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Technology integration applied to project-based learning in science

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This paper reports the findings of a study which observed students' (aged 10–11) use of technology during project-based learning activities in science. As part of the overall process of project-based learning, students used computer technology as a tool for collecting information, organising it and presenting it to their peers. Students conducted research (through guided research processes), interacted with peers, teachers and the community (through personal interviews and visits), and displayed their understanding of knowledge through the presentation of web-pages. The results of the study indicate that all of the students achieved their research goals. Students' learning outcomes were observed based on their achievements in relation to developing skills and ability to synthesise and elaborate knowledge, to engage in scientific exploratory tasks, and to use the technology for supporting and reporting their research work. Teacher's support in relation to providing coaching skills is crucial to students' success in a project-based setting.

Keywords: Project-based learning; technology integration; task-oriented learning; science education; elementary school

Introduction

In recent years, project-based learning has increasingly been supported by computer technologies and has contributed to fostering student-directed scientific inquiry of problems in a real-world setting (Barak and Dori 2005). When integrating technology into learning, students are more likely to build on what they learn from technological skills and experiences when their existing knowledge is acknowledged and made central to the learning process. From this perspective, linking technology-focused knowledge construction to students' needs and interest rather than simply delivering technical training isolated from the curricular or instructional objectives need to be emphasised (Kanaya 2005; Tangdhanakanond, Pitiyanuwat, and Archwamety 2006).

One assumption underlying constructive learning is students' active participation in the learning task given. A common constructivist goal is to support intrinsic motivation and self-directed learning in a meaningful context. To promote such learning, one approach is to equip students with hypermedia tools to explore knowledge and design knowledge artifacts within a learning community (Chen and McGrath 2003; Erickson and Lehrer 2000). It is believed that the comprehensive nature of this approach provides a valuable learning opportunity for developing many important skills needed to complete the tasks. However, precautions need to be taken in linking skills across the curriculum in technology integration. Studies show that students often fail to make these connections, and teachers often fail to design classroom activities to facilitate learning of situated knowledge and a broader understanding of concepts (Archer 1998). Teachers need to take part in planning the environment for technology integration and promote inquiry,

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problem-solving and critical thinking (Pedroni 2004). Well-planned and executed lessons involving teachers from different areas are suggested to bring students to see many connections and obtain a deeper understanding of concepts and skills. It also helps students to employ self-organised learning and obtain meta-cognitive reinforcement for retaining and transferring knowledge (Piccinini and Scollo 2006).

Integrating technology into project-based learning requires a strong linkage with real-world scenarios. Students need to participate in various actions. Along the learning process, scaffolding should be employed as a systemic approach to supporting the learners, focusing on the task, the environment, the learners and the community. Through the process of apprenticeship, students are encouraged to work cooperatively and be engaged in mutual co-construction efforts. In the same vein, as the learners move along, they are progressing from being a novice towards becoming active contributors (Hung et al. 2005).

In the research described in this article, integration of technology into scientific project-based learning was studied. Activities used by teachers and students for the synthesis of knowledge from life science and information technology areas are reported. The aim of this research was to observe the process of integrating technology into scientific project-based learning among students. Specifically, this involved identifying the nature of both *the tasks involved* in the project-based learning experiences and *the outcomes* of the learning activities as a result of students' involvement in each task.

Method

The students involved in the study were fifth graders (aged 10–11) in Taiwan, who participated in science projects in *SciCamp* (a science camp) as an extra-curriculum activity from October 2004 to April 2005. Students were grouped into four or five persons per team for conducting research activities. Topics for research included geographical, ecological and historical exploration about the areas where they lived. These topics were related to the fifth-grade curriculum (e.g. 'water resources', 'the living plants' and 'geographical features of a place'). The use of project-based learning in this study was modelled following the concept of Barron et al. (1998) about '*doing with understanding*' with emphasis on several basic principles: defining learning-appropriate goals, scaffold for supporting both student and teacher learning, creation of multiple opportunities for formative self-assessment and revision, and development of social structures that promote participation and a sense of agency. Student-generated projects were adopted for investigation. Each group was requested to keep a project journal throughout the project. In order to study how students learned from the project-based learning, various approaches, including observations, interviews and questionnaires, were used to collect research data.

As a means of integrating the knowledge students learned from the science and the information technology areas, a task-oriented approach was used to provided students with an authentic learning opportunity which optimised students' involvement and engagement in knowledge acquisition. For example, to conduct the nature science research, students learned to use internet technology to explore the wealth of information available; to present research findings, students learned to use various design tools to interpret knowledge electronically. Students gathered and organised various relevant information and data pertinent to their learning goals. Since accomplishing a project required frequent access to the use of a computer, and use of a computer at home was not easy for every student, the science classroom was equipped with six computers connected to the internet. The science classroom was arranged in a way allowing group project work and laboratory activity. Students used these computers for various purposes, including communication, searching project resources and preparing material for presentation. In conducting laboratory work, students also used computers to record their data and write up their observation notes.

The science teacher set up activity plans and work sheets for group tasks in the *SciCamp* for a regular meeting held once a week. Specific learning tasks, such as water testing, were assigned. The following activities were also arranged in the *SciCamp*.

Using technology as tool for learning

In order to integrate technology into project-based learning, teaching of basic information skills was provided. For example, the use of various sources of web-based materials and application of different computer software to record, analyse and present information was taught. From the information literacy instruction offered, students used the skills and strategies that they developed alongside the science-based learning processes. They applied the Boolean Logic concept and appropriate use of keywords in the search for and utilisation of web-based information. Alongside their project-based learning processes, students experienced the application of digital cameras and various computer software (such as Microsoft's Word and Excel, PhotoImpact and Namo editors) to prepare and present their group projects.

Participating in cyber community

Students worked with a web-based community – being involved in water testing for World Water Day – the students accomplished their mission by testing water samples around their school district. Within the cyber community, students participated in web-based interaction, and submitted the testing data to the website. School-to-school interaction, including sharing water-testing results and protecting water resources, was also arranged.

Experiencing scientific investigation

In the *SciCamp*, basic hands-on lab skills were taught. For example, how to test water pH value and dissolved oxygen (DO) content and how to sample water in the field were taught and actually experienced by students. During these activities, students learned systematically about the processes of conducting research. They were guided by the 'Project Worksheet'. This was used to pose the following items: (1) 'What is the topic you want to explore? Why?'; (2) 'What is the information you need to collect for the problem?'; (3) 'How do you plan to gather data and information?'; (4) 'What have you found?'; and (5) 'How are you going to present the results?'

Accomplishing and presenting assigned project

In the *SciCamp*, the topic 'Exploring Our Hometown' was assigned for group exploratory learning guided by the science teacher. Each group studied a specific area of its choice around its school district for its natural, environmental, geographical, social and historical issues. A list of questions was elicited by students for discovery, and different small tasks were allotted to each team member. For example, 'What is the geographical and ecological nature of the area of exploration?; 'How do we obtain the background information about this area?' Students were guided in creating their actual action plans for gathering information and data to understand their neighbourhood area, including setting times for collecting water samples, testing water, conducting interviews and analysing data. In the *SciCamp*, the following areas were studied by students: Talawken Stream, Sanjaupu Peak, Chilungling and Chung-San Park. At the end of the project, students presented their finding through web pages. They used computers for searching information, selecting information, integrating information and preparing this for the presentation.

In evaluating the project-based learning approach, the mode of learning is less dependent on the acquisition of information from lectures, but more dependent on students' use and interpretation of real-world knowledge. By submitting thorough documentation of students' research

Table 1. In-depth interview guide for analysing the learning process.

Interview questions	Purpose of assessment
Why did you choose the topic for research?	Assess students' interest toward their research topic.
Describe what you were supposed to accomplish in this project.	Assess students' understanding of their learning tasks in various stages.
How many members are there in your group? How did you allot your task to accomplish the project?	Examine students' co-operative actions for accomplishing the task.
Describe the most important contribution you offered to the group. Why do you deem your contribution important?	Assess students' involvement and self-monitoring process in accomplishing the task.
Describe what are the skills most needed in accomplishing the project, and how do you improve these skills.	Assess students' perceived importance and skills needed for accomplishing the task.
What is the strength and weakness in your project?	Examine students' reflections about the skills needed for accomplishing the task.
How and what did you learn from your group members? How did you co-operate with other members?	Assess students' group co-operative effort and ability to work with others.
Were there any happy and unhappy experiences from conducting the project?	Assess students' affective responses (enjoyments and frustrations) from the learning experience.
What are the responses from your teachers toward your achievement?	Examine students' understanding about their achievement.

progress and research journals, formative assessment was made on a weekly basis among students to help identify what needed to be improved as students proceeded. For teachers, it was also a means to observe students' difficulties in the projects in which they were engaged.

In order to assess what students' acquired from their experiences in project-based learning, interviews were conducted. Examples of the questions are listed in Table 1. The questionnaire items were derived from the observation about reactions from students' engagement of their projects. These questionnaire items were used to reflect on the various aspects of project-based learning, including students' involvement, group effort, perceived challenges and actions for accomplishing a research project. These responses were then analysed and summarised into action, affective and cognitive achievement for various learning tasks.

Data analysis

In addition to the above-mentioned interviews, the teacher's journals and students' creative works in their scientific projects were also gathered. A total of 32 field notes, 36 audio-taped records (transcribed into interview data) and 64 teachers' journals were used for qualitative data analysis (see Table 2). The use of various resources of data in the research was needed in order to gain a deeper understanding of the meanings that participants ascribed to their own and each other's actions (Stake 1988). Data coding and grouping were ongoing processes along with the data collection process, so recoding and regrouping were conducted whenever necessary. The data were finally analysed into specific categories such as *Action* (topic selection, task and duty, and group interaction), *Cognitive Achievement* (scientific knowledge, information skills and computer skills) and *Affective* (interest, satisfaction, value and success).

Results

The qualitative data gathered from interviews, field notes, journals and students' work revealed several phenomena. Generally, students who engaged in the project-based learning reflected a

Table 2. Example of codes used for qualitative data.

Code number	Example	Data description
TJ#mmdd	TJ#0506	Teacher journal on 6 May
OB#mmdd(#n)	OB#1006(#1)	Observation notes on 6 October (#1, 2, … more than one video on the same date)
VI#mmdd(#n)	VI#1006(#1)	Video shots on 6 October (#1, 2, … more than one audio-tape on the same date)
AT#mmdd(#n)	AT#1116(#1)	Audio-tape recorded on 16 November (#1, 2, … more than one observation note on this date)
SI#GClassmmdd	SI#5070624(#1)	Students' interview from a specific class on 24 June (#1, 2, … more than one interview on the same date)
OR#Student No.	(OR#50626)	Open responses from student #50626

positive learning experience. Through the guidance provided by the teacher, students experienced scaffolded learning as evidenced by a gradual increase in skills for handling simple to complex tasks. Students' learning outcomes were observed by their achievement in developing skills and an ability in synthesis and elaboration of knowledge, action in engagement of scientific exploratory tasks and the use of technology for supporting and reporting their research work. According to the students' project-based learning experience, 'Task' and 'Outcome' were two interrelated facets for accomplishing the task. From the 'Task' dimension, various subtasks were identified such as 'Gaining knowledge and skills', 'Identifying research tasks', 'Obtaining data and information', 'Organisation and interpretation of content' and 'Presentation through technological tools'. From the 'Outcome' dimension, action, affective and achievement aspects were interpreted to reflect students' learning outcomes (see Table 3).

Gaining necessary knowledge and skills

From the students' perspective, understanding basic scientific knowledge and acquiring information skills are essential to the subsequent learning activity. From a series of actions and experiments, students developed basic computer skills and obtained conceptual understanding of scientific observation and ways of conducting research. Learning was achieved through increasing the access of learners to participating in scientific experimentation and the use of computers for electronic exploration. Students' affective responses toward the process of understanding varied from 'interesting', 'fun', 'anticipation' to 'uncertainty'. Some students are more involved than the others due to individual differences in perceiving the task. In order to foster an understanding of basic scientific concept and the use of lab and computer skills, the teacher provided scaffolded learning opportunities to help students visualise the important concepts and skills they needed to learn (OB#1006-1229). Development of a research framework among students was guided through various activities, including being exposed to various sources of research examples, options of topics for research and ways of conducting research.

Teachers' involvement played a vital role in guiding students through the self-directed approach.

> Before every class period, I planned and prepared to help students relate what they had learned in the previous class. Various activities were planned to make students learn scientific concepts and basic skills from actual experience and experiments. (TJ#1130)

Students experienced learning by doing and were coached by the science teacher. They also learned various basic skills from observing and taking turns in practising or peer-to-peer teaching.

Table 3. The process of project-based learning.

Tasks	Outcomes: Action	Affective	Achievement	Teacher's support
Gaining knowledge and skills	Lab experimentations and computer skills exploration, scientific observation and practice, peer-to-peer teaching	Mixed feelings of fun, interest excitement, curiosity and uncertainty	Construction of concepts and scientific knowledge, and learning of hands-on skills	Scaffolding skill development through step-by-step experimentation procedures
Identifying research tasks	Web-based search, discussion and negotiation, sharing and promoting ideas, and planning and allotting tasks	Mixed feelings of anticipation, confidence, disappointment and uncertainty toward the chosen topics	Group decision about research topic, formation of research focus and development of self-attainment in progress	Guidelines for selecting a topic, mediation for conflicts and reminding students to keep project journals
Obtaining data and information	Field trips, interviews, electronic search of information, data recording and project journals keeping	Mixed feelings of challenging, excitement, frustration and disappointment	Information literacy, skills in data collection and techniques for using digital devices for data collection	Scaffolding skills in conducting observations interviews, search of information and use of digital devices
Organisation and interpretation of content	Data organising, generation of new doubt for study, and interpretation of project content	Feelings of knowing but in need of confirmative support for their interpretation	Co-construction of knowledge, development of organisation, higher-order thinking and reflective skills	Confirmation in content accuracy, suggestion in organisation, interpretation and use of more reliable resources
Presentation through technological tools	Participation of electronic design tasks, using software and experiencing knowing by doing	Mixed feelings of engagement, concentration, success/failure, frustration, time-consuming and achievement	Development of presentation skills, and ability in synthesis and elaboration of knowledge content in a creative way	Scaffolding skill development through step-by-step procedures, provision of experiences, tips, and opportunity for creation and sharing

The use of an exploratory approach by the science teacher reflected a constructist approach to knowledge acquisition for scientific learning. Students were engaged through hands-on, authentic experiences.

> Students tested pollution levels in local waters and researched reasons for the pollution. After the water-testing activity, they realised the critical problem in environmental concerns, and they had to work as a team to research the problem. The arrangement of a set of social experiences allowed students to take part in the group learning and become aware of their roles. (TJ#1008)

Identifying research tasks

When identifying their research topics, students created their own sense of progress and decided on a learning path that led them to completion of the tasks. Discussions with the science teacher and group members were made through face-to-face and electronic communications. Students' choice of topics for research depended on their interest and the amount of available resources. 'We gave up the one (topic) we chose earlier because not much information was available' (SI#5070506#1). Once a research topic was identified, they were guided towards generating a list of questions to be answered. From the question list, the task was divided into subtasks. Several actions were taken, including sharing their understanding, negotiating topics with peers, planning for further exploration and allotting tasks among group members (OB#1010; OB#0307). Within the same group, there were both positive feelings, including anticipation, confidence, and negative feelings, including uncertainty and disappointment. Students' negative feelings came from those who were not interested in the topic chosen by their group. These students gradually learned to deal with disagreement with other group members (SI#5050501). From the process, the teacher co-ordinated among group disagreements. Guidelines for selecting a topic, criteria for identifying a good research project and directions for preparing the related materials were provided. The science teacher also frequently reminded students of keeping a project journal and thorough documentation of their own research progress (OB#0307-0505).

Obtaining data and information

To prepare for the group project, students gathered resources from the web or their field trips, interviews or observation notes. The process provided students with learning opportunities to access and search for various data resources. For example, to study the water resources of their neighbourhood, students worked in groups, and made field trips to Talawken Stream to sample waters for testing (OB#1006). They sampled waters from several sections of local streams and tested its pH value to examine the water quality. In order to achieve the task, students experienced the importance of learning lab skills and skills in using a digital camera for keeping records (OB#1006-1110). They also valued highly the learning of various computer skills and use of web-based materials. 'We learned skills in information search and problem-solving with computers. These skills are very important for future use' (SI#5070325). While most students enjoyed their field trips for gathering data, they felt frustrated when they failed to identify relevant web-based information for their research project (SI#5070506). Although basic search skills and use of Boolean Logic were taught, most students still had difficulty in identifying relevant information from various resources. In the process they had mixed feelings of challenge, frustration, excitement and disappointment (OB#1013). In order to support students' learning in searching information, techniques for using keywords and gathering data from reliable resources were taught. Guidelines for conducting interviews and scientific observations were provided. Techniques for shooting pictures and using a digital camera were also taught (OB#1013).

Organisation and interpretation of content

Students constructed their understanding from information gathered through various resources. Organisation of content involved not only assembling information but also integrating various forms of resource including electronic and paper-based contents to co-construct new meanings and interpretations of knowledge. Students also revealed their feelings of achievement (OR#50511).

The most exciting result found from the process was the discovery of any new facts by the students in the 'Telling Our Hometown' project.

> For 14 years, we have always believed that the mountain standing in front of our school is Ta-Tung Peak. After exploration and investigations, students obtained evidence to support that it should be Sanjaupu Peak, not Ta-Tung Peak. (TJ#1130)

In conducting this project, students made several trips to Sanjaupu Peak, recorded what they saw from the peak (by drawing and taking pictures) and gathered documents and maps. They organised various geographical and historical evidence and compared the maps they drew and photographs taken from their field investigations. This activity revealed an internal reconstruction process among these younger researchers in conducting scientific investigation.

From other class projects, students' conclusions from their findings also revealed the process of organisation and interpretation in project-based learning (OB#0307-0410). Reflections on improvements of the project content were also provided. 'We re-organised the information gathered. Instead of copying and pasting, we used our own words to interpret our findings' (SI#5050501). 'For improving our report, we need to elaborate more on the living plants [one of their topics]' (SI#5050425). To support the students' learning, science teachers emphasised the use of a student's own interpretation of knowledge. Organising groups' knowledge in an integrated content and format was requested. In addition, careful reading of information to avoid misinterpretation and gathering more supportive information from authorised resources to construct more creditable knowledge was also suggested.

Presentation through technological tools

Students actively explored and experimented with various computer tools (such as a a scanner, and software such as *PhotoImpact* and the *Namo* editor). To present what they had researched, students were provided with the opportunity to use the technological tools to share the knowledge obtained from their scientific research. Students enjoyed the design experience in using a web-page editor to present the project (TJ#1228). 'The most exciting thing in accomplishing the project was to use *Namo* [web-page editor] to present our findings, and share it with my friends' (SI#5010517#1). 'We worked very hard, even harder than preparing for exams' (SI#5050610). 'We even sacrificed our break time to work for the project' (SI#5050425). 'I learned to take my job seriously in order to work with others' (SI#5070624). These students experienced feelings of engagement, concentration, confidence and success.

However, some students expressed their feelings of frustration and failure, especially when they encountered obstacles in using technology (TJ#1228). 'Presenting through web pages is a hard job' (OR#50120). 'We often had problems in transforming visual materials into web pages. Sometimes, the pictures did not show up on the web' (SI#5070624). 'Kids were helping each other when they encountered problems. For them, this is also a way of learning' (TJ#1001). During the process of learning, teachers provided step-by-step procedures for developing scaffolding skills. Personal experiences, tips and incentives for students' creativity were also provided.

> Although their [students'] design skills might not be mature or well-refined, I want them to be confident in presenting what they have observed. To me, the accomplishment of the project reflects

> students' achievement in active construction of their knowledge. This experience is more important than the final product. From the experience, they have shared their attitude of learning and exploring, and their views of the world wonder. (TJ#1205)

In the project-based learning approach, teachers also experienced their own growth from the teacher–learners interactions. Teachers had a very high regard for students' learning and construction process.

> We always think we are teaching our kids; however, they [students] are our teachers, too. Through their eyes, we saw things from different perspectives. They taught us to re-examine the way we observed and thought about the world. [The teacher was referring to the new discovery of knowledge from her students.] (TJ#1016)

Discussion

The most valuable finding from the project-based learning approach was to observe the production of new knowledge derived from students' own investigation and exploration. The electronic presentation of students' research work revealed their achievement in relation to the discovery of new facts about the world. When involved in the project task, both learners and teachers experienced benefits from the teacher–learner interaction processes. In the 'Telling Our Hometown' project, the new geographical and historical evidence gathered by the students have enabled them to revise the incorrect facts documented in their school history book. This finding reflects Cobb's argument in socio-cognitive insight that the interaction within the collaborative discourse contains multiple perspectives rather than the single 'right' perspective of the teacher (Cobb 1995, 48–49). This incident revealed an internal reconstruction process and the openness of multiple perspectives among these younger researchers and the science teacher involved in the scientific investigation. From the study, it was found that both the teacher and students made conceptual advances by exchanging views and working towards a new understanding of knowledge. They both shared the enjoyment of new knowledge discovery.

Students learned from each other through co-operative learning and group interaction. Although disagreement and conflict among group members sometimes occurred, this reflected a healthy internal growth among group peers. It is noted that even though the students do not listen to each other when there is disagreement, they reciprocally influence each other's arguments, and exchange views and ideas (Sawyer 2004). In the study, the teacher helped students in learning to deal with conflict in group learning by advising them to use appropriate communication skills. How to develop students' personal/interactive and communication skills needs to be emphasised in the group-based learning approach (Livingstone and Lynch 2000). The results of the study indicate that both group project work and student-centred learning were achieved in the project-based learning approach. The socio-cultural perspective, interlaced with the cognitive aspect of group learning, was noted.

Although many students experienced frustration when using computers (especially when working on the project), the kind of cognitive complexity involved in learning design skills and scientific investigation apparently placed an immense demand on the learners; students' motivation towards the learning tasks took the form of persistence rather than enjoyment. Students felt achievement after the task was accomplished. One aspect of this finding is important. Chen and McGrath (2003) suggest that hypermedia tools could indeed sustain students' motivation and cognitive engagement. The use of the internet for research or producing a website to publish their project results can enhance students' organisational skills, connect them with a real audience and foster a better understanding of the world wide web (Isbell 2005). In the current study, it was also found that the use of the web-page design tool helped engage students in organising knowledge and made them become aware of their own knowledge construction from the science project.

Conclusion

In this study, the project-based learning approach was implemented in the *SciCamp* activity. It was observed that students were devoted to learning from the project work – for example, in respect to taking various group actions and participating in higher-order skills for organising, interpreting and presenting the information. Students valued highly their achievements in accomplishing the project. It was concluded that most goals for the project-based learning initiatives were achieved.

As young researchers, students learned about their social responsibility in a group, and acquired scientific knowledge through the various group actions involved in investigation and exploration. The success of the project-based learning implementation also lies in the involvement of teachers and students in knowledge construction. In the implementation of integration technology into project-based learning, planning for student self-exploratory experiences is important. However, teachers' coaching in making students aware of their ongoing monitoring and meta-cognitive processes in accomplishing the group project task is even more essential. Moreover, whether a science classroom has support for the use of technology might influence students' accessibility to technology. When integrating technology into scientific project-based learning, students need more time to practise skills and prepare for the final presentation, so access to computers and the internet in science classrooms is essential.

From the descriptive aspect, the study interprets project-based learning through 'Task' and 'Outcome' dimensions. From the 'Task' dimension, various subtasks were identified: 'gaining knowledge and skills', 'identifying research tasks', 'obtaining data and information', 'organisation and interpretation of content' and 'presentation through technological tools'. From the 'Outcome' dimension, action, affective and achievement aspects were interpreted to reflect students' learning outcomes. From the prescriptive aspect, the results of this study provide implications for planning and implementation of technology-integrated project-based learning. For students, appropriate experiences and opportunities to support their knowledge development and technological competencies are important. Future implementation for planning on increasing students' involvement and confidence in using technology is needed. Moreover, how to develop students' interpersonal skills in order to foster healthy interaction among group members needs to be emphasised in the group-based learning approach.

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