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10. PROMOTING EARTH SCIENCE TEACHING AND LEARNING

Inquiry-based Activities and Resources Anchoring Teacher Professional Development and Education

Science is a fundamental underpinning for society. Earth Science, which studies the way in which the natural world works as a system, is a key element in our understanding of natural processes and is, therefore, critical to how society responds to many important issues. More specifically, Earth Science (ES) deals with the finding and sustainable use of natural resources (e.g., water, soils, energy, and minerals) that are limited, precious, and relied upon to sustain our existence on the planet. ES also addresses the prediction and remediation of natural hazards such as earthquakes, volcanoes, and mass wasting. Understanding the complexity of the Earth's systems and appreciation for how the Earth has changed over time will inform our responses to current issues of global change, such as increasing global temperatures, melting ice, sea-level changes, and extinctions.

BACKGROUND

ES plays a unique role in the sciences in that it is highly interdisciplinary, utilizing all of the sciences to understand the complex operations and processes in the Earth's systems. While observations and experiments taken in the field are important, so are laboratory experiments and complex computer models. ES is strongly connected with the aesthetic enjoyment of the natural world where humans go to recreate, relax, and experience joy and pleasure—whether it be green spaces in cities or parks featuring mountains, plains, rivers, glaciers, or coastlines. This chapter outlines the authors' efforts to address the role of ES instruction in the K–12 school system in British Columbia (BC). We outline our efforts to enhance and enrich the teaching of ES in schools through a two-pronged approach: teacher professional development and innovative approaches to teacher education.

Earth Science in the School Curriculum

In spite of the relevance of ES to society, there is less focus on it in the BC school curriculum, particularly at the senior levels, compared to physics, chemistry, and biology. The interdisciplinary make-up of ES has the potential to tie together many

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different disciplines and offer personal relevance to students at all ages. Many ES topics, however, are prescribed in the K–10 BC general science curriculum and Instructional Resource Packages (IRP). These topics include soil and water in Grade 2, weather in Grade 4, resources in Grade 5, extreme environments in Grade 6, Earth's crust in Grade 7 (BC Ministry of Education [MoE], 2005), water systems on Earth in Grade 8 science (MoE, 2006a), and energy transfers in natural systems in Grade 10 science (MoE, 2008). In addition, many ES topics are prescribed in the social studies curriculum; for example, physical features and natural resources of Canada in Grade 5, major world geographic and political features in Grade 6, and natural disasters in Grade 7 (MoE, 2006b).

In the senior secondary school years, Earth Science 11 and Geology 12 courses exist; however, these courses are offered in a limited number of schools. Between 2000 and 2005, approximately 8,000, 13,000, and 18,000 students per year took the Grade 12 physics, chemistry, and biology examinations, respectively. Over the same period, less than 2,000 students per year took the Geology 12 examination (Van der Flier-Keller, 2007). In addition, in 2004/05, both the mean provincial examination scores and pass rates for Geology 12 (62% & 79%, respectively) were lower than those for Physics 12 (72% & 90%, respectively), Chemistry 12 (71% & 90%, respectively), and Biology 12 (68% & 83%, respectively).

Earth Science in Schools

Some of the motivation for designing and implementing procedures to increase students' understanding of and interest in ES came about as a result of the first author's experiences with teacher attitudes toward teaching ES when her children attended school (circa 1991–2008). During this time, several teachers explicitly stated at parent-teacher meetings that they would not be teaching the required ES portion of the curriculum of the specific grade in question. A variety of reasons were given including lack of background and interest in ES (for many of these teachers, their science background was primarily in biology). Additional feedback from teachers who subsequently attended ES workshops suggests that the lack of appropriate ES classroom resources (e.g., labelled rock kits, fossil samples, maps, etc.), lack of ES background, and issues with funding and waivers for field trips were other major impediments to teaching ES in the elementary school grades. This is by no means an indictment of those who work as teachers in the BC school system; these comments only provide context and motivation for the work outlined in this chapter.

In fact, the resistance to teaching ES identified by BC teachers is corroborated by studies, including Jenkins (2000) who noted insecurity regarding teaching ES among English and Welsh teachers at having to teach beyond the science specializations in which they were educated. King (2001) stated, "without a proper background or 'feel' for an area of science, it is difficult to teach about it in a way that demonstrates its background, scope, importance, ramifications, links to other areas of science, or the way in which scientific investigations in that area are conducted" (p. 645). He noted, "Since most UK teacher education institutions do not have an Earth science specialist on their staff, students receive little input in this area during their teacher education, and so are generally unprepared for their teaching of NCS [National Curriculum for Science] earth science" (p. 643). Perhaps in consequence, King suggested that, based on a survey of 164 UK science teachers, the content of practical, investigational, and field work in ES courses in UK schools is low.

Student perceptions of their secondary school ES experiences—identified in a 2005 survey of students graduating from BC schools and enrolled in a first year university ES course (Van der Flier-Keller, 2007) are reflected in the following comments: ES was not emphasized very heavily and had low status compared to chemistry and physics; 'Academic' students were encouraged to take chemistry, physics, and biology; The other sciences were definitely more of a focus; Senior ES courses are often considered to be 'rocks for jocks'. In addition, written comments identified the small amount of time spent on the subject, a lack of enthusiasm by teachers, and the boring teaching methods as key factors that negatively affected their enjoyment and interest in ES in secondary school.

Teacher Professional Development in Earth Science

Watters and Ginns (2000) noted, "at the core of making science meaningful for children are the actions and initiatives of classroom teachers" (p. 301). Further, Fensham (2008) stated, "the fundamental factor in the improvement of students' learning in science and technology is the quality (knowledge, skills and enthusiasm) of their teachers" (p. 39). Based on this recognition of the key role of teachers in student learning about science, it follows that supporting teachers in teaching ES through good quality professional development should be of highest priority. Teachers themselves have expressed a strong interest in professional development support for ES teaching (e.g., King, 2001). The need for and interest in ES professional development is particularly acute when new ES curricula are introduced or when ES topics become examinable.

Professional development is not just important in ES; it is widely recognized as a critical part of a teachers' professional career. The USA's *National Science Education Standards* (United States National Research Council [NRC], 1996) state:

> Becoming an effective science teacher is a continuous process that stretches from preservice experiences in undergraduate years to the end of a professional career. Science has a rapidly changing knowledge base and expanding relevance to societal issues, and teachers will need ongoing opportunities to build their understanding and ability. Teachers also must have opportunities to develop understanding of how students with diverse interests, abilities, and experiences make sense of scientific ideas and what a teacher does to support and guide all students. And teachers require the opportunity to study and engage in research on science teaching and learning, and to share with colleagues what they have learned. (p. 55)

Given that ES appears to not be taught well in some schools—if at all—and given the assumed importance of professional development of preservice and inservice teachers for the effective teaching of ES, we developed a project to examine the role such professional development might play in the academic success of students enrolled in the Education Laboratory section of EOS 120 and if this constructivist-based experience and associated resources would effectively support these preservice teachers in delivering ES during and following their teacher education program.

Effective Teacher Professional Development

The goal of effective continuing professional development for teachers is to support teaching and learning in the classroom. Researchers (e.g., Adey, Landau, Hewitt, & Hewitt, 2003; Day, 1999; Guskey, 2000; Joyce & Showers, 1988; Lydon & King, 2009) generally agree that the major characteristics of effective professional development include:

– provision of new knowledge, ideas, and skills that are relevant to the needs of the teacher (e.g., linked to the curriculum, direct benefit in the classroom, etc.)
– delivery in a content-appropriate manner by a skilled practitioner
– a collaborative and sustained approach
– provision of opportunities for discussion and exploration with colleagues
– a chance to experiment and reflect, away from the pressures of the classroom
– provision of coaching
– support by school management.

Four outcomes of professional development were identified by Joyce and Showers (1988): knowledge or awareness, changes in attitude, development of skills, and transfer of training and control. Harland and Kinder (1997) discussed different order outcomes: third-order (lowest impact) deal with materials, information, and awareness. Second-order outcomes are based on motivation, affect, and institutional change while first-order outcomes comprise knowledge, skills, and change in attitude. However, there is general consensus that, if some of the seven elements of professional development are not present, the effectiveness will be reduced, “possibly to nil” (Lydon & King, 2009, p. 67).

Considerable teacher professional development takes place in informal learning environments (see Yore & Van der Flier-Keller, Chapter 1 this book). Fenichel and Schweingruber (2010) suggested that:

> ... teacher professional development offered by informal science institutions should adhere to the following criteria:
> – goals need to be defined clearly and need to be attainable;
> – programs should be developed in collaboration with teachers and schools to ensure the applicability and usefulness of the strategies offered (conduct a needs assessment);
> – programs ought to aim beyond the immediate professional development experience and focus on implementation in the classroom, with attention to fidelity of implementation while allowing teachers to adjust to their specific situation;
> – professional development experiences need to allow teachers to learn from one another, share experiences, and model new strategies; and
> – online offerings need to include “practice at school” and follow-up support should be provided. (p. 181)

These criteria are remarkably similar to those discussed in the broader professional development literature and provided the template from which we explored this issue with practicing and preservice teachers through the Pacific CRYSTAL Project at the University of Victoria from 2005 to 2010.

Professional Development in Earth Science

There are many models globally for ES teacher professional development. For example, in the UK the Earth Science Education Unit developed and provided 90-min workshops to entire secondary school science departments (Lydon & King, 2009). In Canada, locally developed ES workshops that were monetarily supported by EdGEO facilitated the provision of resource packages (e.g., rock and fossil kits, activity manuals, etc.) for teachers to take with them for classroom use (Van der Flier-Keller, Clinton, & Haidl, 2009). In the USA, the *Earth Science by Design Handbook for Professional Developers* (McWilliams et al., 2006), which was based on *Understanding by Design* (Wiggins & McTighe, 2005), was designed to improve science teachers' knowledge by implementing inquiry-based pedagogy using web-based visualizations of Earth processes. These workshops examine the teaching, learning, and development of curriculum-based understanding of the big ideas in Earth system science. Another USA professional development program focusing on the Earth systems approach, provided through the Earth System Science Education Alliance (http://esseacourses.strategies.org/) developed a series of online, inquiry-based courses to provide content knowledge and tools to support teachers in incorporating Earth system science into their curricula.

PACIFIC CRYSTAL TEACHER PROFESSIONAL DEVELOPMENT IN EARTH SCIENCE

A recent model for offering ES teacher professional development was provided through Pacific CRYSTAL: stand-alone workshops and a special laboratory section for EOS 120. The ES workshops were developed by professional geoscientists with feedback from practicing teachers; the interdisciplinary ES workshops were developed by the first author in collaboration with a biologist and an environmental scientist with feedback from inservice and preservice teachers. While the workshops were designed as one-time events, many teachers attended several workshops, often coming back year after year.

Workshops were held on province-wide professional development days, at school district professional development conferences, interdisciplinary conferences, provincial science teacher conferences, and national conferences (e.g., Geological Association of Canada) and nongovernmental organization (NGO) teacher conferences (e.g., Mitchell Odyssey). Workshops ranged in duration from 1 hr to 1.5 days, including a field trip. Activities were based on a constructivist learning model (i.e., people learn best by actively constructing their own understanding based on prior knowledge, concurrent experience, and sociocultural interactions) and were classroom tested prior to the workshops. Between 6 and 12 classroom workshops were held per year (2005–2010). In addition, a lesson study approach was used with the activities and workshops where the content, delivery, and approach were modified and improved in response to teacher feedback. The intended workshop outcomes included increasing teacher confidence in teaching ES, developing more positive attitudes toward and enthusiasm for ES, and improving knowledge and understanding of key ideas in ES. The workshops were designed to provide support in specific areas of the science curriculum around which teachers had expressed a need for professional development, while highlighting "the 'Big Ideas' and supporting concepts" of ES as outlined in the *Earth Science Literacy Principles* (Earth Science Literacy Initiative, 2009, para. 1). Topics and curricular links are shown in Table 1.

Table 1. Earth science (ES) teacher professional development topics by grade level

Topic	*BC science grade level (ES)*	*Collaboration or impetus*
Grade 10 ES	10	Introduction of provincial Grade 10 science examination
Earth history fossils and the stories rocks tell	7, 10, 11, 12	
Plate tectonics, earthquakes, and volcanoes	6, 7, 10, 11, 12	
ES and society: Resources, hazards, and global change	4, 5, 7	
Geological journey	7–12	CBC Learning (Canadian Broadcasting Corporation, 2007)
What on earth is in our stuff: Nonrenewable resources & BC	5	BC Ministry of Energy, Mines, & Petroleum Resources
Wet and wild: Water systems, weathering, and erosion	2, 8	
Interdisciplinary ES & biology: Soils	2	Pacific CRYSTAL & Kelly Nordin
Interdisciplinary ES & biology: Nearshore marine ecology and evolution	Biology 9, 10, 11	Pacific CRYSTAL & Seaquaria in Schools Project

Design of Workshops

Key features of the ES workshops, which met effective professional development requirements (Lydon & King, 2009), are as follows:

Provision of new knowledge, ideas, and skills relevant to the needs of the teacher

– Direct teacher participation in constructivist based hands-on activities, experiments, literacy activities, field trips as well as discussions, question sessions, and brainstorming.
– Directly relevant to the practical and pedagogical classroom needs of teachers, meeting curriculum requirements through workshop content and practice with concepts, activities, and discussions. Workshops also met teacher needs for inspiration and a boost to science enthusiasm.

- Promotion of hands-on curriculum activities and experiments in line with ES practice.
- Classroom resources, such as rock and fossil kits, provided to support the transfer of hands-on learning activities and ideas into the classroom.

Delivery in a content-appropriate manner by a skilled practitioner

- Leaders are skilled practitioners, a combination of experienced ES-savvy teachers and professional Earth scientists, who can address both ES content or knowledge issues and classroom applications. The hands-on, field-based approach is content appropriate, modelling how ES is done in practice.

Collaborative and sustained

- Inherently collaborative given the mix of practitioners; in addition, teachers collaborate amongst themselves to share applications, approaches, and what works and does not work.
- One-time events; however, ongoing opportunities are advertised through teacher professional development networks so that teachers may attend multiple workshops as they require and choose.

Provides teachers with opportunities for discussion and exploration with colleagues

- Promote small group discussion among teachers both during activities, which are done in groups of 3–5, and in dedicated discussion time.
- Leader-scaffolded discussions are an important part of workshops enabling transfer of ideas, suggestions, and comments between the larger groups of participants.
- Participants are encouraged to link with the wider ES education community through membership in the Canadian Geoscience Education Network (n.d.). This network facilitates interaction between teachers and practicing Earth scientists and provides opportunities for ongoing professional development.

Involves experimentation and reflection, away from the pressures of the classroom

- Typically held on professional development days at a centrally located venue, often a large school, so that most participants are away from their normal environments and everyday pressures.
- Activities are designed to incorporate experimentation as well as reflection, both in small and larger groups.

Provision of coaching

- Modelling plays an important role; the active participation of teachers in all of the workshop tasks and activities (e.g., role-playing, experiments, etc.) provides many opportunities for one-on-one support and discussion, both in terms of ES content and teaching approaches.

Supported by school management

- Invited by school board professional development coordinators, often cosponsored by individual schools, reflecting support by the school system and school management. Teacher leaders are supported in this role by their school administration.

Classroom Resources

While the development of ES understanding and teaching practice through hands-on activities, peer collaboration, discussion, and modelling good pedagogy were important aspects of the workshops, the provision and use of good-quality, appropriate classroom resources were considered key components. Availability of resources was deemed critical to successful constructivist teaching, especially since teachers have cited this as a barrier to teaching ES. Local resources—including the *South Vancouver Island Earth Science Fun Guide* (Van der Flier-Keller, 1998), *A Field Guide to the Identification of Pebbles* (Van der Flier-Keller, 2005), and *Geoscape Victoria* (Yorath, Kung, & Franklin, 2002)—were important for relevance and place-based examples and contexts. In addition to these resources, the teachers received relevant rock and fossil kits, books, posters, and manuals containing activity descriptions and lesson plans.

Workshop Evaluation Methods and Results

The workshops were evaluated using a short survey (EdGEO evaluation) completed by teachers at the end of each session. Additional comments were provided by workshop, NGO, and other conference organizers. The evaluation goals, as part of the lesson study design, were to determine what the teachers considered useful or not and elicit suggestions to facilitate iterative change and workshop improvement. In addition, remarks about the activities, resources, and approaches were requested. Analysis of the responses indicated that they were overwhelmingly positive. On a 7-point scale (0 = poor … 6 = outstanding), teachers evaluated the workshops as primarily outstanding (6) or excellent (5). Feedback was collected and analyzed for content, revealing five main aspects (sample comments are included to illustrate the theme):

> *Workshop approach*: Wow!! How much more practical could a workshop be—I can now teach a science unit that I've had so much difficulty with before (Grade 2/3 teacher). Excellent information, interesting presentation, hands-on, applicable. Things I can take back to my classroom to show and use. I found this so helpful for my ES unit (Grade 7/8 teacher). Excellent demonstrations and materials. Strategies to help students to understand these concepts were outstanding (Grades 6–10 teacher). Hands-on/real life problem solving. Nice to be in the place of our students for a change. Need more specialized workshops like this one (Grade 11/12 teacher).

> *Active involvement*: She had us engaged in hands-on activities. It was a wonderful session. Hands-on, resources, meaningful activities for kids, fascinating (Grade 6 teacher).

> *Links to the curriculum*: Hands-on strategies/examples to teach/show my students the material/curriculum (Grades 6–10 teacher).

> *Classroom resources*: Very practical resources and ideas I can't wait to try in a classroom. Excellent information, demonstrations, and take-home goodies

> (Grades 6–10 teacher). Excellent visuals and demos—very useable. Thank you for the materials. I really enjoyed this and will be using your demos THIS WEEK in EarthSci 11 (Grade 10/11 teacher).
>
> *Inspiration*: Excellent presentation, great materials. Thank you very much; you've really inspired me (Grades 10–12 teacher). Having neither taught the curriculum strand "Rocks and Minerals" nor distinctly studied it, my initial expectations on the subject were low and of little excitement. After experiencing the lessons prior to and the journey on our 'rock walk', I have a new-found appreciation and energy for the subject (Grade 5/6 teacher).

A school district professional development conference organizer (from a location where we offered two workshops) commented: *In short, you've made a difference to many of our teachers—and that's what good professional development is all about*.

Expanding from Teacher Professional Development to Teacher Education

Working with practicing teachers in the ES workshops indicated that ES was not only de-emphasized in their initial teacher education program and science curricula, but that there was also a disconnect between how ES was being taught in university content courses and how it should be taught to elementary, middle, and secondary school students. We recognized that "[e]xtensive rethinking of how teachers are prepared before they begin teaching and as they continue teaching—and as science changes—is critical to improving K–8 science education" (NRC, 2007, pp. 1–2). This requires coordinated efforts by the Faculty of Science and the Faculty of Education to ensure consistent expectations are established and demonstrated in the science content and science pedagogy courses in the university program. Adopting these integrative approaches will more likely lead to potential teachers adopting an informed pedagogical understanding of teaching ES. As one preservice teacher commented, *Let's make good teachers now as opposed to fixing them later*. For the authors, the logical step forward in engaging teachers in ES was to expand the practicing teacher professional development approach to include similar opportunities for preservice teachers.

With the support of Pacific CRYSTAL, the EdGEO National Teacher Workshop Program, and the University of Victoria (School of Earth and Ocean Sciences, Learning and Teaching Centre, and the Department of Curriculum and Instruction), a program was designed and implemented building on lessons learned from teacher workshops and integrating them into the teacher education program. The outcome was the development of a new laboratory section in an ES course commonly taken by preservice education students as part of their Bachelor of Education degree to partially satisfy the laboratory science requirement. The research project to develop and evaluate the effectiveness of this *Education Laboratory* is a unique collaboration between the Faculties of Science and Education. Expanding into the realm of teacher education is an unusual step for science departments and is additional evidence of the success and impact of the research network encouraged and facilitated by the Pacific CRYSTAL Project (Fenichel & Schweingruber, 2010).

The Education Laboratory in EOS 120

EOS 120 is a university science course entitled Introduction to the Earth System II. This 1-term (4 months) course includes lecture and laboratory components and is offered by the Faculty of Science. The Education Laboratory (EdLab) is one of several laboratory sections (all with the same content) to reinforce the lecture material and provide practical experience with the course objectives. Piloted over 3 years (2005–2007), the EdLab is now an ongoing part of the EOS 120 course. Regular laboratory sections consist of 12 3-hr sessions; the EdLab has an additional preliminary teaching tutorial in which constructivist teaching methods, the basis for all succeeding laboratory activities, are introduced. The EdLab was distinct from regular laboratory sections in that the approach was to present the course materials, with resources, transferable to the K–10 classroom and curriculum. The same ES concepts as the other laboratory sections were taught, but a teaching strategy grounded in constructivist pedagogies advocating an inquiry approach was adopted. In particular, this section sought to develop learning experiences that reflected those advocated by the science methods courses in the Faculty of Education on the premises that aspiring teachers should learn from these approaches as early as possible and that science content and pedagogy should be aligned. Every class activity was considered from the perspective of modelling effective teaching practice and giving students ideas for lesson planning and resources for teaching.

Pre-Education students were provided opportunities to model, experience, and practice a wide range of teaching methods, including the EDU (Explore, Discuss, Understand) modified learning cycle (Blades, 2000, 2001); hands-on activities; demonstrations; think–pair–share; student-generated representations (e.g., classification charts, diagrams, etc.); role playing; language arts links (e.g., fortunately/unfortunately stories, rock obituaries, etc.); experiments; peer teaching; lesson planning; jigsaw discovery; concept mapping; group work; discussions; and field trips.

Distinct from regular laboratory sections, there was minimal lecturing and use of worksheets. The dedicated laboratory manual provided activity instructions, background information, and EDU sheets with sample questions to assist in skill development for leading teacher-scaffolded discussions at different stages of the activity. The capacity of the EdLab is 20 students per year; they are screened based on their interest in teaching and proximity to time of application and entry into the teacher education program. Following the approach for the ES professional development workshops, resources were provided to these students for use in their future classrooms, including rock kit (26 samples), mineral kit (20 samples), fossil kit (11 samples), books, posters, colour overheads, and activity blackline masters.

RESEARCH DESIGN

The EdLab was the focus of an evaluation study conducted over the fall of 2005, 2006, and 2007. It consisted of two major groups: EOS 120 students in regular laboratory sections (n = 421) representing 88% of the students enrolled and pre-Education students in the EdLab sections (n = 60) representing 22% of the students. Several aspiring teachers in EOS 120 were not able to be accommodated in the EdLab and thus enrolled in another section composed of regular students. The numbers of students were reasonably consistent, with 135 in the regular sections and 20 in the education section in 2005, 142 and 20 (respectively) in 2006, and 144 and 20 (respectively) in 2007. Students' ages were collected as categorical data and ranged from 16 to over 40 years. Overall, 53% were in the 16–20 range, 26% in the 21–25 range, 4% in the 26–30 range, and 5% in the >31 group (approximately 10% did not report their age). Additionally, 51% of the sample was female and 37% was male (again, approximately 10% did not report their gender).

Procedure

Ethical approval for this study was secured through the Human Research Ethics Board (HREB) at the University of Victoria. The study employed a mixed method (Patton, 1990) of quantitative and qualitative data toward gaining a rich understanding of the impact of the special laboratory section, both in terms of the understanding of and attitudes toward ES. None of the information on study participants was made available to the researchers until after submission of term grades for each year as per the HREB requirements. The data collection tools used over the 3-year study are described next.

Surveys. Pre- and postlaboratory surveys were completed by all EOS 120 students regardless of laboratory section. Surveys included demographic information (i.e., dichotomous gender, age range), information about their ES secondary school experiences (i.e., dichotomous for if they attended school in BC, Likert scale for ES class experiences), an attitude toward ES question, and 20 multiple-choice knowledge questions based on common misconceptions about ES (same on pre and post). These data were used to document gains in attitude and knowledge between the students in the EdLab and regular laboratory sections. The surveys were given at the beginning and end of term, each time without prior notice so that the knowledge–question results represented long-term knowledge as opposed to last-minute cramming. Content validity of the knowledge questions was verified by the instructors; both are tenured faculty in Earth Science and Science Education. Reliability of the content test was explored using a Cronbach □ analysis that revealed an internal consistency coefficient of 0.53 amongst the 20 items. Furthermore, the means of the pretest (11.8) and posttest (13.7) were significantly different ($p < .001$), thereby lending support to the sensitivity of the content items.

Interviews. Student group interviews were conducted at the end of the term but prior to the final examination for the EdLab and a regular section (taught by the same teaching assistant) for comparison.

Course grades. Student grades (laboratory, lecture midterm and final examinations) were analyzed for comparisons of overall achievement in the EOS 120 course.

RESULTS

The results of the evaluation study are reported in order of the global question of performance to more specific, detailed performance. Course grades are used to address the normative values of the Faculty of Science and the Faculty of Education in which most judgments are based on grade point average. The knowledge, attitude, and perception results are more specific to the ES education community.

Achievement in Earth Science – Course Grades

EOS 120 student grades over the 3-year pilot study were analyzed as indicators of understanding of ES concepts. Results for all years for laboratory, lecture, and final grades for both cohorts of students are provided in Table 2. Students in the EdLab scored better in their laboratory grades than their peers in the regular sections while performances in lecture and final grades were mixed but generally favoured the EdLab students.

Achievement in Understanding of Earth Science – Survey Questions

All students in this study completed a 20-question, selected-response test addressing common misconceptions as part of the pre- and postlaboratory surveys. A series of Wilcoxon signed-rank tests was conducted on all scores in all laboratory sections across all 3 years of the study on these content knowledge questions. Wilcoxon was selected as these data did not meet parametric assumptions of normality; the analysis is simply a count of the number of differences that are positive and negative and then making decisions based upon these counts (Elliot & Woodward, 2007). The Wilcoxon signed-rank test results (Table 3) indicate the number of scores on the posttest that improved over the number of students taking both tests. The significance is based upon a *Z* score and subsequent *p* value with □ set at .05 (a Bonferroni adjustment was added to the interpretation to accommodate for inflated Type 1 error). According to this output, there was a significant increase in students' scores on the content test for five of the six sections (only the 2006 EdLab section was not significantly different from zero). Effect sizes tended to be in the medium range for the regular group and high for the education group.

Table 3. Output for Wilcoxon signed-rank tests

Group	*2005*	*2006*	*2007*
Regular	66/108; Z = -3.84; p < .001, r = -.37	70/117; Z = -3.52; p < .001, r = -.33	87/128; Z = -5.64; p < .001, r = -.49
Education	16/20; Z = -3.37; p = .001, r = -.76	11/18; Z = -2.34; p = .019*, r = -.55	17/18; Z = -3.64; p < .001, r = -.86

* Nonsignificant difference with Bonferroni adjusted □.

Of the 20 questions, 7 were identified as being most sensitive to instruction (Q1—age of the planet, Q2—date life recorded on the planet, Q5—human and dinosaur coexistence, Q7—earthquakes in BC, Q8—Vancouver Island plate name, Q11—soil formation, Q12—ground and surface water system). The results of these questions for both groups across all 3 years are presented in Table 4. Inspection of these results revealed that Q7, Q8, and Q11 offered the lowest pretest performances and, therefore, the potential for improvement. The aggregated data across all years revealed two patterns. First, there is an identified increase in the percentage performance for the EdLab group on all three questions while the performance for the regular group was mixed (Q8, performance decreased on the posttest). Second, the absolute posttest performances of the EdLab group were higher than the regular group while their pretest performances were either lower or equal to the regular group. For example, the EdLab group changed by a percentage of +15, +10, and +12 for the three questions, respectively, while the regular group changed by a percentage score of +8, –4, and +8. There appeared to be a positive influence of instruction on the correction of misconceptions across the entire study, and this influence was greater for the EdLab group.

Attitude toward Earth Science

This section addresses the pretest and posttest answers to students' attitude toward ES to explore any change following instruction. Data were collected on students' responses measured on a 5-point Likert scale (1 = strongly disagree … 5 = strongly agree) to the question: *Do you feel the study of Earth Science is relevant to society?* These results are presented in Table 5. Initial interpretations and comparisons of these data show that students generally agreed that ES was a topic relevant to society with little difference observed either across the years or between the EdLab and regular laboratory sections.

Given this pattern of relationship, the data were aggregated across all three groups and a McNemar's test was performed on each group to determine if student impressions of the relevance to society changed significantly after instruction. McNemar's test is designed for the analysis of paired dichotomous categorical variables much like a paired t-test for quantitative data (Elliot & Woodward, 2007). Using McNemar's test, no significant change was found for students being more likely to feel ES was more relevant if they were in the EdLab section ($p = 0.31$); however, students were significantly more likely to feel ES was more relevant if they were from the regular group ($p = 0.04$).

Finally, considerable data were collected from student interviews, written reflections, and evaluations. Although all data have not been fully analyzed for content, some themes are evident upon initial observation. For example, EdLab students generally and overwhelmingly commented on their increased comfort level and enjoyment of ES following the course. Sample comments include: *I was scared of this course, as a science course coming from an Arts background, but now I feel comfortable and confident to teach ES. I enjoyed it. I would take another science*

Table 2. Laboratory, lecture, and final grades (mean, standard deviation, number) for education and regular students enrolled in EOS 120 in 2005, 2006, and 2007

Laboratory	*M*	*SD*	*N*	Lecture	*M*	*SD*	*N*	Final	*M*	*SD*	*N*
2005 Regular	40.5	3.4	150	2005 Regular	30.3	6.9	150	2005 Regular	70.8	9.1	150
2005 Education	43.4	1.5	20	2005 Education	32.4	7.1	20	2005 Education	75.8	8.0	20
2006 Regular	39.5	3.3	114	2006 Regular	35.2	6.4	114	2006 Regular	74.8	8.8	114
2006 Education	43.4	1.5	18	2006 Education	34.6	8.1	18	2006 Education	74.5	11.3	18
2007 Regular	40.5	3.5	132	2007 Regular	30.1	6.5	132	2007 Regular	70.0	10.1	132
2007 Education	41.5	2.8	20	2007 Education	30.9	5.8	20	2007 Education	72.3	8.4	20

Table 4. Percentage correct for pre- and posttest student responses to select questions on common misconceptions

	2005		2006		2007	
Question	Regular (*n* = 118)	Education (*n* = 20)	Regular (*n* = 115)	Education (*n* = 18)	Regular (*n* = 134)	Education (*n* = 17)
Pre #1	98	100	99	100	99	100
Post #1	100	100	99	100	98	100
Pre #2	99	100	99	100	97	94
Post #2	99	100	100	93	98	100
Pre #5	95	85	96	94	88	100
Post #5	95	95	95	100	95	100
Pre #7	28	20	20	17	21	41
Post #7	31	40	28	23	33	38
Pre #8	56	78	50	41	30	12
Post #8	60	70	34	43	34	42
Pre #11	68	80	59	56	59	61
Post #11	73	85	65	79	72	67
Pre #12	85	80	77	83	83	89
Post #12	89	90	91	79	87	89

Table 5. *Number and (percentage) pre- and posttest perceptions of the relevance of the study of earth science to society*

	2005 Education		*2005 Regular*		*2006 Education*		*2006 Regular*		*2007 Education*		*2007 Regular*	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
SD	0 (0)	1 (5)	1 (1)	4 (3.3)	0 (0)	0 (0)	2 (2)	0 (0)	0 (0)	1 (5.5)	1 (1)	1 (1)
D	1 (5)	0 (0)	5 (4)	6 (5)	0 (0)	1 (5.5)	2 (2)	3 (3)	0 (0)	0 (0)	0 (0)	3 (2)
N	8 (40)	7 (35)	15 (12.5)	11 (9)	0 (0)	0 (0)	12 (10.5)	6 (5)	1 (5.5)	0 (0)	7 (5)	13 (10)
A	4 (20)	7 (35)	52 (43.5)	35 (35)	7 (39)	6 (33)	43 (37)	41 (35.5)	4 (22)	4 (22)	61 (45.5)	52 (39)
SA	7 (35)	5 (25)	47 (39)	53 (44)	9 (50)	9 (50)	55 (48)	65 (56.5)	1 (48)	13 (72)	63 (47)	60 (45)

Note. SD = Strongly disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly agree.

course now—I am much more confident about science in general. This class and especially this lab, has definitely made me more confident and enthusiastic about the teaching of ES to young children. Additionally, students commented on how much more relevant this class seemed once they had completed the experience: *I didn't see it* [ES] *as very important in my life, but I've changed my view now that I see the environment isn't necessarily set in stone. I have previously taken EOS 110 and wasn't too excited about this class initially but with the fun, interactive lab experience and Dr. Eileen's lectures, I became interested in the course. ... The lab was more than just sitting, listening and writing. It involved working together as a team, activities which made learning fun, I think which was key. Earth science is the most interesting science there is, relevant!*

SUMMARY, CONCLUSIONS, AND LESSONS LEARNED

It has been argued here that, due to the fundamental role Earth Science plays in promoting an understanding of the way the natural world works as a system and in aiding society to respond to important and current issues, there should be an increased role for ES in the BC education system. In fact, data collected by Van der Flier-Keller (2007) on first year ES students who had graduated from BC secondary schools showed that ES was not as highly emphasized as the more traditional sciences (i.e., biology, chemistry, physics) and that it was often awarded lower status by both teachers and students.

In an effort to address some of the misunderstandings and beliefs of low importance and low relevance toward ES, this chapter has outlined a series of procedures that were designed and implemented within the Pacific CRYSTAL Project. Following the suggested outcomes for professional development by authors such as Joyce and Showers (1988), Harland and Kinder (1997), and Fenichel and Schweingruber (2010), numerous ES professional development workshops were offered each year to empower teachers in their teaching of ES. These workshops were developed by professional geoscientists with feedback from teachers and were jointly led with professional scientists and experienced teachers.

The evidence of the positive effects of the professional development workshops was overwhelming. Participating teachers evaluated the workshops as primarily outstanding or excellent. In addition, they spoke of a new and renewed confidence and an increased interest in and a desire to bring these ES ideas to their students. Obviously, capturing the enthusiasm of teachers just after a workshop is much different than having them take these ideas and implementing them in their classrooms. The literature is full of suggestions that transference is less than assured. However, this overall finding does suggest that workshops offering hands-on, constructivist-type activities—where participants are actively involved and leaving with increased enthusiasm toward ES and physical materials for classroom use—is an important step in improving ES classroom instruction.

In addition to the professional development opportunities for current teachers, a new laboratory section was developed for a first year ES course over the 2005–2007 academic years. This course was chosen because it is often taken by preservice

Education students as a science prerequisite course for their teaching degree. The EdLab is distinct in that it presents course material using constructivist-based activities and resources that are linked and transferable to the K–10 classroom. This EdLab section was the focus of a 3-year study that measured understanding of ES concepts, common misconceptions, and attitudes toward ES. Overall, findings indicated that (a) the EdLab section outperformed the regular one; (b) misconceptions were correctly addressed for both sections, with the EdLab performing slightly better in a few areas; and (c) students in the regular laboratory sections after instruction believed that ES was more relevant to society. The evidence of effects for the EdLab group, although not overwhelmingly positive, does point to a clear and consistent trend indicating the instruction for this population following a constructivist hands-on design was effective in improving conceptual understanding, correcting misconceptions, and increasing attitudes toward the relevance of ES. A key point here may be that students in the EdLab section scored as well if not better than those in the other sections while being exposed to innovative and pedagogically sound instructional practices that have the potential to influence their interactions with students as they progress to becoming teachers.

As is always the case with research, this overview of the Pacific CRYSTAL work in ES raises many questions. We wonder, for example, if the workshops for teachers led to increased instruction in ES in their classrooms. We intend to study if the EOS 120 course experience encourages the teaching of science, and especially ES, in the practice of new teachers who enrolled in this course. We intend to continue studying the effects of the EdLab section on student understanding of ES and especially wish to study in more detail attitude development. While there is clearly more research needed, the studies reported in this chapter offer insights into some potentially positive areas of intervention for improving the delivery and understanding of Earth Science in the BC education system; they help to articulate additional questions more precisely as well as offer further research hypotheses that can lead us in new and different directions of inquiry. Moreover, it has given us a glimpse of what can be achieved by allying ourselves with those who work as teachers in the educational system in British Columbia.

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