constructivist, learner-centered features of GeogDL include the ability to find related information across examination questions and related geographical information, as well as facilities for collaboration and knowledge sharing whereby students can contribute to the digital library. Deep learning in students can be promoted if students are engaged in personally relevant

educational activities (Anderson & Pearson, 1984; Moreno & Mayer, 2000). For example, in Moreno and Mayer's (2000) investigation, students who received personalized messages were more likely to attain deep understanding and were better able to solve new problems than students who received depersonalized messages. Personalizing the context improves learning by helping students interpret and interrelate important information in the familiar versus abstract problem statements (Mayer, 1984). In addition, the use of solutions and supplementary resources in GeogDL and G-Portal is consistent with research demonstrating that transfer of complex problem-solving skills is facilitated with the introduction of worked examples to an assignment (Cooper & Sweller, 1987; Van Merriënboer & de Croock, 1992; Paas & Van Merriënboer, 1994). In Paas and Van Merriënboer's (1994) study for example, subjects who trained with readily available worked examples in the solution of geometrical problems in computer numerically controlled machinery programming had better transfer performance than with those training with conventional problems-solving conditions in which the solutions to problems were available only after subjects attempted the problems.

In summary, this paper has argued for the theoretical and conceptual efficacy of GeogDL as a Web-based system built upon constructivist, learner-centered principles that can encourage meaningful learning and enhance real-world application of geographical concepts and knowledge. Although the "piecemeal" approach to learning via individual examination questions may seem antithetical to constructivist theories of learning, GeogDL adopts the view that learning should "balance" (Lebow, 1993) principles such as personal autonomy with gentle guidance from instructors to meet certain desired objectives (Mager, 1997).

GeogDL and G-Portal were pilot-tested on a group of secondary school students in Singapore and the results suggest the viability of the systems. Although the students initially encountered difficulties in using the systems because of a lack of unfamiliarity, they soon found GeogDL and G-Portal useful and indicated that they would continue using them once they became publicly available. It was especially encouraging that the students also mentioned that they would recommend the systems to their classmates. The next phase in the testing of the system is to investigate experimentally if GeogDL and G-Portal are superior to traditional non-constructivist approaches in enhancing learning and maximizing student academic outcomes.

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