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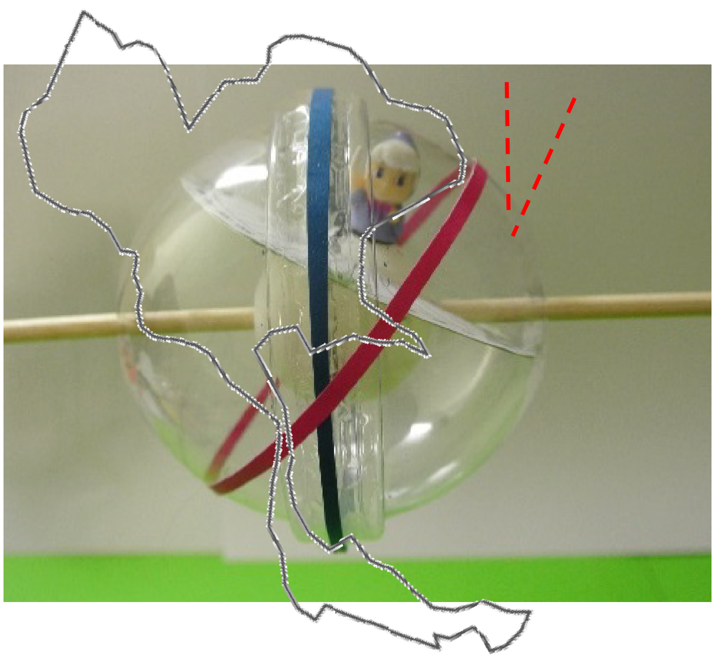

In This Issue: Astronomy Education in Thailand, Québec, England and Europe

Journal and Review of Astronomy Education and Outreach (*JRAEO*)

JRAEO Scope

Articles on any topic relating to educating students or the general public about astronomy are of interest. This can include areas of study often designated as astronomy education or space science education, as well as topics from allied fields such as physics, geoscience, math or history education, as long as the topic is found in an astronomy course or used to excite and inform people about astronomy.

The subject areas include all grade levels–primary, elementary, middle school, and secondary level (in the US, the K-12 system)–undergraduate education (both astronomy majors and general education courses or other domains where astronomy can be included, such as exobiology or cosmochemistry), teacher education, graduate education, and informal or free-choice education involving the general public, including studies of the media (newspapers, social media, etc.) and dedicated facilities such as science centers and planetariums.

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Journal and Review of Astronomy Education and Outreach

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Section A – Research

Section B – General Articles

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Larry Krumenaker
Editor

The best laid schemes o' mice an' men / Gang aft agley." (Often go awry.)
– Robert Burns "To A Mouse"

If ever a statement would qualify as the motto of the past seven months, this one outdoes all competitors. A brief explanation of what's gone on since Issue 1.

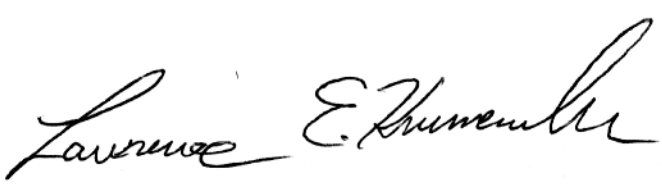
Right after Issue 1 went out, yours truly entered a hospital because of a doctor's misdiagnosis and subsequent mis-prescribing of a particular pharmaceutical; an excellent example of the continuing decline of the American healthcare system. It took a fair amount of time to recover from the mistake, during which Kristine Larsen thankfully kept the reviewing going, for which I will be forever grateful. During the time that I was incapacitated, I was unable to handle my share of editing and doing layout. I was able to spend an hour a day, perhaps, answering emails and doing triage on submissions.

But that was the first several events that created a perfect storm of tragedies, including a death in the immediate family, another of a colleague, an unexpected move, and a bitter legal battle. Some of those 'war fronts' have been quashed, but not all is finished. Thus, only now is Issue 2 going out the door to you all. Articles are already in the works, in review or even into layout, for Issue 3, to come out soon.

Another change we've had to work with…we've made all past issues of JRAEO open access (Issue 1 already was), and instituted a small page / open access fee, much lower than any other peer-reviewed publication. What does this do for subscribers who paid for Issues 2-4? Their incentive was no page charges, and so we will continue with them for the duration of their subscriptions. However, new subscribers will get a reduced page charge from those of the non-subscribers and one-issue exclusive access to the current issue. In fact, we will have a two-tier charge, one level for Research Universities, and one for small teaching colleges, museums and high schools. It all rides on the first author's status.

At least I can give you some good news on myself after all this travail. Starting on March 1st, in addition to everything else I am doing with Hermograph Press, I will be Science Journalist in Residence at the Heidelberg Institute for Theoretical Studies, in Germany! You'll still be able to call me; there will be a six-hour (from the U.S. East Coast, anyway) time difference you'll have to account for, though. I will be there for six months. I'm praying that being closer to Scotland, Robert Burns' home country, may keep everything quite NOT agley, for a change. Happy End of Old Year!

Sincerely,



Kristine Larsen
Assistant Editor

The central mission of *JRAEO* is to bring you a wide variety of interesting and academically sound articles focusing on all aspects of astronomy education and outreach research. In order to assure the quality and integrity of the journal, we rely on our cadre of volunteer peer reviewers. Their objective, careful, and timely double-blind review of all manuscripts submitted plays a central role in this quality control process.

I think it is important for all article authors and peer reviewers to realize that articles to *JRAEO* go through a three-stage process.

The **First Stage** is Editor Larry Krumenaker doing a quick triage on whether the article is topically right for us, which section it might go into (Section A or B), and whether the article is complete enough that we can review it as-is. I also take a look at it and make suggestions or concurrence with Larry's decision.

If the article is acceptable at this stage, it goes to peer reviewers, always two for Section A articles, one for Section B. *Some* Section B's are reviewed and handled only by Larry if they are short. Otherwise, all stories are then given to me to ride herd.

Second Stage has me selecting reviewers and sending the redacted submissions on to them. For those pieces with statistical work within, I send them on to our staff statistician, Dr. Seock-Ho Kim, something we do that no other publication we know of does.

Once the reviews are in, Larry and I share, review, and decide on whether to provisionally accept the piece. If so, we send the reviews to the authors to make revisions. Upon receipt of the revisions, we send the revised work to the original reviewers (again, something not done often in scholarly publishing!) to see if their comments have been taken care of.

If all is well at that point, the **Last Stage** has it going to Larry, who then passes his detailed editorial eyes on the work, making new figure requests, asking for clarifications, and so on, until he can put it into our formatting templates.

Upon full acceptance, whether after Stage 2 or 3, we send a copyright transfer form to be sent back before publication.

In all this, we have a continuing need to increase our party of peer reviewers, so I invite you to consider whether you would like to take part in this process yourself. Professionals in both formal and informal astronomy education and outreach are most welcomed. [We do ask that you fill in our Peer Reviewer form, found on the website; also, generally, if you've written an article that was successfully navigated to publication with *JRAEO*, you're automatically put on our list of reviewers]. I am always open to discussing the process with potential reviewers. Just email me at assteditor@jraeo.com.

Collegially yours,

THE STATE OF ASTRONOMY TEACHING IN QUÉBEC'S PRIMARY AND ELEMENTARY SCHOOLS: A SURVEY OF TEACHERS

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Received July 17, 2014; Accepted December 17, 2014

Abstract: We present the results of a survey of Québec primary and elementary (K-6) teachers that questioned them about their practice of astronomy teaching in K-6 classrooms, background in Science and Technology (S&T), pre-service education, goals and objectives for astronomy teaching, attitudes toward teaching astronomy, resources and materials used, efficacy of pre- and in-service training, and needs for in-service training. A total of 138 respondents completed the questionnaire using an iPod app. We found that the majority of respondents didn't study science after high school and have no experience in S&T employment. It was also found that only 43% of respondents actually teach astronomy to their class, using mostly reading material, and that half of them teach astronomy less than 5 hours per year. Major obstacles to teaching astronomy are lack of experience and training, lack of resources and equipment, insufficient classroom arrangement, and perceived incompetence in astronomy. Pre-service education in astronomy, in science, and in science teaching is considered mainly unsatisfactory or non-existent; in-service training consists mainly of conversations with colleagues and is considered inefficient or non-available. Most respondents consider that 3 to 5 hours of training per year in astronomy teaching would be sufficient for them to gain more confidence in teaching astronomy. Based on these results, ways to enhance the teaching of astronomy in Québec's K-6 classrooms are discussed.

Keywords: in-service teachers - primary school - elementary school - astronomy education - K–6 - teachers' training - teachers' survey

INTRODUCTION

In 2006, Québec's Ministry of Education (Ministère de l'Éducation, du Loisir et du Sport; MELS henceforth) introduced a new curriculum for primary and elementary schools (grades K to 6 in Québec, ages 5 to 12; K–6 henceforth) that, for the first time in recent history, included astronomy as one of the subjects to be taught during science class (MELS, 2006a). Previously, the only astronomical topics covered from grade levels K to 12 in the province were diurnal motion, seasons, Moon phases, and the location of Earth in space, all of which were taught in the first weeks of geography class at the beginning of the first year of high school (grade 8 in Québec).

Québec's new K–6 curriculum was introduced in part to try to address criticisms that science education in the province's primary and elementary classrooms was poor or non-existent, consisting mainly of rote learning of disconnected facts, and was not oriented enough towards a better understanding of the processes of science through genuine problem solving (Conseil supérieur de l'éducation, 1982, 1990; Société pour la promotion de la science et de la technologie, 1995; MELS, 1996). What's more, including astronomy in the curriculum was

[1] Département de didactique

thought to be a way of broadening the scope of science teaching beyond the "traditional three," i.e., physics, chemistry, and biology. It was recognized that astronomy caught the interest of many students (Jarman & McAleese, 1996), and that the understanding of key concepts in astronomy, like Moon phases and seasons—phenomena that are present in our everyday life and affect us in many ways—were essential to a balanced school science program (Marcel Thouin, 2012, personal communication).

Including astronomy in the new K–6 curriculum raises the questions: how is astronomy taught in K–6 classrooms; is it taught at all? Since most in-service K–6 teachers who are active today were trained *before* or *soon after* astronomy was included in Québec's curriculum, they likely received very little astronomy instruction themselves during their pre-service education. One wonders how these teachers approach astronomy studies with their students, what material and resources they use, how often and for how long they teach astronomy, and how they perceive their pre-service and in-service training in astronomy, if any was provided. Now, 10 years after astronomy was made part of Québec's school program, we thought it was time to study the state of astronomy teaching in the province's K–6 classrooms. This research was conducted with the objective of determining the following:

- The demographic profile of a typical K–6 teacher in Québec
- K–6 teachers' background in science and astronomy through science courses and employment
- If and how K–6 teachers teach astronomy in their classrooms
- K–6 teachers' goals and objectives when teaching astronomy to their class
- K–6 teachers' attitude towards teaching astronomy
- What resources and materials K–6 teachers use to teach astronomy
- How K–6 teachers perceive the efficacy of their pre- and in-service training in astronomy and science
- K–6 teachers' needs in terms of in-service astronomy training

Once the state of astronomy teaching in Québec's K–6 classrooms has been documented, we hope to use our research to propose ways of improving astronomy teaching in Québec's primary and elementary schools.

ASTRONOMY IN QUÉBEC'S NEW K–6 CURRICULUM

The following is a brief summary of the new K–6 curriculum introduced in Québec schools in 2006.

The new curriculum essentially has three aims: 1) to empower students so that they can 2) build their own identity and 3) develop a vision of the world (MELS, 2006a). In this sense, Québec's new curriculum is based on the constructivist theory of learning (Bransford, Brown, & Cocking, 1999; Schunk, 2004). The curriculum identifies five broad areas of learning: 1) personal and career planning, 2) health and well-being, 3) environmental awareness, and consumer rights and responsibilities, 4) citizenship and community life, and 5) media literacy. Overarching these five areas of learning, the curriculum presents five subject areas for teaching in K–6 classrooms: 1) languages, 2) social sciences, 3) personal development, 4) art, and 5) mathematics, science, and technology. Finally, the new curriculum lists 19 subject-specific programs, one of which is science and technology, a program for which astronomy is one of the key subjects.

Québec's new curriculum is also competency-oriented with nine cross-curricular competencies divided into four categories:

- Intellectual: students 1) use information, 2) solve problems, 3) exercise critical judgment, and 4) use their creativity
- Communication-related: students 5) communicate properly
- Personal and social: students 6) cooperate with others, and 7) reach their potential
- Methodological: students 8) adopt effective methods, and 9) use information and communications technologies.

Additionally, each subject-specific program has its own set of competencies that is arranged according to grades. For instance, science and technology has the following subject-specific competencies: Students …

1. Construct their vision of the world (K)
2. Explore the world of science and technology (grades 1–2)
3. Propose explanations for or solutions to scientific or technological problems (grades 3–6)
4. Leverage the tools, objects, and processes of science and technology (grades 3–6)
5. Communicate using the language of science and technology (grades 3–6)

Along with the above-listed competencies, the subject-specific science and technology program covers a long list of essential knowledge (i.e., learning objectives), also spread across the different grades and divided into three categories: the material world (physics, chemistry, engineering); the living world (plants, animal and human biology, ecology, environmental science); and Earth and space (geology, astronomy, atmosphere science, space science). Twelve of these elements of essential knowledge are directly related to astronomy. They are listed in Table 1 in the order they appear in the K–6 science and technology program (MELS, 2006a, pp. 149, 157–160).

It appears from Table 1 that the list of essential knowledge mainly targets grades 3 to 6. Furthermore, the curriculum does not list any essential knowledge for preschoolers (K). Also note that, despite the word "essential" in "essential knowledge," the list in Table 1 is non-binding for K–6 teachers, who can pick and choose as they like from the "essential knowledge" in the science and technology program (this is true for all essential knowledge in the K–6 curriculum). This means that K–6 teachers may very well teach science to their students without ever touching on astronomy. However, the new curriculum for secondary school (high school), also introduced in 2006 for grades 8 to 12 (students aged 13 to 18), includes a list of compulsory concepts (MELS, 2006b), some of which overlap the above list of essential knowledge, such as the solar system and seasons. As a result, children graduating from grade 6 may enter high school without ever having studied the Earth's rotation, the solar system, or seasons.

Three years after the new K–6 curriculum, MELS (2009) introduced a new document entitled *La progression des apprentissages* (The Progression of Learning). This document makes a closer association between the elements of essential knowledge and the specific grades, and proposes a progression of learning. The goal of this document was to assist teachers in planning their teaching according to a child's age and intellectual development (maturation) and to present the essential knowledge in a more logical sequence. For instance, the progression of learning suggests studying the Sun as a star, the Earth as a planet, the Moon as a satellite, and the formation of shadows in grades 1–2 *before* studying the rotation of the Earth (diurnal motion) and the revolution of the Moon (phases and eclipses) in grades 3–4 (MELS, 2009, p. 9). Note that this document introduces two new elements of essential knowledge in astronomy that were not included in the 2006 curriculum, i.e., phases of the Moon and eclipses. These have already been included in the list of essential knowledge at the bottom of Table 1.

Table 1

List of essential knowledge in astronomy in Québec's K–6 curriculum

Essential Knowledge in Astronomy	Grade						
	K	1	2	3	4	5	6
Light and Shadows		X	X				
The sun-earth-moon system		X	X	X	X		
Solar energy				X	X	X	X
The earth's rotation				X	X		
Tides						X	X
The solar system						X	X
Seasons						X	X
Stars and galaxies (constellations)				X	X	X	X
Earth, atmosphere and space technologies				X	X	X	X
Use of simple observation instruments (binoculars, telescopes, etc.)				X	X	X	X
Use of appropriate terminology, conventions, and drawings for astronomy (terrestrial globe, star chart, etc.)				X	X	X	X
Phases of the Moon and eclipses				X	X		

(MELS, 2006a, 2009)

It must also be said that no time has been officially allocated for science instruction in the class schedule in grades 1 and 2, even though both the new K–6 curriculum and the progression of learning for the science and technology program include essential knowledge for these grades. It is left up to the grade 1 and 2 teachers whether or not to teach science in their classrooms. For grades 3 to 6, the science and technology program (including astronomy) is part of an 11-hour weekly block of elective teaching time shared with other subject-specific programs, such as English or French, langue seconde (Second Language, which can be either of the two languages, depending on the student's first language); art (music, dance, visual arts, etc.); ethics and religious culture; and geography, history and citizenship education. K–6 teachers decide for themselves which subjects to teach during those 11 hours every week.

PREVIOUS STUDIES

Few research papers published in recent years examine the state of astronomy teaching in primary and elementary schools, and there have been no studies on the situation in Québec. Our study is inspired by the closest study that we were able to find, which documented science teaching in K–6 schools in Alberta about ten years ago (Rowell & Ebbers, 2004). Another important source is the 2012 National Survey of Science and Mathematics Education (Banilower, Smith, Weiss, Malzahn, Campbell & Weis, 2013) conducted in the United States. We will also briefly discuss recent studies about astronomy teaching conducted in American high schools (Krumenaker, 2008, 2009a, 2009b; Plummer & Zahm, 2010; Sadler, 1992; Slater, Slater, & Olson, 2009). We will look at the type of information collected through surveys and examine the main findings to compare them with our own results.

Rowell and Ebbers (2004) developed an important survey that was a follow-up to a national study conducted two decades earlier by Orpwood and Alam (1984) to determine science teacher beliefs about the aims of science education, their perceptions of the effectiveness of their teaching, and the obstacles that prevented them from achieving their aims. Rowell and Ebbers set out to determine the beliefs about and perceptions of elementary (K-6 in Canada) science teachers in Alberta, while maintaining the focus of the previous study by Orpwood and Alam to ensure continuity and establish a basis for comparison. Their survey was quite elaborate and addressed several components of science teaching at the elementary level, including demographics, the teachers' aims of science education, their backgrounds and experience, the resources and material used (including physical facilities), the students' abilities and interests, and community and professional support. A written survey was mailed to approximately 3000 elementary teachers in Alberta, 1116 of whom returned the completed questionnaire.

Among the major findings that are relevant to our study, Rowell and Ebbers reported that Alberta's elementary teachers are predominantly female, are over 35 years of age, and have more than 10 years' experience. As for their educational background, the majority of teachers were found to have a Bachelor's degree, to not have studied science or technology at university, and to have no science and technology-related employment experience. Major obstacles to effective science teaching reported by Alberta teachers were insufficient institutional arrangements (not enough time in the class schedule, for instance), inadequate physical facilities, and lack of equipment. Also, Rowell and Ebbers' findings show that elementary teachers mainly use reading material to teach science. In-service training is considered mostly ineffective or non-existent and, when available, typically consist of conversations between colleagues. As we will see when we analyze the data collected in our study, the situation described by Rowell and Ebbers in 2004 is quite similar to the situation in Québec's elementary schools ten years later.

As reported by Krumenaker (2009a), Sadler (1992) conducted a survey of astronomy teaching practices in high schools in Boston, Massachusetts, in 1986. He was mostly interested in finding out about astronomy teachers, their backgrounds and training, the materials they used, and the curriculum they were following. Sadler found that only about a tenth of all high schools surveyed offered stand-alone astronomy courses and that very few teachers taught only astronomy (41% were also teaching physics and more than 25% also taught earth sciences). 88% of the teachers were males, most of whom were amateur astronomers and/or had developed a personal interest in astronomy, leading 80% of them to develop their own curriculum. Few used a manual (14% of teachers), which happened to be a college-level textbook. Each astronomy class was made up of approximately 22 students, mostly in grades 11 and 12, and about a third of the courses were spread over an entire school year.

About 20 years later, Krumenaker (2008, 2009a, 2009b) conducted a survey similar to Sadler's, in which he hoped to reveal differences between the 1986 results that might have been caused by introducing the No Child Left Behind (NCLB) Act in American schools. In 2007, 300 high school teachers answered a 55-question online survey (Krumenaker, 2009a), while another 115 teachers answered a paper-pencil version of the same survey (Krumenaker, 2009b). Both surveys asked teachers to describe their astronomy courses, the makeup of the classroom, and their own education and teaching experience, including professional development resources. Questions had the respondents describe the particulars of their astronomy course, including duration, materials and equipment used, and school characteristics. Questions were also asked about how astronomy courses had been affected by the NCLB Act.

There are surprisingly few differences between Sadler and Krumenaker's surveys, despite them being separated by 20 years and three major curricular and political milestones. The percentage of female teachers grew from 12% to 33%, websites surpassed magazines as a source of information, the percentage of high schools where astronomy was taught rose from 9% to about 12% nationwide, and 75% of teachers were now using a textbook, compared to the 14% who "relied upon" this resource in Sadler's survey. Astronomy courses were still created by a teacher with a personal interest in the field but few respondents had pre-service training in astronomy as an undergraduate. Teachers also reported that in-service training was rare and that they mainly kept up with astronomy topics through websites (NASA and other astronomical organizations). Krumenaker (2009b) also found that more emphasis was put on traditional topics in astronomy courses, rather than contemporary astronomical research. Also, teachers reported making more use of planetarium software, in addition to fixed and portable (physical) planetariums, than before. The NCLB Act was deemed to have had an indirect and mostly negative effect by astronomy teachers, some of whom saw their astronomy course cancelled to make room for more math and language courses in underperforming and underprivileged schools.

Slater et al. (2009) surveyed 799 elementary, middle, and high school (K-12) astronomy teachers to determine if and how they were using planetary science data in their courses and how they were teaching astronomy. Their sample contained highly engaged, motivated, and innovative astronomy teachers, people actively looking for new resources to teach astronomy. Slater and his colleagues found that these teachers took advantage of several online resources and frequently tapped into other data sources. The authors also reported that about a quarter of astronomy teachers used open or guided inquiry to teach their students, but when they did use inquiry methods, it was still highly structured or used as part of confirmation activities, rather than introductory activities. Although these teachers said they were interested in increasing the use of real inquiry in their astronomy class, they also indicated that the large number of topics that had to be covered with their students to fulfill state standards, and the amount of time required to teach these topics, prevented them from increasing their use of authentic inquiry practices.

Plummer and Zahm (2010) used an online survey of middle and high school science teachers and interviews with curriculum directors to investigate the coverage of astronomy in high schools in the greater Philadelphia region in southeastern Pennsylvania. Plummer and Zahm were interested in how astronomy was covered in schools as well as the characteristics of teachers who teach astronomy in this region, not only in elective astronomy courses, but in all other instances of astronomy education in secondary schools. Their study focused mainly on coverage of state standards, time spent on astronomy in class, availability of resources, teacher efficacy, and teacher pedagogical beliefs. The researchers found that astronomy is not taught in depth in the schools studied, and that many students receive no astronomy instruction across both middle and high school. After a curriculum reform in Pennsylvania a few years earlier, they found that many teachers held reform-based perspectives on astronomy teaching but also maintained traditional beliefs about how astronomy should be taught.

Lastly, the 2012 National Survey of Science and Mathematics Education (NSSME) (Banilower et al., 2013) studied many important topics, such as teachers' background and beliefs, professional development in science, instructional decision-making, objectives, instructional resources, and factors affecting instruction. A total of 7,752 science and mathematics teachers in elementary, middle, and high schools across the United States participated in this survey. In the case of elementary teachers, demographics for the NSSME survey are very similar to what we found with Québec teachers. Results also indicate that elementary science teachers do not have strong content preparation in science, and that they do not feel well prepared to teach this subject. Authors attribute this situation to the fact that very few elementary science teachers have taken undergraduate courses in this field. Also, staying up-to-date in science is particularly challenging for teachers at the elementary level because they typically teach multiple subjects, and also because of the relative paucity and average quality of in-service professional development in science that is offered to them, including college courses.

The NSSME also found that elementary teachers teach science less often and for shorter durations than other subjects, such as reading/language arts and mathematics. Science is taught all or most days every week in only 20% of K–3 classrooms and in 35% of 4–6 classrooms, compared to 99% and 98% respectively for math. Also, many elementary classes receive science instruction only a few days a week or during some weeks of the year. On average, science is taught roughly 19 minutes per day in grades K–3 and 24 minutes per day in grades 4–6, compared to 89 and 83 minutes per day, respectively, for reading/language arts, and 54 and 61 minutes per day for math. Finally, the use of science specialists, either in place of or in addition to the regular classroom teacher, is uncommon in elementary schools (only 10% to 16% of schools).

Among other results, the NSSME found that elementary science classes are much more likely than high school classes to use a science textbook, module, or other science-related reading material. A total of 69% of elementary schools use commercially published textbooks or programs in science, and teachers admit that they rely heavily on textbooks to organize their science teaching. About two-thirds of science teachers rated their resources in science as somewhat adequate or less. The amount of money schools report spending on instructional resources also seems quite inadequate, especially when viewed as a per-student expenditure. In science, the problem is especially pronounced in the elementary grades, where median per-student spending is half of that spent in middle schools and less than one-third of that spent in high schools. Finally, among problematic factors for science instruction in elementary school, the survey found inadequate funds for purchasing equipment and supplies, a lack of science facilities, insufficient time to teach science, and inadequate science-related professional development opportunities for teachers.

SURVEY INSTRUMENT

In order to achieve the goals and objectives listed in the introduction of this paper, we developed a 31-question survey with multiple-choice answers inspired by the papers presented above, particularly the 2004 study by Rowell and Ebbers. The original survey was written in French, and an English version was prepared by the author to accompany this paper; it can be found in PDF format here (see Appendix).

- Questions 1 to 13 (all survey respondents): Demographics (age, gender), teaching experience, pre-service education and training in science and technology, science and technology-related employment experience, astronomy and science teaching experience, number of hours per week of science teaching, and demographic and socioeconomic information about the school, classroom, and students.
- Questions 14 to 23 (only survey respondents who teach astronomy): Integration of astronomy into other topics, essential knowledge in astronomy taught, number of hours per year devoted to astronomy teaching, goals and objectives of teaching astronomy, classroom arrangements, resources and equipment available, perceived obstacles to teaching astronomy.
- Questions 24 to 31 (all survey respondents): Perceived efficiency of pre- and in-service training in astronomy, in science and technology, and in science teaching, perceived needs for in-service training in astronomy, and self-interest in teaching astronomy.

The survey was created in Fall 2013. After going through several iterations of the survey questionnaire, testing it for understandability of questions and multiple-choice answers with university colleagues, and testing it again for understandability and readability with six volunteer K–6 teachers, we came up with a version that was then transferred on an iPod™ app designed by Logiciels Systamex and used under license for this research. The iPod version was tested again for readability, after which some questions and answers were further modified to fit the device's small screen. The final questionnaire contained 31 questions and multiple-choice answers and took about 10 minutes to complete on a regular iPod. Typically, respondents would read a question, answer by touching the screen to check one or more answers provided, and then touch an arrow at the bottom of the screen to move to the next question. Normally, respondents should not have been able to skip questions without answering them first, but five respondents did just that with several questions, although we are unsure as to how this happened (these five respondents used different iPods thus excluding a software or hardware glitch on a particular device). In the analysis, the skipped questions were labeled as "No answer."

Once the questionnaire was completed on an iPod, the data was stored in the memory until the device was connected to a computer; the data was then automatically downloaded and added to an Excel™ spreadsheet for further analysis. All figures presented in this paper were created with Excel using various statistical functions to sort and arrange the data.

Note that for several questions in our survey, more than one answer was possible, for example, grades taught (those who taught different grades could check several boxes). When presenting our findings, we always show the percentage of all respondents who chose each particular answer, which explains why the sum of percentages is sometimes greater than 100. Some questions asked respondents to state their level of agreement with a given statement or their level of satisfaction about a certain situation. In these cases, we used an even-numbered Likert scale, thus avoiding neutral options (i.e., more or less agree, more or less satisfied) and forcing respondents to commit to a clear judgment. Grondin & Blais (2010) have shown that including a neutral answer could skew the results towards the middle of the Likert scale. So, for instance, when asked what importance they attach to a series of statements about their goals and objectives in teaching astronomy, respondents could choose between "Very important," "Important," "Not important," and "Not at all important." A neutral answer like "More or less important" was not provided.

METHODOLOGY

To collect data for this survey, we took 13 iPods (loaded with the survey app) to the annual AQEP convention held at Québec City's Palais des Congrès on December 12 and 13, 2013. The AQEP is Québec's K–6 teachers association, not a union, made up of 54% K–6 in-service teachers and 42% undergraduate students in K–6 education. Exactly 1,000 people attended the 2013 convention in Québec City (76.8% of them K–6 teachers, and 91.9% women). Sixty-two percent were returning participants. According to the convention organizers, the demographic, socioeconomic, and professional profiles of the AQEP members closely resembled Québec's K–6 teachers (Loïc Fauteux-Goulet, AQEP, 2014, personal communication). Although this statement should make us confident that our sample is representative of Québec's K–6 teachers in general, it is possible that sampling bias affects our results. We hope to be able to conduct the same survey online in the near future with more K-6 teachers to validate this claim.

Our survey respondents were personally greeted by the author or an assistant (an undergraduate K–6 education student) either at the Centre des Congrès coffee shop or at the entrance of the vendors exhibit hall—two spots with heavy traffic all day. Teachers were asked to take a short, 10-minute survey about science teaching. They were immediately assured that the survey was entirely anonymous and that there would be no way of identifying them afterwards or of linking them to their survey answers. The only constraint imposed on respondents was that they had to be an in-service K–6 teacher (part- or full-time) at the time they took the survey (2013–2014 school year) or during the previous school year (2012–2013). This included in-service K–6 teachers and university students in K–6 education on internship programs, but excluded vendors, pedagogical counsellors, school administrators, and others not in direct contact with children in classrooms.

We collected data from 138 teachers, i.e., 18% of all primary and elementary school teachers in attendance (768 of the 1,000 attendees). Even though this represents a convenience sample, we calculate a margin of error at 90% confidence using the approximate formula for random samples, i.e. $0.82 \div \sqrt{N}$ (Howell, 1998). With N = 138, the margin of error of our survey is slightly below 7% ($p < 0.1$).

We recognize that our sample is relatively small compared with the total number of K–6 teachers attending the 2013 convention (768) and compared with the number of K–6 teachers in Québec (27,369 in 2012–2013 according to MELS, 2013, p. 5). As we will also analyze the data for subgroups in our sample (for instance, teachers who teach astronomy, i.e., a subgroup of 59 individuals), thus increasing the margin of error, we chose to broaden the confidence interval of our survey to 90%, effectively reducing the margin of error. As we analyze the results of our survey in the following sections, we will concentrate on results and differences that reach well beyond the margin of error. We also recognize the limited power to generalize our results beyond our sample to the general population of Québec’s K-6 teachers, due to the nature or our sampling method (convenience sampling). We hope that a future online survey with the same instrument and more respondents will help us solidify this aspect of our work.

In retrospect, we realize that it would not have been physically possible to have more survey respondents during the two-day convention because of the one-on-one nature of the collection method (briefly explaining the goal of the survey, obtaining written consent from each participant, explaining how to use the iPod, and allowing respondents enough time to answer the entire survey). There were also periods when most attendees were in session, grinding the collection process to a halt. But meeting the teachers in person (as opposed to an online or mail survey) came with the bonus of casual conversations about astronomy and science teaching, pre- and in-service training, and other practical considerations about the obstacles to teaching Québec’s science and technology curriculum in primary and elementary schools—subjective information that confirmed anecdotally many insights and conclusions that will be presented at the end of this paper. In the future we may try to use these in a more acceptable qualitative research way.

SURVEY RESULTS

In the following section and subsections, we will present the findings of our research, covering each survey question. We will analyze the results in a later section.

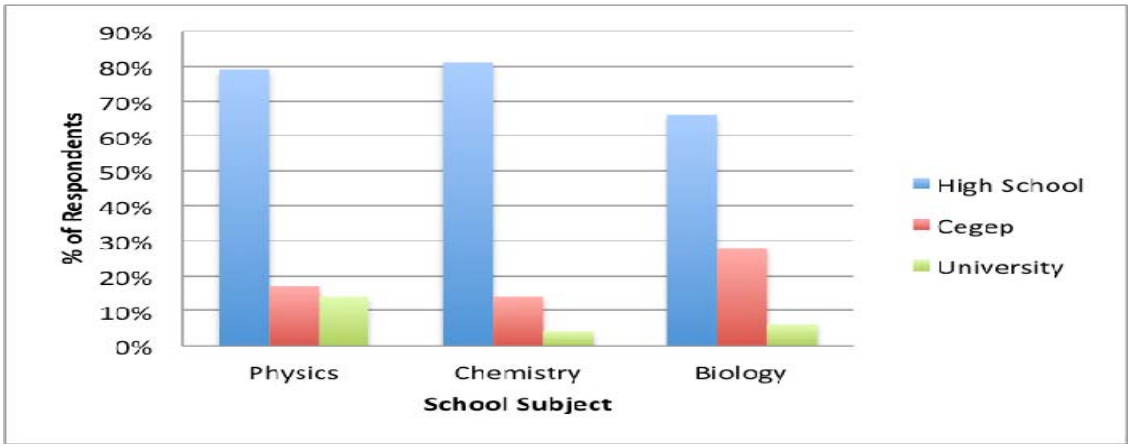
Demographics, Education and Experience in Science and Technology, and Astronomy and Science Teaching

Demographics: Who is a typical K–6 teacher in Québec?

Based on the demographic data for the 138 survey respondents, a typical K–6 teacher in Québec is a woman (92%), aged between 25 and 44 years old (70%), whose highest level of education is a four-year Bachelor’s degree in education (B.Ed.) (83%). The typical K–6 teacher in our survey has 1-10 or 11-20 years of teaching experience (36% and 48% respectively), works full time (91%), and teaches a class of 16 to 25 students (69%); they are distributed evenly between grades 1 to 6. The typical K–6 teacher works in a school in an urban or suburban area (73%) where the Index of socio-economic background (ISEB[2]) is evenly distributed between 1 and 10, 1 being the most favoured and 10 the least favoured. It is interesting to note that one respondent out of five did not know their school's ISEB.

Québec K–6 teachers' science and technology education and employment experience.

We asked respondents to indicate the last time (school year or grade) they studied the following six subjects: history, geography, math, physics, chemistry, and biology. According to the results, most teachers stopped studying science after secondary (high) school (79% for physics, 81% for chemistry and 66% for biology, see Figure 1a), whereas history and geography studies (Figure 1b) continued after secondary school, indicating a postsecondary[3] education in the humanities rather than in science and technology. Note that Figures 1a and 1b use the same vertical scale for ease of comparison.



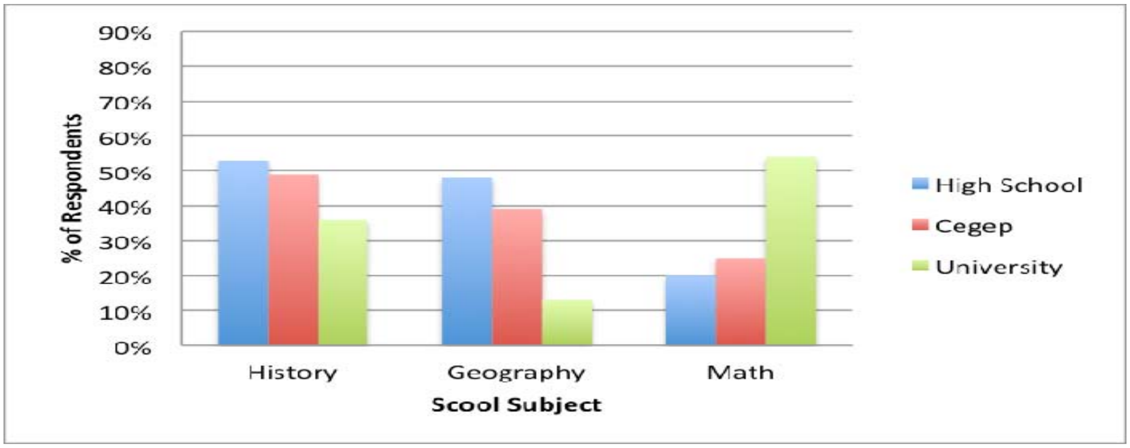


Figure 1. Last grade in which survey respondents studied physics, chemistry and biology, (top, 1a) and history, geography and math (bottom,1b). (Note: Cegep is a preparatory two-year education taken before entering university.)

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[2] The Index of socio-economic background (ISEB) is composed of two variables, the low education of the mother and the unemployment of the parents, which emerged as the strongest predictors of children's academic difficulties (MELS, 2014).

[3] In Québec, high school graduates typically do two years of pre-university study at Cegep (Collège d'enseignement général et professionnel [College of general and professional education]) before moving on to university.

We also asked respondents if they had any science and technology-related employment experience before, during, or after their K–6 education. Possible answers included science museum, lab work, engineering, agriculture, mines and fisheries, R&D, S&T research and S&T library. The answer was a resounding No (91%), with only 4% having worked in a science museum, and even fewer choosing other possible science and technology-related jobs.

Science teaching in the classroom.

When asked how many hours of science they teach each week, 17% of respondents said that they do not teach science in the classroom at all (see Figure 2) or do so less than one hour a week (30%); however, 49% still say they teach 1 to 2 hours of science a week. A small fraction of respondents teach more than 3 hours of science per week.

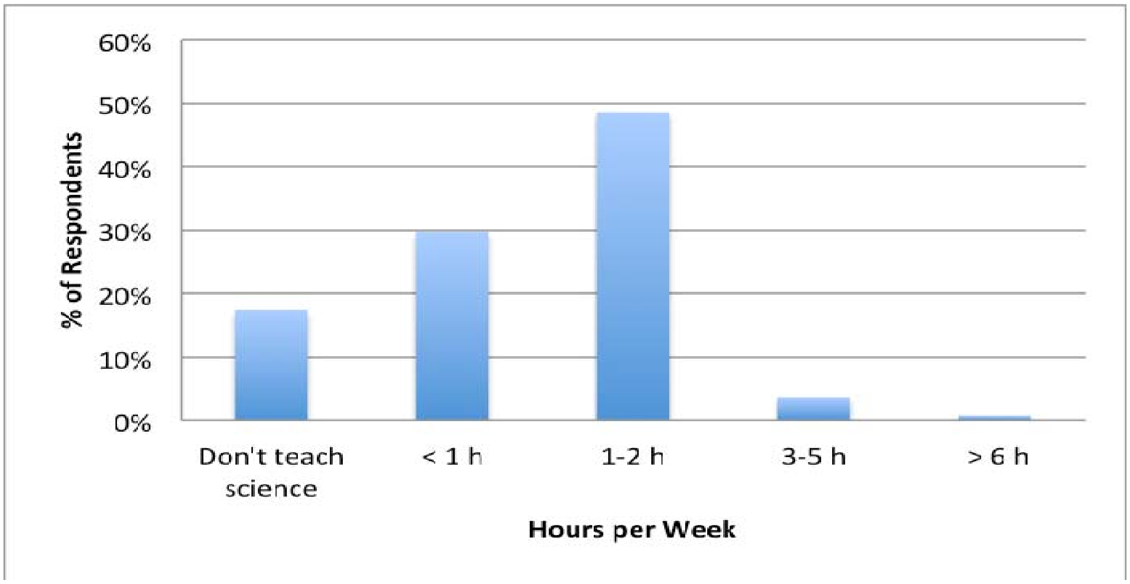

Figure 2. Number of hours survey respondents teach science every week in their classroom.

The Case of Astronomy Teachers

We asked all 138 survey respondents if they taught astronomy in their classrooms; 59 of them (43%) answered Yes, a result that surprised us as we were expecting a much lower number. Nonetheless, 57% of K–6 teachers who took our survey admitted to not teaching astronomy to their students, so there is still work to be done to increase this number. In this section, we will present the answers to a series of questions (questions 14 to 23 in our survey) that only targeted individuals who teach astronomy in their classrooms (other respondents skipped directly to question 24 if they answered No to the question about astronomy teaching). With $N = 59$, the margin of error for results in this section is 11% ($p < 0.1$).

Number of astronomy teaching hours per year.

First, we asked astronomy teachers how many hours they spent per school year teaching this subject in their classroom. Most astronomy teachers teach this subject less than 10 hours per year (78%, Figure 3). Breaking down this last result, we find 8% of respondents teach astronomy less than an hour per year, 42% teach between 2 to 5 hours yearly, and 27% between

6 and 10 hours. In fact, exactly half of the astronomy teachers in our survey teach less than 5 hours of astronomy per school year.

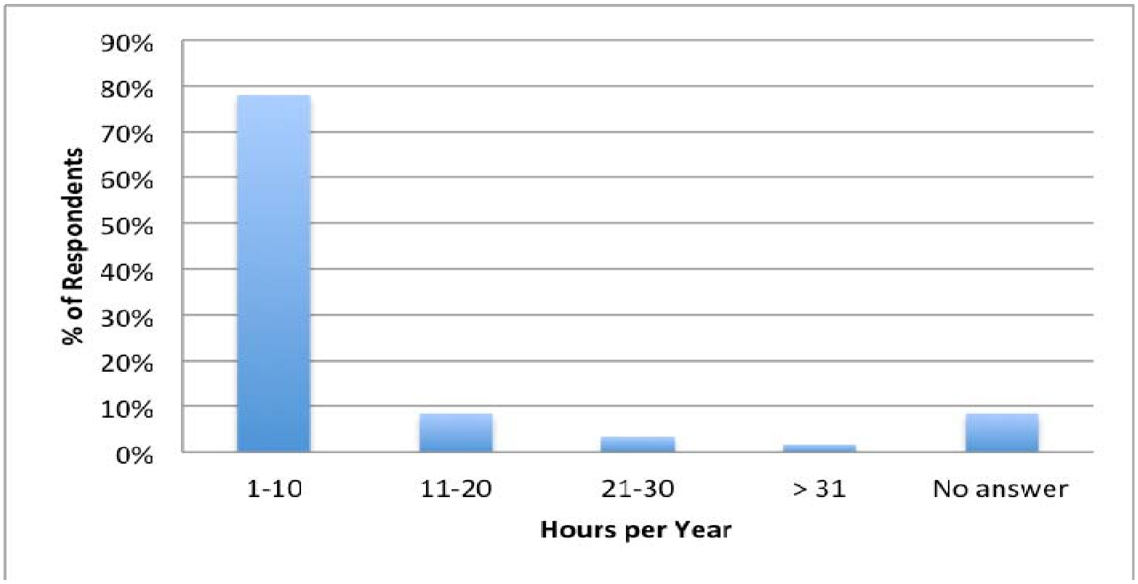

Figure 3. Number of hours survey respondents who teach astronomy do so every year.

Subject integration.

Next, we asked astronomy teachers if they taught astronomy as a stand-alone subject or by integrating it into another subject, like French, math, art, etc. Twenty-one teachers answered that they integrate astronomy into another subject (the margin of error for this result is quite large at 18%, $p < 0.1$). Since respondents could choose more than one answer, the total of percentages is larger than 100; each percentage represents the fraction of 21 respondents who chose each particular answer. Most respondents answered that they cover astronomy content in French courses (76% of 21 respondents) or the arts (29%). Integrating astronomy into math (19%) or computer science (10%)—a choice that would seem more natural since both subjects are closely related to science and technology—were not among the most popular answers. Other possible answers were ethics and religion (5%) and geography and history (5%); English as a second language, dance, music and physical and health education were not chosen by any respondent.

Essential knowledge in astronomy.

Next we asked teachers which elements of essential knowledge in astronomy they taught in their K–6 classroom. The results in Figure 4 show the list of essential knowledge presented earlier in Table 1 in order of descending popularity among respondents, who were allowed to choose as many elements of essential knowledge as they wished. Thus, the results in Figure 4 show the percentage of the 59 astronomy teachers who chose each element of essential knowledge. The most popular subjects listed were those that are also probably the most popular among K–6 students, namely the Sun-Earth-Moon system (chosen by 71% of astronomy teachers) and the solar system (64%), with Earth's rotation (59%) and the seasons (47%) close behind. At the bottom of Figure 4, we find Earth, atmospheric and space technologies (chosen by only 8% of astronomy teachers) and observation instruments (5%), which fared less well.

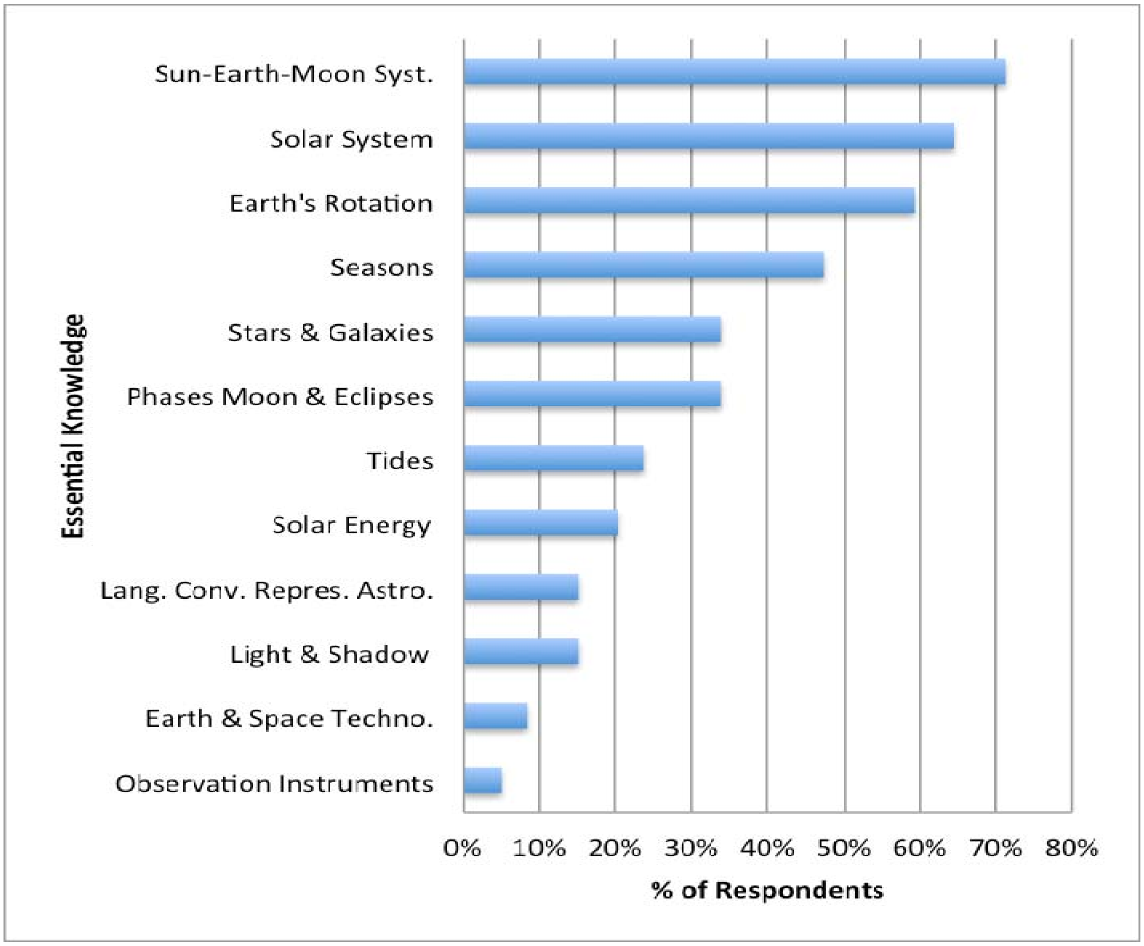

Figure 4. Percentage of astronomy teachers who teach each Essential knowledge in astronomy in Québec's Primary and Elementary Curriculum.

Goals and objectives for teaching astronomy.

We asked astronomy K–6 teachers how much importance they placed on a number of goals and objectives for astronomy teaching. For each goal and objective proposed, respondents had to choose between very important, important, not important, and not very important. To calculate the results presented in Figure 5, we combined the number of very important and important answers and divided them by 59 (the number of astronomy teachers) before converting the result into a percentage. The results in Figure 5 represent the goals and objectives in descending order with those considered very important or important *by the majority of surveyed astronomy teachers* at the top. Figure 5 shows that developing a scientific attitude among students (chosen by 96% of astronomy teachers), helping them understand astronomical concepts (86%), developing their know-how in astronomy (85%), and understanding the importance of astronomy in their lives (83%) were considered very important or important by a majority of astronomy teachers. Developing subject-specific competencies in science and technology (80%) and teaching essential knowledge in astronomy (75%), the official tasks assigned to K–6 teachers by Québec's curriculum, came up close to the top as well. But discovering the tools and applications of astronomy—goals and objectives that could be considered more practical—were considered very important or important by less than half of astronomy teachers (47% each), whereas developing reading/writing skills fared much better at 59%.

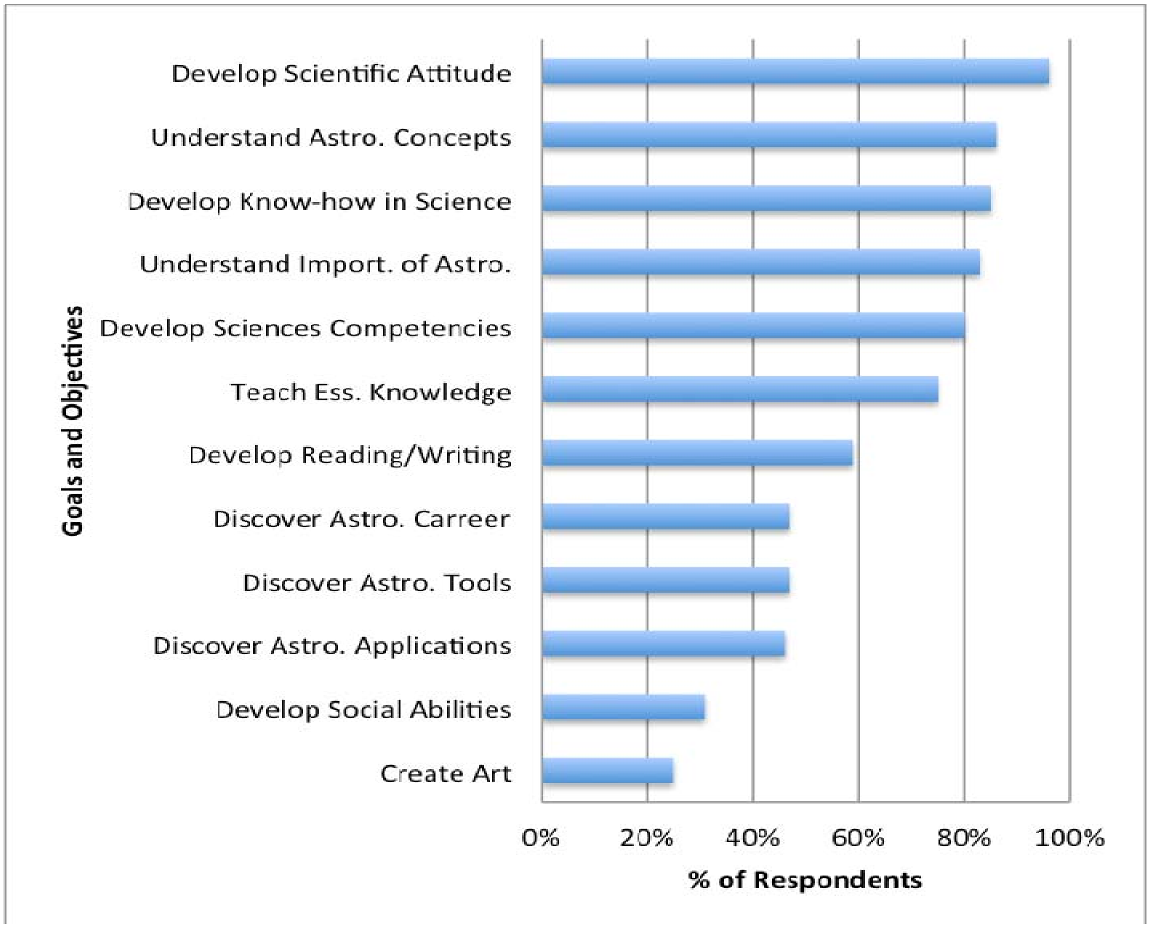

Figure 5. Percentage of astronomy teachers who consider listed goals and objectives for teaching astronomy to be very important or important.

Difficulty in teaching astronomy.

When asked if they encounter any difficulties teaching astronomy, 17% of astronomy teachers said they encounter none at all (Figure 6). For the majority of astronomy teachers in our survey, the biggest obstacles were their perceived lack of experience and training in astronomy teaching (chosen by 58% of astronomy teachers), the lack of resources available for astronomy teaching (47%), and their perceived incompetence in the subject matter (36%). The feeling of not having enough time to teach astronomy (31%)—often because the class needs to devote more time to French and math (the only two subjects tested province-wide in grades 4 and 6)—and the lack of adequate space to teach astronomy (22%)—for instance, a classroom that can be made completely dark by blocking the windows—were present but less so. A lack of interest from students and a lack of support from the school were definitely not factors.

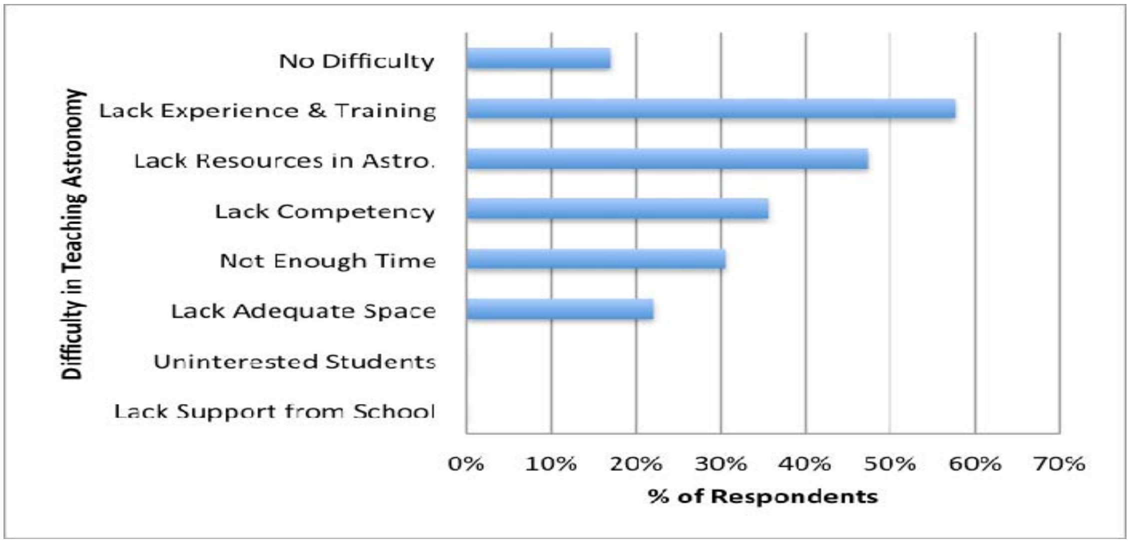

Figure 6. Astronomy teachers' perceived difficulties in teaching astronomy.

Resources available for astronomy teaching.

We wanted to know what resources, if any, astronomy teachers use to teach astronomy to their students. For this question, teachers could choose as many answers as they liked. The results are shown in Figure 7. The good news is that only 3% of astronomy teachers claimed to have absolutely no resources at their disposal for teaching astronomy. It is also interesting to note that the top four resources used by astronomy teachers consist of reading material, i.e., the Internet (chosen by 71% of astronomy teachers), books (58%), textbooks (46%), and newspapers and magazines (36%). Binoculars and telescope (15%), government documents (7%) and planetarium software (2%) seemed to be much less available.

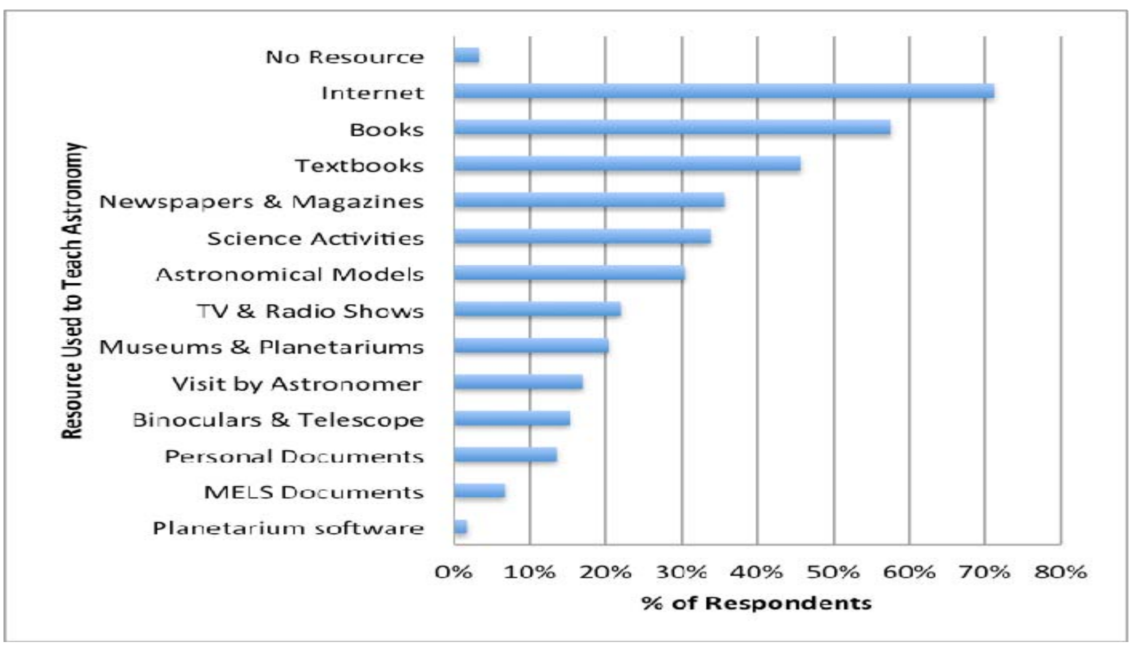

Figure 7. Percentage of astronomy teachers who use listed resources to teach astronomy.

Classroom arrangements and available equipment and materials.

We asked astronomy teachers to describe their classroom arrangements and the equipment and materials available to them for astronomy teaching. For both questions, respondents could choose more than one answer. Classrooms equipped with audio-visual equipment (the reality for 53% of astronomy teachers) and ordinary classrooms (46%) clearly dominate (see Figure 8). Very few teachers have access to a special room for demonstrations and experiments (12%) and even fewer have access to a proper science laboratory (8%). As for the equipment and materials, it seems that the few available (an answer chosen by 25% of astronomy teachers, see Figure 9) are considered in poor condition and outdated (chosen by half of the astronomy teachers). Again, we see that planetarium software is not widely used (3%). As shown in Figure 10, when asked how they would describe the overall quality of resources and equipment available to them for astronomy teaching, respondents answered mainly poor (42%). Note that, in this case, we made an exception and added a neutral choice ("fair") to this question.

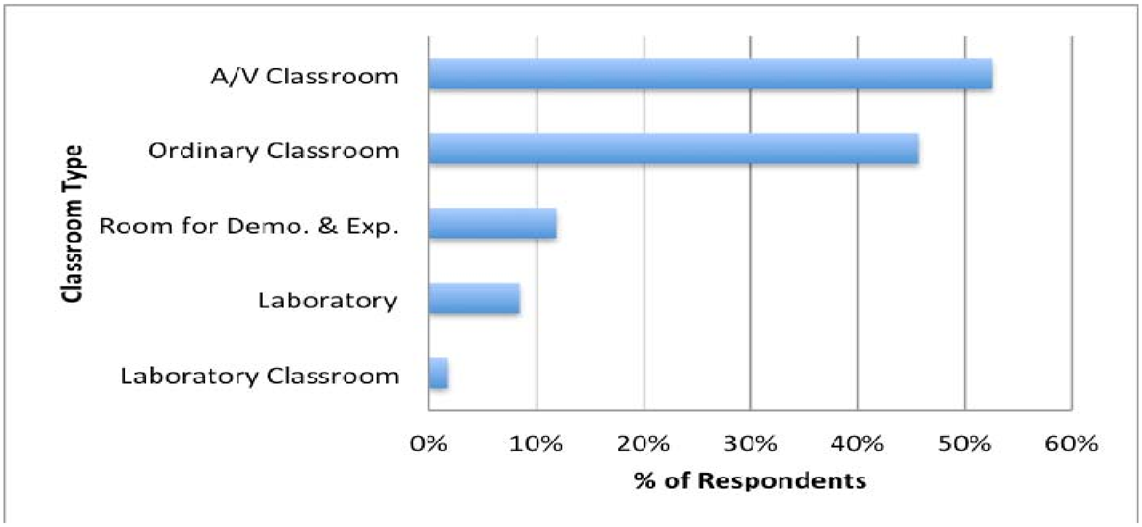

Figure 8. Type of classroom where astronomy teachers teach astronomy.

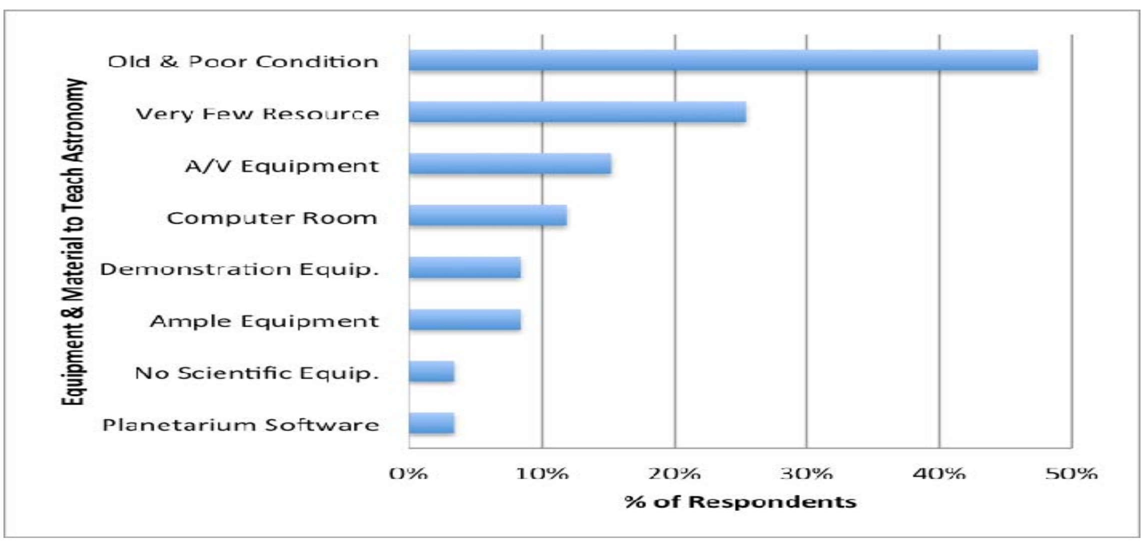

Figure 9. Equipment and material used by astronomy teachers to teach astronomy.

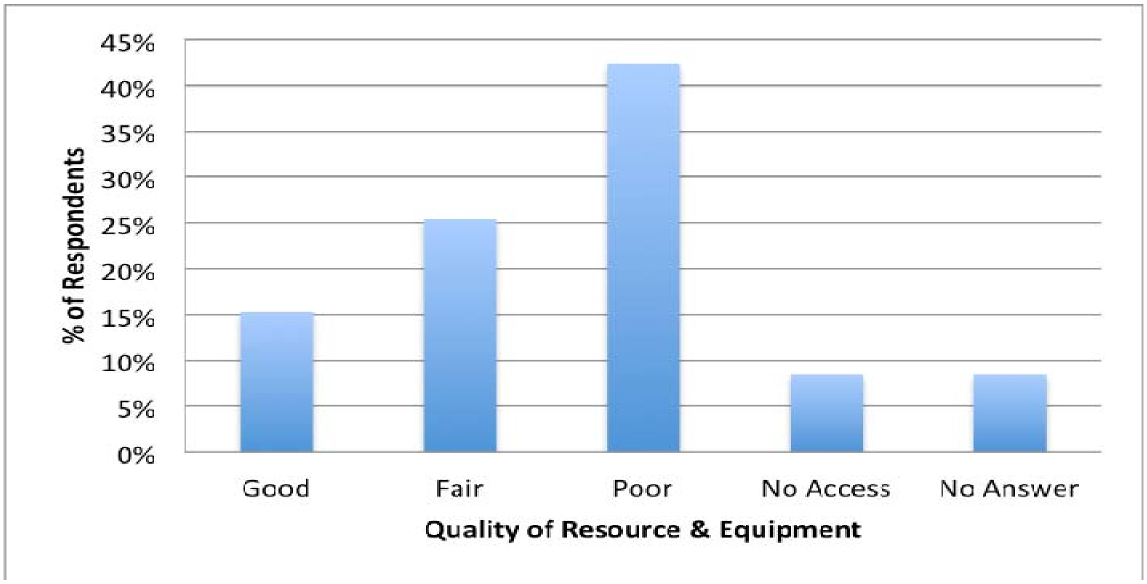

Figure 10. Astronomy teachers' estimation of the overall quality of resources and material available to them to teach astronomy.

Pre- and In-serviceTraining in Astronomy and Science

In this section, we will present the results of the final series of questions (questions 24 to 31) that were asked to all 138 respondents (the margin of error is 7% at $p < 0.1$). These questions touched on various aspects of their pre- and in-service training in astronomy, science, and science teaching.

Satisfaction with pre-service training.

We asked all respondents how they would rate their satisfaction with their pre-service training in astronomy, science, and science teaching (science didactics). The results, as shown in Figure 11, are worrying; not only was the pre-service training in astronomy, science, and science teaching considered unsatisfactory or very unsatisfactory by most K–6 teachers who answered our survey (46%, 69%, and a combined 64% unsatisfied and very unsatisfied answers, respectively), but a large fraction of them (47%) had no astronomy training at all. This confirms our initial assumption, as stated in the introduction, that most in-service K–6 teachers who began their careers before or soon after astronomy was added to the curriculum had no astronomy training at all.

Type and availability of in-service training in astronomy, needs of K–6 teachers.

Figure 12 shows the answers given when respondents were asked what type of in-service training in astronomy was available to them (multiple answers were possible). For most, in-service training in astronomy consisted mainly of meetings and conversations with colleagues (chosen by 43% of 138 respondents) or no training at all (30%). What's more, as shown in figure 13, in-service training in astronomy seems to be rather ineffective (24% said training was ineffective or very ineffective) when available (70% did not have access to any form of training in astronomy).

Figure 11. Survey respondents' level of satisfaction with their pre-service training in astronomy, science, and science teaching (science didactics).

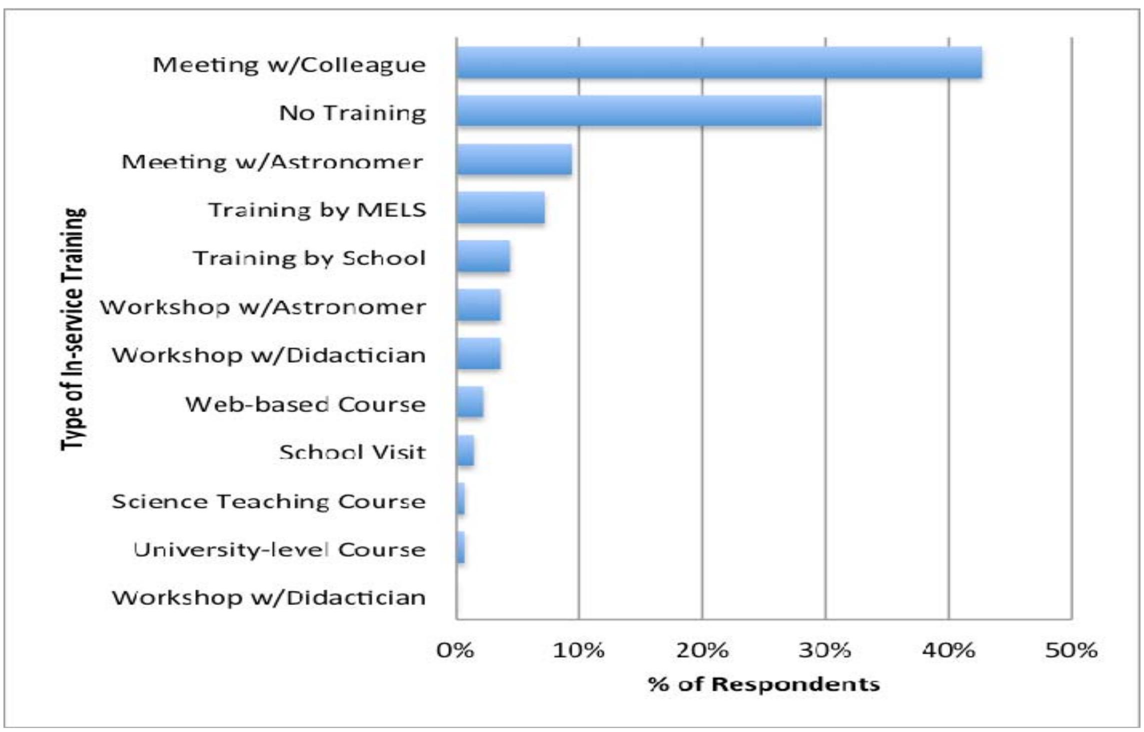

Figure 12. Type of in-service training in astronomy available to survey respondents.

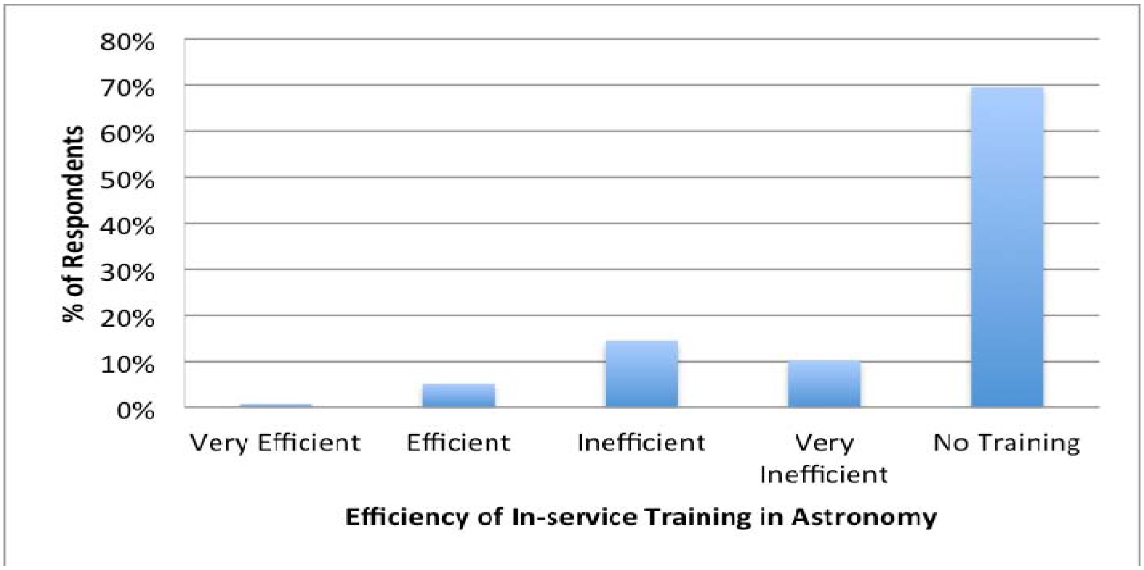

Figure 13. Survey respondents' perceived efficiency of in-service training in astronomy, when available.

Type and availability of in-service training in astronomy, needs of K–6 teachers.

As shown in Figures 12 and 13, there is an obvious need for in-service training in astronomy for K–6 teachers. We asked respondents how many hours of in-service training they felt they needed to confidently teach astronomy to their class and when this training should be offered. Figures 14 and 15 show the results to these two questions.

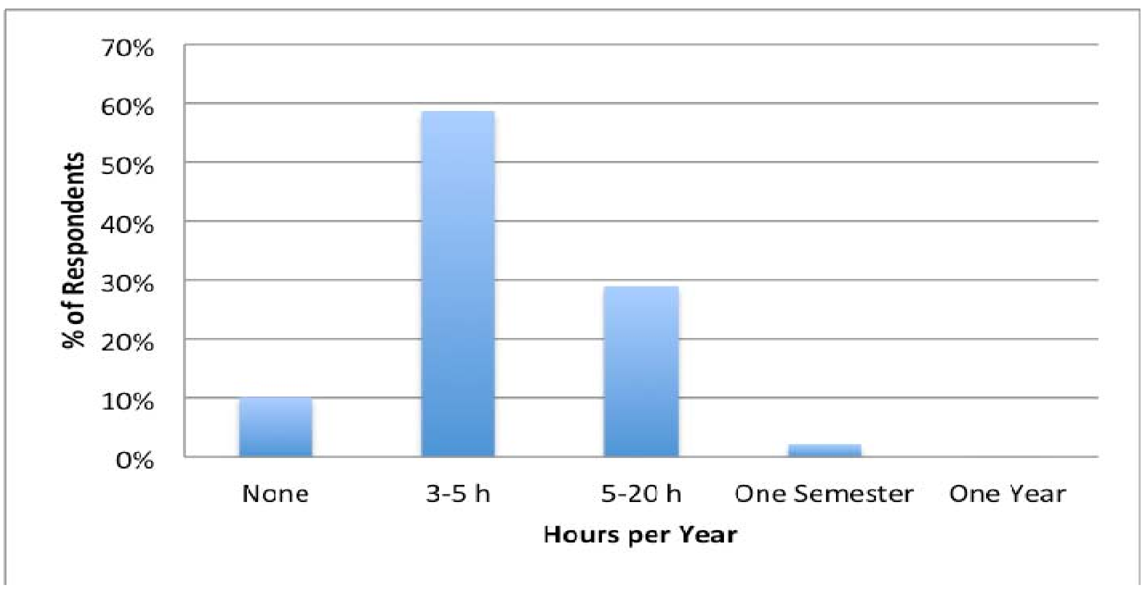

Figure 14. Number of hours of in-service training per year survey respondents feel they need in order to be able to confidently teach astronomy to their classroom.

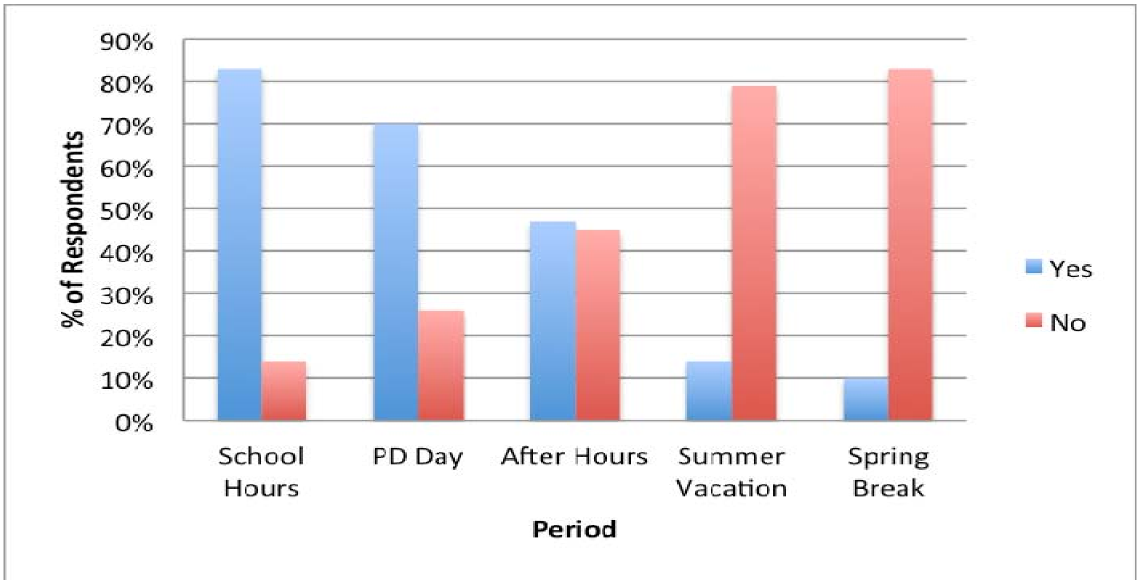

Figure 15. Best time for in-service training in astronomy to be offered, according to survey respondents.

It appears that most respondents would be satisfied with an astronomy course of 3 to 5 hours (59%) that would be offered during school hours with a substitute teacher taking care of their class (83%) or during professional development days (70%). Not as many Québec teachers would be willing to participate in trainings scheduled for evenings (47%), spring break (14%), or summer vacation (10%).

Would you rather not teach astronomy at all?

Lastly, we asked all survey respondents if, given the choice, they would rather not teach astronomy at all. Twenty-eight said Yes (20%), 76 answered No (55%), and 34 said they didn't know (25%). We then asked the 62 respondents who answered Yes or "I don't know" why they would prefer not to teach astronomy (multiple answers were possible). With N = 62 and the margin of error 10% ($p < 0.1$), it comes as no surprise that the most common answers were poor pre-service training (chosen by 45% of the 62 ambivalent teachers, see Figure 16), a lack of resources (42%), and the lack of in-service training (37%). All the other reasons and explanations presented in Figure 16 seemed irrelevant in comparison. The real challenge will be finding ways to address the three main reasons invoked.

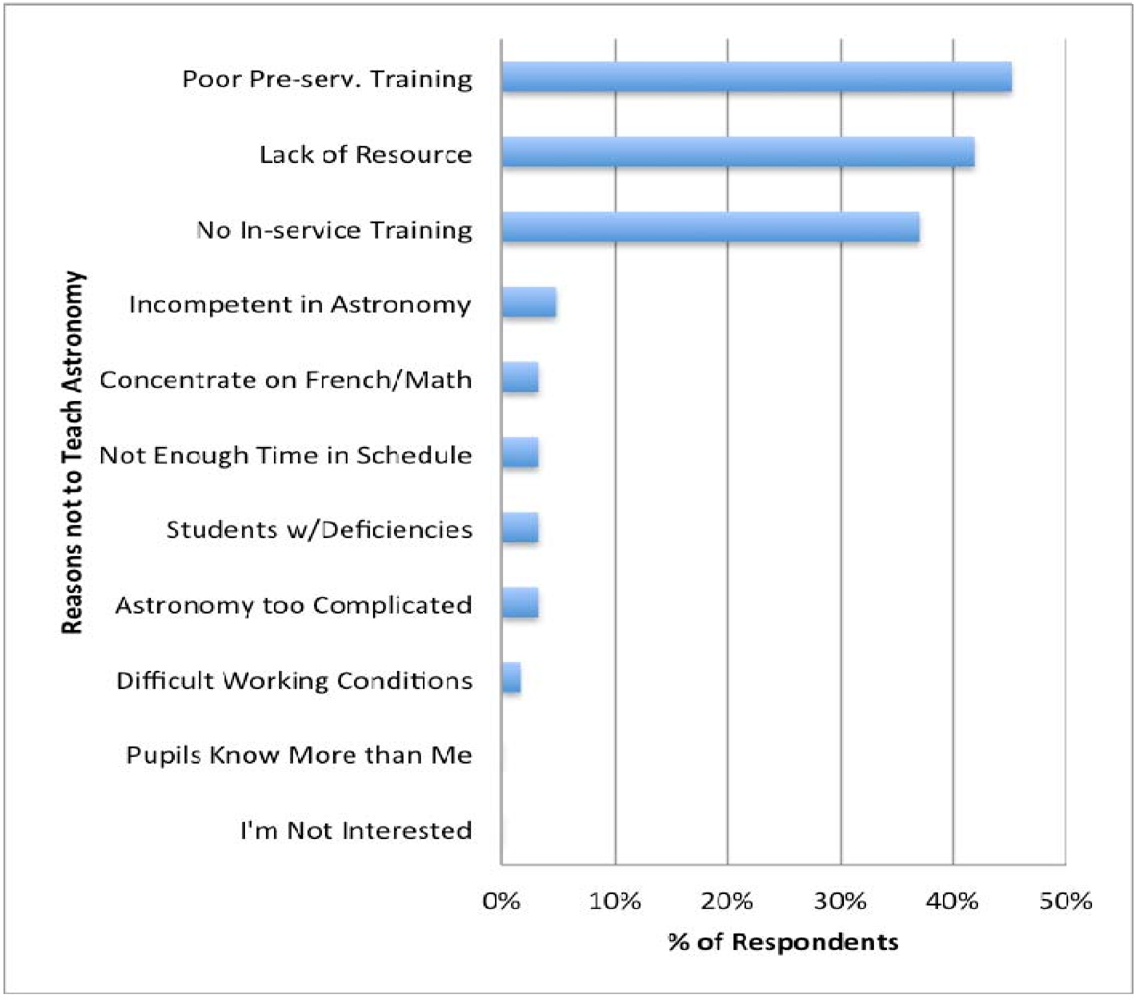

Figure 16. Reasons why survey respondents would rather not teach astronomy in their classroom.

A Comparison of Astronomy and Non-astronomy Teachers

Next, we wanted to find out if the answer profiles for the questions completed by all 138 survey respondents (questions 1–13 and 24–31) would be different for astronomy and non-astronomy teachers. We hoped to use these differences to identify key characteristics of astronomy teachers that could be promoted to and developed by non-astronomy teachers to improve astronomy teaching in Québec's primary and elementary schools. Unfortunately, the large margin of error (7% at $p < 0.1$ for $N = 138$) made it impossible to make any statistically significant comparison for most answers. We hope that by adding more respondents to our survey through the online version, we can reduce the margin of error and further explore the differences between both groups. That being said, the results for a few questions were beyond the margin of error. We discuss these below.

Grades taught.

Figure 17 presents a comparison between astronomy and non-astronomy teachers according to the grades they teach. We see a clear drop in the proportion of astronomy teachers

(5% astronomy teachers versus 17% non-astronomy) in grade 4. This could be due to the province-wide unified tests in French and math that are administered near the end of the school year to all grade 4 classes. Fourth-grade teachers could be forsaking astronomy to focus on the basics, i.e. French and math, to make sure their students pass the tests. To a lesser extent, the same phenomenon might be at play in grade 6 (7% astronomy versus 12% non-astronomy), at which time a unified test in French is also administered at the end of the school year, but the difference here is too small compared with the margin of error for our survey. Note that Québec's primary and elementary schools do not have a unified test in science and technology.

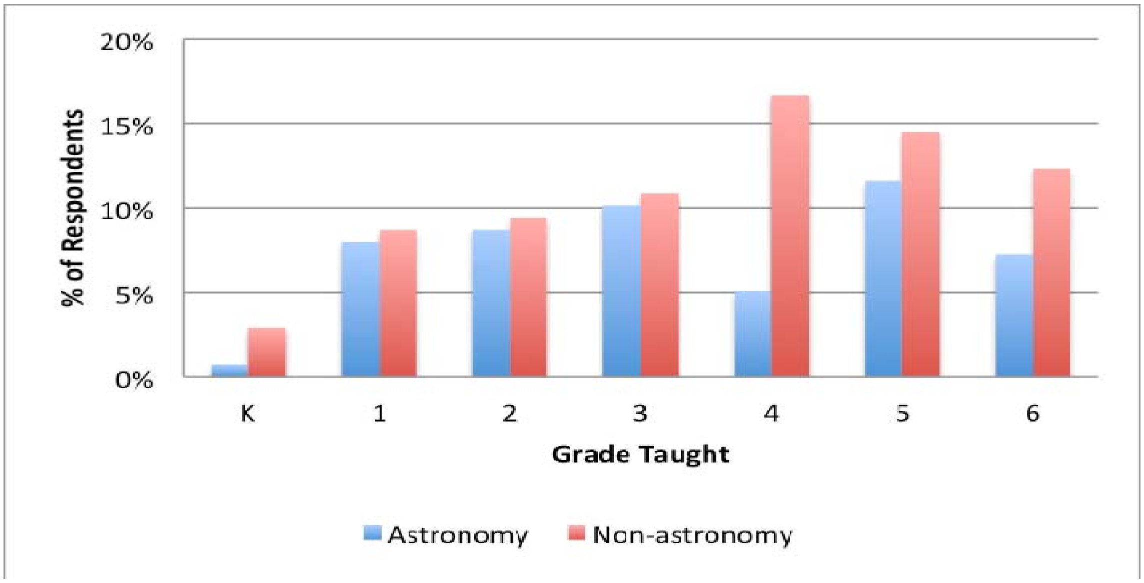

Figure 17. Percentage of astronomy and non-astronomy teachers among survey respondents according to the grade they teach.

Class size.

One would not expect there to be any differences between astronomy and non-astronomy teachers based on class size, but Figure 18 shows there is a clear drop in the number of astronomy teachers with classes of 16 to 20 students (8% versus 25%). In Québec's K–6 schools, the maximum class size for regular classes ranges from 22 (grade 1) to 26 (grade 6) (MELS, 2013) but drops to 20 (grades 1 to 6) for underprivileged classes or groups with disabilities. Therefore a class with 20 or fewer students probably serves more children with special needs than a regular class. In this case, the teacher might choose to concentrate on the basics (such as French and math) and not teach subjects considered less useful to get past K–6 school (such as science and astronomy). On the other hand, private schools (which often pick and choose the best students and serve a more privileged population) usually have larger classes than public schools (sometimes up to 30) and propose a richer curriculum that may include more science and, therefore, more astronomy. This would explain why non-astronomy teachers lead when the number of students is between 11 and 20, whereas we find the reverse for classes with 21 or more students. More respondents would be required to lower the margin of error for these results to determine whether or not these differences are significant.

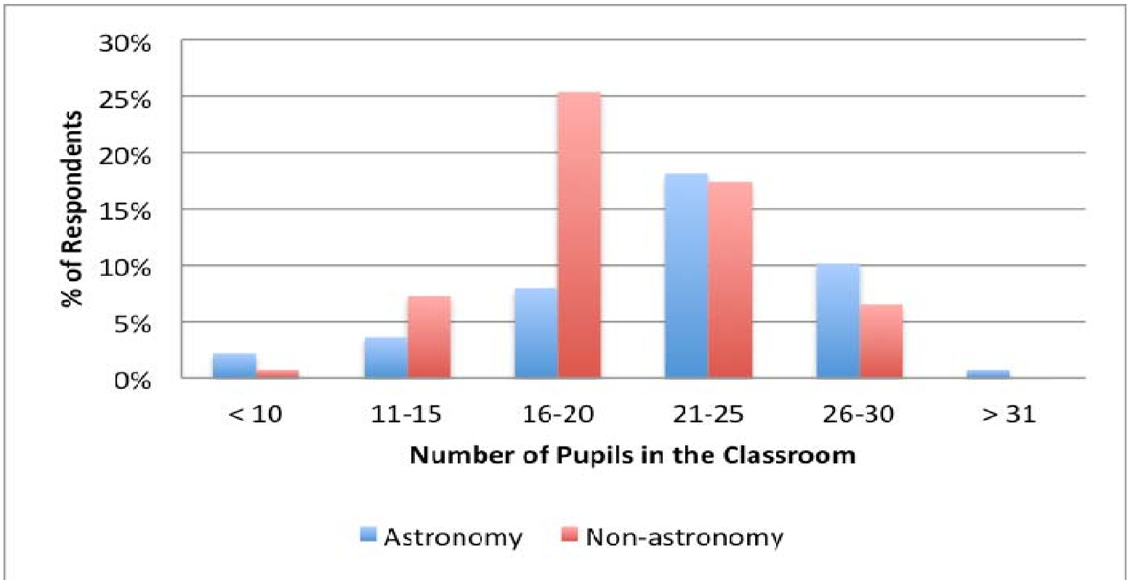

Figure 18. Percentage of astronomy and non-astronomy teachers among survey respondents according to the number of pupils in the classroom.

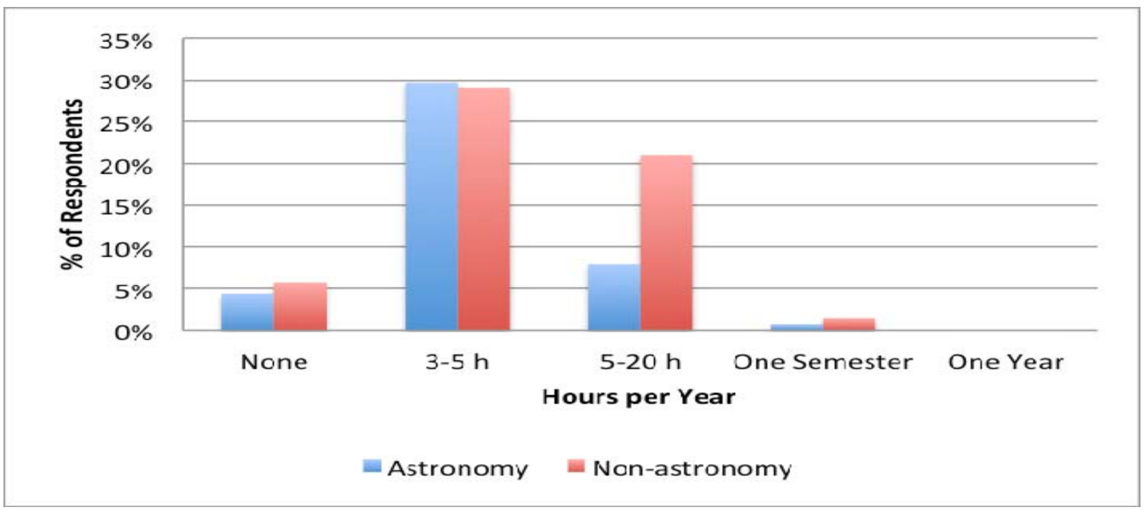

Figure 19. Percentage of astronomy and non-astronomy teachers among survey respondents according to the number of hours of in-service training in astronomy needed to teach astronomy confidently in their classroom.

K-6 teachers' in-service training needs.

Figure 19 shows that more non-astronomy than astronomy teachers (21% versus 8%) feel they need 5 to 20 hours of training in astronomy—a result that should come as no surprise since these teachers certainly feel they need more time to learn the basics than those who teach it already. Overall, however, more astronomy *and* non-astronomy teachers think that with 3 to 5 hours of training, they would be better prepared to teach astronomy (30% and 29%, respectively). This is encouraging since providing 5 hours of astronomy training to an in-service teacher, for example, during a PD day, is far less costly and much easier than planning a

20-hour affair. So there is hope that this kind of in-service training could be created and delivered rapidly to Québec schools.

Would you rather not teach astronomy at all?

The final comparison between astronomy and non-astronomy teachers looks at whether they would rather not teach astronomy at all if given the choice. Figure 20 shows that an almost equal percentage of astronomy and non-astronomy teachers answered No to this question (28% and 27%, respectively) but twice as many non-astronomy teachers answered Yes or "I don't know." There are even larger differences between the two groups when we consider the reasons why a teacher would prefer not to teach astronomy. Figure 21 shows the data for the top four reasons why teachers would rather not teach astronomy as identified earlier in Figure 16. For non-astronomy teachers, it is a lack of resources (chosen by 34% of ambivalent teachers), the lack of in-service training in astronomy (31%), and the ineffectiveness of their pre-service training in astronomy (26%) that justify why they would rather not teach astronomy. Most astronomy teachers say it is due to the ineffectiveness of their pre-service training in astronomy (19%). As expected, a few non-astronomy teachers (5%) blame their incompetence in astronomy on why they would rather not teach astronomy.

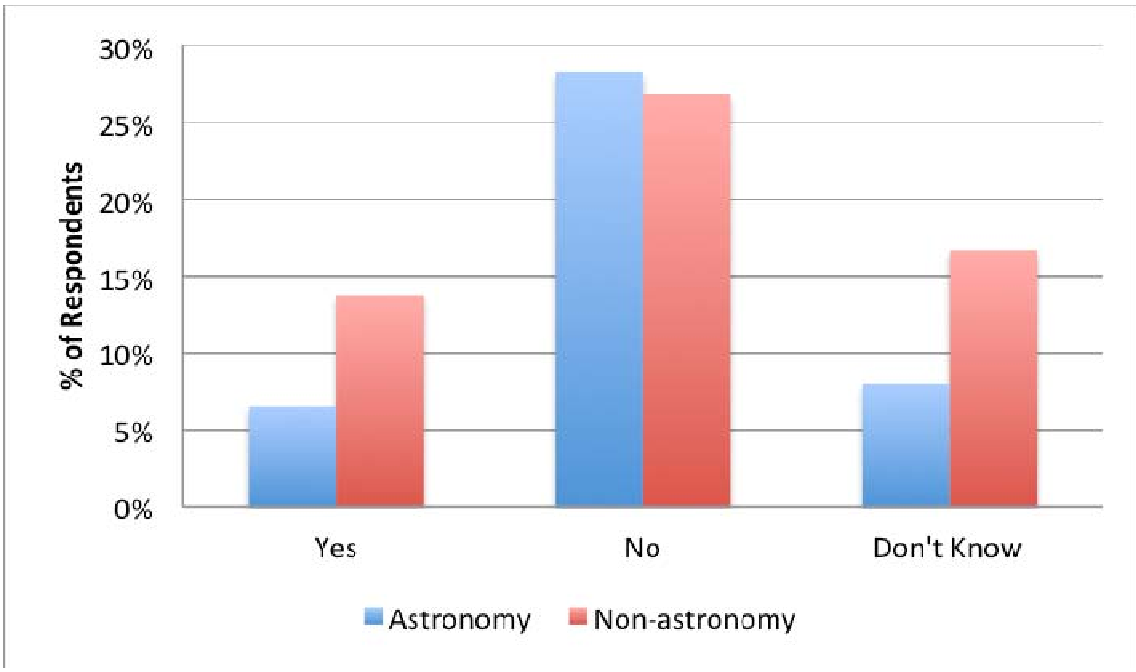

Figure 20. Answers of astronomy and non-astronomy teachers to the question "Would you rather not teach astronomy in your classroom if you had the choice?"

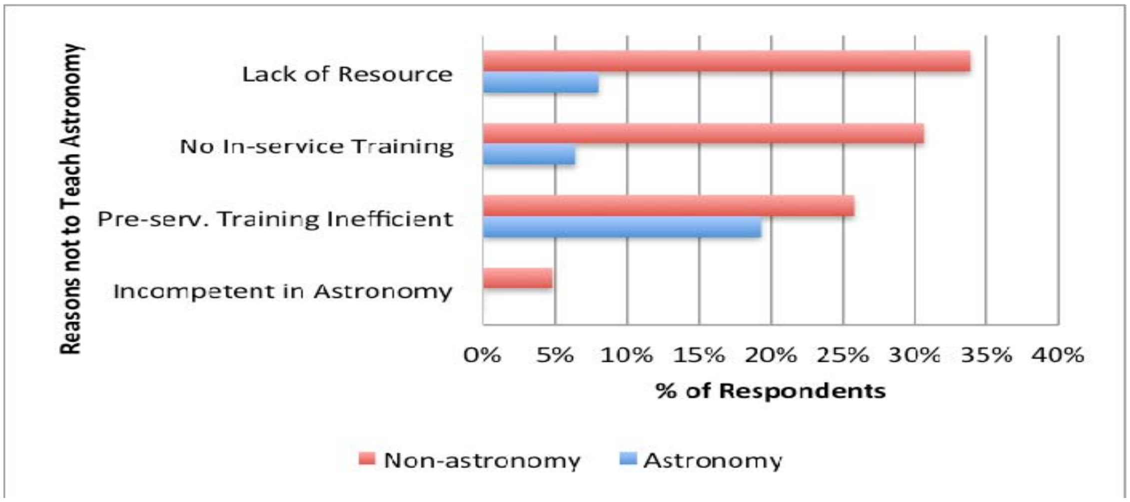

Figure 21. Reasons why astronomy and non-astronomy teachers would rather not teach astronomy in their classroom.

RESULTS ANALYSIS

In this section, we will review the findings presented earlier and use them to describe, as accurately as our sampling procedure and the margin of error allow, the current state of astronomy teaching in Québec's primary and elementary schools.

In terms of demographics, our sample of K–6 teachers is predominantly middle-aged females with 11–20 years of experience. These are the same demographics as AQEP members and convention participants (AQEP 2014, personal communication). The vast majority hold a B.Ed., which is the minimum requirement for a K–6 teaching license in Québec. Only 17% of respondents have a higher degree (M.Ed. or equivalent), and none of the 138 respondents have a Ph.D. This is understandable as there is no financial incentive for Québec teachers to go beyond a B.Ed.; experience is the only factor when determining wages.

Approximately half of the respondents teach classes with less than 20 students (special-needs students) while the other half teach classes with more than 21 students (regular classes, private schools) in urban or suburban schools, also representative of the overall makeup of Québec's primary and elementary schools (MELS, 2013). The respondents were also evenly distributed across the grade levels (17% of respondents teaching grade 1 and 26% teaching grade 5), the only exception being kindergarten, taught by only 4% of our respondents. Comparing our results with the annual reports from MELS and AQEP's demographics makes us confident that our sample, although relatively small, is representative of Québec's K–6 teachers. While we will only consider results that are clearly beyond the margin of error affecting our data, we believe that the analysis below gives a clear portrait of astronomy teaching in Québec schools.

Our results with respect to K–6 teachers' interest in science and technology and S&T-related employment experience tell the story of primary and elementary teachers who have little interest in the subject, and thus probably a low level of science literacy. Our survey did not ask K–6 teachers about their S&T culture or interest in science and technology specifically, and this is something we will certainly want to add to our online version. However, the fact that most K–6 teachers did not study science beyond high school and have no background in S&T might help explain why there are so many who admitted to not teaching science in class or to doing so less than one hour per week, and why close to 60% of respondents said they do not teach astronomy in the classroom. You cannot give what you do not have, and as long as K–6 teachers are not encouraged (or forced, for instance, with a university course in science literacy) to develop their own scientific culture, the state of science and astronomy teaching in Québec schools is bound to remain problematic.

There is also a worrying possibility that our survey *overestimates* the number of K–6 teachers who teach science in the classroom. This could be the result of social desirability bias, the tendency of respondents to answer questions in a way that will be viewed favourably by others (in this case, the researcher, who is also a well-known astrophysicist and science populariser in Québec, or the undergraduate student). Since participants were told from the start that the survey was about their science and astronomy teaching practices, some may have wanted to embellish their accomplishments in that particular field. On the other hand, respondents were told that the questionnaire was completely anonymous so social desirability bias might not have been much of a factor after all. The online version of this survey (to be conducted at a later date) might show whether or not social desirability bias was at play.

It must also be said that most K–6 teachers in Québec are generalists, teaching all subjects on the curriculum to the same class all year long, and will often choose to teach subjects that they themselves are interested in or are comfortable with. Some schools have a teacher who specializes in science and meets with each class for about an hour a week, often in a laboratory classroom. In our survey, these individuals would have responded that they teach science more than 6 hours per week (see figure 2). The fact that only 1% of respondents gave that answer is a sign that these K–6 science teachers are rare in our sample, and probably in all of Québec schools.

As for astronomy teaching, we were pleasantly surprised by the number of respondents who said they teach some astronomy to their classes, even though it represents less than half the teachers surveyed and leaves much room for improvement. Here also, there is the possibility of desirability bias. One might question the *type* of astronomy teaching happening in Québec schools, given that half of these astronomy teachers devote less than five hours per year to this subject. One has to wonder what can be covered in so little time, and how. For instance, five hours does not seem like enough time to observe and record the phases of the Moon over the course of a month before studying the lunar phases, or to follow where the Sun rises and sets on the horizon and to measure the length of shadows at noon for a few months before discussing seasons. Initiating the study of astronomical phenomena with real sky observations (or simulations using planetarium software) and hands-on manipulation of observation instruments and models is considered by many to be the best way to teach astronomy (Hobson, Trundle, & Saçkes, 2010; Kavanagh, Agan, & Sneider, 2005; Sneider, Bar, & Kavanagh, 2011; Trundle & Bell, 2003). Five hours a year does not seem to allow enough time to do that in any meaningful way.

To the contrary, there is much evidence in our data that astronomy teaching in Québec is based mainly on using reading material. For example, when astronomy is integrated into other subjects, the vast majority of teachers chose language (French). The study of Earth and space technologies and the use of observation instruments, which are indicative of a desire to use more practical approaches to teach astronomy, were popular with less than 10% of respondents. In terms of goals and objectives, discovering the tools and applications of astronomy was chosen by less K–6 teachers than developing reading/writing skills. Finally, the resources most used by primary and elementary astronomy teachers are Internet, books, textbooks, and newspaper and magazines, whereas binoculars, telescope and planetarium software were far less popular. Interesting resources such as listening to a TV or radio show, viewing a planetarium show, and listening to a talk by an amateur or professional astronomer visiting the classroom fell somewhere in between, but placed students in a more passive role. Again, we see no signs of activities that encourage students to observe the real sky (or a simulated version, using planetarium software) or manipulate astronomical instruments. These are all indicative of astronomy teachers mostly using reading material in a magisterial approach to teaching, instead of observations and modeling of astronomical phenomena, an observation also previously made by Allard and Boucher (1991), Kikas (1998), Couture (2002) and Minier and Gauthier (2006) in similar situations.

Among the major obstacles encountered by astronomy teachers when trying to teach this subject are a lack of experience and training in astronomy teaching, a lack of resources, and their perceived incompetence in the field, as well as a lack of time and adequate space. Some teachers feel pressured to devote more time to French and math, the only two subjects that are tested province-wide in grades four and six. This situation might be detrimental to science and astronomy teaching, as we have seen in comparing the data collected from astronomy and non-astronomy teachers of the same grades (Figure 17). In terms of classroom arrangements, very few astronomy teachers have access to more than an ordinary classroom with audio-visual material and the few resources available are mostly old and in poor condition. These difficulties are not easily solved. Classroom arrangements and resources cost money to fix and require a huge investment of public money. As for the perceived lack of time, one way to insist on the importance of science teaching in K–6 schools would be to introduce a mandatory province-wide science test in grades 5 or 6, as is done in Alberta in grade 6, a proposition made by Québec's Conseil supérieur de l'éducation in 2013. This would also help convince teachers with special needs students that science teaching is as important a subject as French or math.

Teacher training, experience, and competency in teaching astronomy in K–6 classrooms are the remaining obstacles. Théoret (2009) found that K–6 teachers generally demonstrate a certain reluctance to teach science since they feel they did not receive proper training through pre-service courses or in-service training. These fears should be easier to address but our data shows that the actual situation is far from ideal. For K–6 teachers, pre-service training in astronomy, science and science teaching was mostly unsatisfactory; what's more, pre-service training in astronomy was non-existent for half of the respondents. Unfortunately, in-service training does not seem to remedy the situation, as our data shows that training programs are mostly considered to be ineffective or non-existent. Yet, a majority of K–6 teachers feel that 3–5 hours of in-service training during class time or a PD day would give them the tools and skills they need to teach astronomy to their students. High quality in-service training would also answer the concerns of those who said that, if given the choice, they would rather not teach astronomy in their classroom.

CONCLUSION AND FUTURE RESEARCH

This paper presents the results of a survey conducted among Québec primary and elementary (K-6) school teachers during the two-day AQEP convention in Québec City in December 2013. Our goal was to document the current state of astronomy teaching in Québec's primary and elementary schools (K-6 classrooms) by asking teachers about their experience with science and astronomy courses, their practice of science and astronomy teaching, their goals and objectives in teaching astronomy, their attitude toward astronomy teaching, the resources and material they used, their perceptions of the quality of pre- and in-service training, and their needs in terms of in-service training in astronomy.

The research was conducted in person by the researcher and an undergraduate student. The participants were asked to answer the 31-question survey using a regular iPod. The questionnaire was completely anonymous and took about 10 minutes to answer. In total, we were able to gather 138 completed questionnaires in a convenience sample. A comparison of the demographics of our survey with data from the AQEP (personal communication) and the Ministère de l'Éducation, du Loisir et du Sport (MELS, 2013) indicate that our sample seems to be representative of the overall makeup of the province's primary and elementary school teachers, an assumption that we will want to confirm by conducting a larger, online survey in the near future.

Our general conclusion is that, despite unsatisfactory or absent pre- and in-service training in astronomy and science, despite outdated and poor equipment and resources, and despite a self-perceived incompetence at teaching astronomy, a surprisingly large number of K–6 teachers in Québec do teach astronomy and science to their students, although there is room for improvements. In practice, though, astronomy teaching in Québec schools seems to rely heavily on written material and not on observations of the actual sky or simulated astronomical phenomena, nor on the use of observing equipment and models. Among the possible solutions to this problem, we suggest better pre-service training in astronomy, science (including a university course in science literacy), and science teaching, better in-service training in the form of annual teachers' development workshops (3–5 hours), and access to better equipment, resources and specially equipped classrooms.

We also think that the importance of science and astronomy as teaching subjects in K-6 schools should be raised by a number of political and curricular measures, as suggested by the Conseil supérieur de l'éducation in its 2013 Report. These include making time allocated to science and technology mandatory across grades K to 6 (for instance, one hour a week or bi-weekly) and introducing a mandatory province-wide science and technology test (perhaps in grade 5) similar to Alberta's Provincial Achievement Test in Science conducted in grade 6 (CSE, 2013).

Although the conclusions we reach are only representative of the situation in Québec K–6 schools, they are similar to the results in the study on science teaching in K–6 classrooms conducted by Rowell and Ebbers 10 years ago in Alberta's elementary schools, as well as the 2012 National Survey of Science and Mathematics Education for elementary schools in the United States. This should come as no surprise, since the demographics from these two studies are quite similar to our own, and the curricula in Québec and Alberta are comparable. More surprisingly, we found similar conclusions and remedial propositions in a review of astronomy education in American schools done by Bishop (1977) almost forty years ago. We did not expect as many similarities with the other American studies cited earlier, as most of them were conducted in high schools where teacher demographics, classroom arrangements, and curricular resources are generally quite different from our own study. But there are still similarities, for example the rarity of in-service training found by Krumenaker (2009a), and the fact that astronomy is often dropped from the curriculum to make room for more language and math courses in underprivileged or underperforming schools (Krumenaker, 2009b), a situation similar to what we saw in our data when we compared grade 4 astronomy and non-astronomy teachers where astronomy teaching declined probably because of the province-wide tests in French and math.

As for the survey instrument that was developed for this research, we are generally satisfied with its use, and it is our intention to create an online version that we hope will be completed by more teachers, either through AQEP membership, school boards (with special permission) and/or MELS. Our goal is to reduce the margin of error to about 3% (N = 600, approximately) to allow a meaningful comparison between astronomy and non-astronomy teachers. In the present situation, comparison was not possible for many questions because the differences were smaller than the margin of error, but we think such comparisons could offer useful insights. We will also add more precise questions about the respondents' scientific culture and, when asked to specify a number of hours, years, students, etc., we might allow them to directly enter a numerical value on the keyboard, instead of forcing them to choose between pre-formatted answers.

Finally, we hope to repeat the survey 5 to 10 years from now to document the changes in the state of astronomy teaching in Québec's primary and elementary schools when more teachers who trained *after* astronomy was added to the curriculum will have reached 10–20 years of experience in K–6 teaching. We also hope that the findings of this research lead to better pre- and in-service training in astronomy and science, better resources and equipment, and more appropriate classrooms to teach astronomy in K-6 classrooms. A longitudinal study would document the effects of these new measures on the state of astronomy teaching in primary and elementary schools in Québec.

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APPENDIX

Questionnaire (for iPod)—English version

1. Do you agree to participate in this research that questions you about your teaching practice in astronomy and in science in primary and elementary school? Your answers are completely confidential and anonymous.
   a) Yes (Go to question 2.)
   b) No (You're done! Thank you for your cooperation.)

2. You are...
   a) A woman
   b) A man

3. What age group do you belong to?
   a) 18-24 years old
   b) 25-34 years old
   c) 35-44 years old
   d) 45-54 years old
   e) 55-64 years old
   f) 65 years old and over

4. How many years of experience do you have teaching primary and elementary school, including the present school year, either part-time or full-time?
   a) Less than a year
   b) 2-5 years
   c) 5-10 years
   d) 11-20 years
   e) 21-30 years
   f) More than 30 years

5. What is the highest level of education you have completed?
   a) B.Ed.
   b) DESS[4]
   c) M.Ed.
   d) Ph.D.

6. Indicate the highest level in which you have taken courses in the following disciplines:

a) Mathematics	High school	Cegep[5]	University
b) Physics	High school	Cegep	University
c) Chemistry	High school	Cegep	University
d) Biology	High school	Cegep	University
e) History	High school	Cegep	University
f) Geography	High school	Cegep	University

[4] DESS (Diplôme d’études supérieures spécialisées) is a post-Bachelor degree, equivalent to a M.Ed., but without a thesis.
[5] Cegep (Collège d’enseignement général et professionnel) is a two-year preparatory school before entering university.

7. What grade(s) do you teach during the current school year? Mark as many as necessary.
   a) Kindergarten
   b) Grade 1
   c) Grade 2
   d) Grade 3
   e) Grade 4
   f) Grade 5
   g) Grade 6

8. How many students attend your class during the current school year? If you teach several different classes, indicate the average class size.
   a) Less than 10 students
   b) 11-15 students
   c) 16-20 students
   d) 21-25 students
   e) 26-30 students
   f) More than 30 students

9. You teach…
   a) Full time
   b) Part time

10. What is the Index of Socio-Economic Background (ISEB) of the school where you teach? Enter a number from 1 to 10 (Note: 1 = most favoured school, 10 = most disadvantaged school). If you do not know your school's ISEB, enter 0. ___________

11. What best describes the neighbourhood where your school is located?
    a) Urban (i.e. large city)
    b) Semi-urban (i.e. suburb, small and medium municipality)
    c) Rural (i.e. village)
    d) Remote area (i.e. fishing, mining or lumber towns)

Note: The following questions relate to your teaching activities carried out during the last full school year (2012-2013) and from September 2013 to the present (current 2013-2014 school year).

12. In your estimation, how many hours **per week** do you spend teaching science in your class?
    a) I do not teach science in my class
    b) Less than one hour per week
    c) 1 to 2 hours per week
    d) 3 to 5 hours per week
    e) More than 5 hours per week

13. During the period described above (2012-2013 school year and from September 2013 to the present), did you teach any essential knowledge in astronomy in your class?
    a) Yes (Go to question 14.)
    b) No (Go to question 24.)

14. If you have taught essential knowledge in astronomy in your class, was it mostly by integrating it into other subjects (i.e. French, math, arts, etc.) or separately as an autonomous subject?
    a) Integrated with other subjects (Go to question 15.)
    b) Separately as an autonomous subject (Go to question 16.)

15. With what subject(s) have you integrated your astronomy teaching? Mark as many as necessary.
    a) French
    b) English
    c) Mathematics
    d) Geography, history and citizenship education
    e) Drama
    f) Arts
    g) Dance
    h) Music
    i) Physical and Health Education
    j) Ethics and Religious Culture
    k) Information and communication technology

16. Among all the essential knowledge in astronomy listed below, which one(s) have you taught to your class? Mark as many as necessary.
    a) Light and shadows
    b) The Sun-Earth-Moon system
    c) Solar energy
    d) The Earth's rotation
    e) Tides
    f) The solar system
    g) Seasons
    h) Stars and galaxies (constellations)
    i) Earth, atmospheric, and space technologies
    j) Use of simple observation instruments (binoculars, telescopes, etc.)
    k) Use of appropriate terminology, conventions, and drawings for astronomy (terrestrial globe, star chart, etc.)
    l) Phases of the Moon and eclipses

17. In your estimation, how many hours **per year** do you spend teaching essential knowledge in astronomy in your classroom?
    a) Less than an hour
    b) 2-5 hours
    c) 6-10 hours
    d) 11-20 hours
    e) 21-30 hours
    f) More than 30 hours

18. How important are the goals and objectives listed below for the teaching of astronomy in your class? (1 = very important, 2 = important 3 = not important, 4 = not at all important). "I teach astronomy in my class to help my students..."

a)	Learn essential knowledge in astronomy	1	2	3	4
b)	Develop their competencies in astronomy and in science	1	2	3	4
c)	Understand key concepts in astronomy	1	2	3	4
d)	Develop their social skills	1	2	3	4
e)	Discover the tools of astronomy	1	2	3	4
f)	Develop their reading/writing skills	1	2	3	4
g)	Create art productions	1	2	3	4
h)	Develop their scientific attitude	1	2	3	4
i)	Explore careers in astronomy	1	2	3	4
j)	Discover the use and applications of astronomy in their lives	1	2	3	4
k)	Develop their expertise in science	1	2	3	4
l)	Understand the importance of astronomy in their lives	1	2	3	4

19. If you encounter difficulties in teaching essential knowledge in astronomy in your class, what are they? Mark as many as necessary.
    a) I have no difficulty teaching astronomy.
    b) There are not enough resources (books, demonstration equipment, astronomical instruments, etc.) available in my school.
    c) I don't have any experience or training in astronomy.
    d) I don't have access to a suitable classroom to do demonstrations/experiments in astronomy.
    e) My students show little interest in the subject of astronomy.
    f) I run out of time in the classroom schedule.
    g) I lack support from the school administration, the parents' committee, etc.
    h) I do not feel competent enough to teach astronomy to my students.

20. Among the resources listed below, which one(s) did you use in your teaching of essential knowledge in astronomy? Mark as many as necessary.
    a) Textbooks approved by MELS[6]
    b) Books, picture books, novels, science fiction books, etc.
    c) Websites
    d) Educational material found on the Internet (activity sheets, etc.)
    e) Newspapers and magazines (print or online versions)
    f) Visit to a science museum, observatory or planetarium
    g) Binoculars, telescope, star finder, sundial, etc.
    h) Amateur or professional astronomer visiting my classroom
    i) Television or radio show
    j) Astronomy software
    k) Scale models (Earth, moon globe, scale model of the solar system, etc.)
    l) Educational materials (texts, posters, PowerPoint presentations) that I have developed myself
    m) Documents from government, academic or business sources
    n) I have not used any of these resources

[6] Ministère de l'Éducation, du Loisir et du Sport, Québec's Ministry of Education.

21. Check the statement(s) that best describe the room where you teach astronomy to your students. Mark as many as necessary.
    a) A laboratory classroom designed for teaching science
    b) A classroom with access to a laboratory
    c) A classroom where I can do demonstrations or experiments using models
    d) A classroom with audio-visual aids (video projector, screen, etc.)
    e) A classroom offering no particular arrangement for teaching astronomy or science

22. Check the statement(s) that best describes the equipment (telescope, binoculars, globes, models, etc.) and the resources (activity sheets, astronomy software, etc.) that you use to teach astronomy to your students. Mark as many as necessary.
    a) There are plenty of equipment and resources for students and myself to use.
    b) The equipment we have access to is cheap, very old and in poor condition.
    c) There is almost no equipment and resources available in my school.
    d) I have access to appropriate equipment for classroom demonstrations.
    e) I have no access to scientific equipment in my school.
    f) I have access to audio-visual equipment in my classroom/at my school.
    g) I have access to a computer room.
    h) I have access to astronomy software.

23. In general, how would you describe the quality of the equipment and resources available to teach essential knowledge in astronomy in your class?
    a) Excellent
    b) Good
    c) Fair
    d) Low
    e) Poor
    f) I do not have access to equipment or resources for teaching astronomy.

Note: The following questions concern your education and pre-service training in astronomy and in science.

24. How would you describe the education that you received in the following subjects as part of your pre-service training (Bachelor of Education) to become a teacher?
    (1 = very satisfactory, 2 = satisfactory, 3 = unsatisfactory, 4 very unsatisfactory, 5 = I have not received any training in this subject)

a) Astronomy	1	2	3	4	5
b) Science (in general)	1	2	3	4	5
c) Science education or science teaching	1	2	3	4	5

25. In addition to your current teaching position, have you ever been employed in a scientific or technological job?
    a) No
    b) Yes, in a scientific library
    c) Yes, in a science museum
    d) Yes, in a laboratory
    e) Yes, in S&T research and development
    f) Yes, in basic research in science (medicine, biology, physics, chemistry, environment)
    g) Yes, in agriculture, fisheries or in mines
    h) Yes, in industry, including engineering

i) Yes, other

26. Indicate all in-service training activities in astronomy teaching that you have attended since becoming a teacher. Mark as many as necessary.
    a) Informal meetings with colleagues
    b) Informal meetings with university researchers in science education
    c) Informal meetings with amateur and/or professional astronomers or scientists
    d) Workshops presented by teachers/education consultants/MELS representatives
    e) Workshops offered by the school and/or school board
    f) Workshops presented by astronomers or scientists
    g) Workshops presented by academics in science education
    h) Workshops/training courses online (Internet)
    i) University courses in astronomy and in science
    j) University courses in science education for the teaching of astronomy and science (science education)
    k) Visits to other classrooms or other schools
    l) I have not participated in any in-service training activity in astronomy

27. How would you describe your level of interest in participating in in-service training activities in astronomy if they were offered in the following contexts:
    (1 = I would participate willingly, 2 = I would probably participate, 3 = I would probably not participate, 4 = I would definitely not participate, 5 = I do not know)

a) During school hours (with another teacher taking care of the class)	1	2	3	4	5
b) After hours class	1	2	3	4	5
c) Professional development day	1	2	3	4	5
d) Spring break	1	2	3	4	5
e) Summer vacation	1	2	3	4	5

28. How many hours of in-service training **per year** do you feel you need to develop, maintain or improve your astronomy teaching?
    a) None
    b) 3 to 5 hours per year (i.e. half-day workshop)
    c) 5 to 20 hours per year (i.e. a few days of training)
    d) A semester-long intensive course (i.e. university course)
    e) A full year without teaching (i.e. certificate or university degree)

29. How would you describe the in-service training program in astronomy offered by your school and/or school board?
    a) The program is very effective.
    b) The program is effective.
    c) The program is not very effective.
    d) The program is not effective at all.
    e) There is no such program.

30. If you had the choice, would you prefer not to have to teach astronomy in your class?
    a) Yes (Go to question 31.)
    b) No (You're done! Thank you for your cooperation.)
    c) I do not know (Go to question 31.)

31. If you would prefer not to have to teach astronomy in your class, please indicate the reason(s) for your choice. Mark as many as necessary.
    a) I do not have access to enough material and educational resources to teach astronomy.
    b) My initial training was inadequate for teaching astronomy.
    c) I have not received in-service training in astronomy since I became a teacher.
    d) Astronomy is of little or no interest to me.
    e) I think astronomy is too complex and challenging.
    f) Working conditions in my classroom are difficult.
    g) My class has several students with learning difficulties in basic subjects (French, math).
    h) I'm afraid of not being competent enough in astronomy to teach the subject well.
    i) I'm afraid that my students know more than me about astronomy.
    j) There is not enough time in my class schedule for teaching astronomy.
    k) I prefer to concentrate my efforts on core subjects (French, math, English).

Thank you very much for taking the time to complete this survey!

THE DEVELOPMENT OF A MINI-CELESTIAL SPHERE MODEL TO ENHANCE HIGH SCHOOL STUDENTS CONCEPTUAL UNDERSTANDING OF ASTRONOMICAL PHENOMENA

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Abstract: This study investigated the impact of The Mini Celestial Sphere Model (MCS model) on high school students' conceptual understanding of the celestial sphere, astronomy coordinate systems, the path of the Sun, and seasons. The MCS model was developed to enhance students' understanding of the apparent motion of celestial objects in relation to Earth's rotation on its axis. Ninety four high school students in Bangkok Thailand participated in an astronomy class for four weeks. A 5E learning cycle approach was used to facilitate students' use of the MCS model to explore astronomy concepts. Twenty items pre-posttest was used to assess students' conceptual understanding. Thirty students were interviewed before and after using the MCS model and were provided with a clear plastic dome to demonstrate their understanding during the interviews. The results indicated that prior to using the MCS model most of students held alternative concepts about the path of the Sun and seasons. After using the MCS model students' conceptions and understanding of all topics improved. Most of them could explain that the apparent motion of celestial objects is caused by the Earth's rotation on its axis and that the Sun's path change and seasonal change is caused by the Earth's tilted axis and its revolution around the Sun.

Keywords: astronomy - celestial sphere - hands-on models - high school student

INTRODUCTION

Traditionally, Thai education in astronomy was mostly neglected until 2001 when this subject was added to the National Science Curriculum (The Basic Education Core Curriculum A.D.2001) with strong support from the astronomy community. However, as a result, Thailand now faces a serious shortage in teachers capable of teaching astronomy, such that teacher training has become an important priority in the plans to further develop astronomy in Thailand (Kramer, 2007). In 2002, the Institute for the Promotion of Teaching Science and Technology (IPST), in cooperation with the Faculty of Science of Chiang Mai University, initiated the development of a teaching and learning of astronomy and space database. However, there remains a general lack of learning materials and resources to support the teaching and learning of astronomy at the secondary level in Thailand. Furthermore, in the 2001 Basic Education Core Curriculum most of the astronomy content was represented at the elementary level; only one chapter of the secondary level curriculum (grades 7-9) was devoted to Earth and space science. In grades 11-12 both science and non-

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science emphasis students were introduced to astronomy concepts in a small book that lacked depth and challenging content (Buaraphan, 2009; Soydhurum, 2004).

In 2008, the Thailand science standards curriculum (The Basic Education Core Curriculum A.D. 2008) was revised significantly. The new curriculum had major changes, especially in sub-strand 7, which emphasizes concepts related to astronomy and space. The new curriculum includes more astronomy concepts than the Basic Education Core Curriculum A.D. 2001. One topic in this sub-strand is the celestial sphere, including actual motions and relative positions of celestial objects. This curriculum document calls for students to be able to apply celestial motion ideas to explain the apparent daily motion of the Sun and sunrise and sunset positions, including an explanation of seasonal changes (IPST, 2008). As this is a new topic, one that Thai students have never studied before, it may be a challenge for students to develop deep understandings of these concepts.

Astronomy, being an abstract subject area, may not be easy to understand, and research has shown that even pre-service teachers and university students hold misconceptions or alternative conceptions related to astronomy concepts (Çelikten, İpekçioğlu, Ertepınar, & Geban, 2012). Trumper's (2001) studies with junior high school students suggest that some students believe that the Sun passes directly overhead every day. Plummer (2009a) found that most (90%) eighth grade students responded that the Sun's path is a straight path through the zenith. Trumper's (2000) investigation of university students' understandings of basic astronomy concepts found that students recognized the tilt of the Earth's axis relative to the plane of its orbit as the reason for the change of seasons. Still, they did not understand that this tilt also causes changes in the Sun's position in the sky at specific times of the day and year. The greatest proportion of students in Trumper's study (55.3%) believed the Sun to rise directly in the East. Trumper offered a probable explanation for this finding, suggesting that we teach that the Sun ‘‘rises in the East,’’ disregarding seasonal fluctuations resulting from the Earth's axial tilt. Accordingly, students in this study (47.4%) believed that the Sun is directly overhead every day. In another study Plummer (2009a) found no increase in level of accuracy in understanding of seasonal change and the Sun's path change in eighth-grade students compared with third-grade students. All of them described the Sun as having the same length of path in summer and winter.

An understanding of celestial motion is an essential ingredient to continued learning of other standard topics such as the seasons and the motions of the planets in astronomy. Plummer et al. (2010) found that when students do not hold scientific understandings or explanations of celestial motion it may impact their ability to learn more advanced topics such as the phases of the Moon and the seasons.

Scientific knowledge of apparent celestial motion includes an understanding of the Sun's apparent rising and setting motions across the seasons, the Moon's rising and setting motions, and the stars' rising and setting throughout the night. All of these motions can be explained by the slow rotation of the Earth on a daily basis (except for the change in the Sun's path across the seasons, explained by the Earth's tilt as it orbits the Sun) (Plummer, Zahm, & Rice, 2010). Celestial motion concepts may be too challenging to expect students to fully master at the secondary level. However, inquiry into astronomical phenomena has always been difficult in astronomy courses because an understanding of these phenomena relies on indirect experience and observations.

METHODOLOGY

Model-Based Reasoning in Science Education

Astronomers make sense of the world by looking for explanatory models to understand their observations, and describe and explain phenomena that cannot be experienced directly. Hansen et al. (2004) note that 3D computational modeling tools enable students to more easily visualize, manipulate and establish a context for their learning, and enable them to learn by interacting with their model, their peers, and the instructor.

Modeling activities have become more commonplace in inquiry-based science classrooms, because educators have recognized that an important activity of scientists is building, designing, testing, and evaluating models of natural phenomena (Hestenes, 1987). Crawford and Jordan (2013) note that through the act of modeling, the learner can develop intellectual ownership. Taylor et al. (2003) explain how the building of mental models is a developmental process in which learners come to understand the scientists' viewpoint and then repeatedly critique the model's ability to explain and predict related subordinate concepts.

In addition to engaging students in the design process of constructing models to understand phenomena, educators also use existing models as instructional tools to foster students' comprehension of complex concepts. Astronomers have always used physical models to understand phenomena and to transmit that understanding to others. Barab et al. (2000) found 3-D models to be an effective tool that has supported students in developing deep understandings about various astronomical phenomena. Ruangsuwan and Arayathanitkul (2009) found that a low-cost celestial globe helped high school students describe the position of celestial objects and their motion due to the rotation of the Earth; this globe was also used to demonstrate the relationship between the equatorial coordinate and horizontal coordinate systems, and the rising and setting of the stars, and circumpolarity. Passmore et al. (2010) point out that engaging students in model-based inquiry presents an authentic context that requires them to make connections and use one set of ideas to lead them in their investigation of new ideas, and is useful in developing explanations for patterns in the natural world.

In the current study the researchers designed their own instructional model to help students understand celestial motion as viewed by observers on the Earth. This model can be used to guide students' understanding of the Sun's path change, sunrise and sunset position change, and the cycle of seasons as observed at different locations on the Earth. In this paper we focus on the effects of using the novel handheld Mini-Celestial Sphere model (MCS model) to enhance high school students' conceptual understanding. We examine students' conceptual understanding of four foundational astronomical concepts: the celestial sphere, astronomical coordinate systems, the apparent motion of the Sun, and seasons.

Context of the Study

Three high schools in the Bangkok metropolitan area, Thailand, served as the context for investigating the efficacy of the Mini-Celestial Sphere Model (MCS model, see Appendix A) as an instructional tool for fostering students' understanding of astronomical phenomena. Participants in the study included 94 high school students (61 girls and 33 boys) enrolled in an astronomy course that met for 3 hours each week for four weeks. In this course, students explored the concepts of celestial sphere, astronomical coordinate systems, apparent motion of the Sun, and seasons. They used the MCS model to discuss and explain their observations through a 5-E inquiry process (see Appendix B). The study was guided by the following research questions:

In what ways does the MCS model foster high school students' conceptual understanding of the celestial sphere, including astronomy coordinate systems, path of the Sun, and seasons?

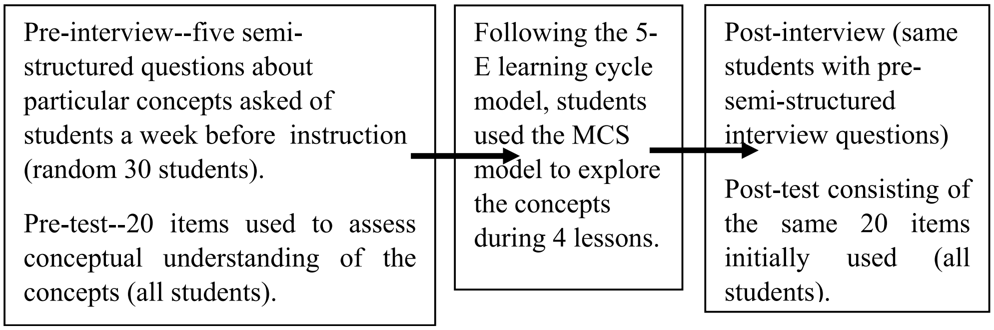

Figure 1. An overview of the procedures of the study.

Research Design and Data Collection

A pre-post one-group experimental design was employed to frame the research study. At the beginning of the study, one week prior to the start of the astronomy class, a 20-item pre-test was administered to all 94 students to assess conceptual understanding of the celestial sphere, astronomical coordinate systems, the path of the Sun and seasons. Thirty students (10 students per school) were randomly selected to participate in a five-question semi-structured interview designed to ascertain their conceptual understanding. During this interview students were provided with a clear plastic dome to use to explain their answers. During astronomy class, students were randomly divided into six groups to facilitate in- depth interaction with peers and hands-on experience with the model. Each group participated in the 5-E learning cycle process of inquiry using the MCS model described in Appendix A. After students completed the four week astronomy class, a post-test was administered consisting of the same test used initially. Another semi-structured interview of the 30 students was conducted at the conclusion of the course to assess students' conceptual understanding after using the MCS model (Figure 1). The pre-posttest and interviews were conducted in the Thai language but are translated for the purposes of this paper. All instruction was also conducted in the Thai language.

Interview questions, test items and questionnaire items were validated by three experts in astronomy (a physicist-astronomer, an astronomical educator, and a secondary school astronomy teacher). They judged the content validity of the semi-structured interview questions and test items. After making some minor changes as suggested by the evaluators, the test was deemed valid. The reliability of the 20-item pre-test was determined in a pilot test with 25 pre-service science teachers enrolled in an astronomy class. Reliability was calculated by using the Kuder-Richardson 20 and found to be 0.86.

RESULTS

In what ways does the celestial motion model foster high school students' conceptual understanding of the celestial sphere, including astronomical coordinate system, the path of Sun and seasons?

The results of pre-post tests with high school students for the purpose of describing students' conceptual understanding is organized in four sections--the celestial sphere, astronomical coordinate systems, path of the Sun, seasons--are given in Table 1. This table lists the percentage of students correctly answering questions for each concept group. The pre-test mean score is 7.23 and the post-test mean score is 16.39. Most of the students had more prior knowledge of the astronomy coordinate system and celestial sphere; 43.6% could answer questions about the astronomy coordinate system correctly before instruction. Only 24.9% of students could correctly answer questions about the path of the Sun. A paired-sample t-test between pre-test and post-test score indicates that after instruction with the MCS model, high school students had significantly higher scores on the posttest over the pretest score ($M = 9.16$, $SD = 2.50$, $t = 35.481$, $p < .001$).

Table 1

Mean Scores of Pre- Post Tests of High School Students

Topic	Percentage of students answering correctly			
	Pre-Test		Post-Test	
	Score	SD	Score	SD
Celestial sphere	40.2%	1.14	85.7%	0.89
Astronomy coordinate system	43.6%	0.97	80.0%	0.90
The path of the Sun	24.9%	1.04	84.2%	0.77
Seasons	35.9%	1.06	77.8%	0.95

Celestial sphere.

The pre-tests indicated that, before instruction, half of the students (50%) knew that the Sun appears to move because of the Earth's rotation, but less than half (41%) understood that latitude defines the amount of the celestial sphere visible from a specific location on the Earth, and 37% of the students understood that if they are at a high latitude location the North Star will not appear near the horizon.

After instruction using the MCS model, data from the post-test indicated that 82% knew that the Sun appears to move because of the Earth's rotation, and 87% of the students understood that latitude defines the amount of the celestial sphere visible from a specific location on the Earth. Most students (93%) understood that if they are at a low latitude location, the North Star will appear near the horizon.

Latitude effects.

In terms of the results of the pre-interview with thirty students about their prior knowledge of the celestial sphere, the majority of the students expressed uncertainty in terms of responding to the questions: "How do people who live in different latitudes on the Earth see the stars on the celestial sphere at the same time? Do the stars appear to move at night, explain? Plot the positions of zenith, horizon, meridian, NCP, the North Star of the observer at Bangkok (latitude 15°N) and directions on the clear plastic dome." During this interview students were provided with a clear plastic dome to represent a celestial sphere for demonstrating their ideas about position. Results include:

- Eleven students (37%) believed that people in different latitudes will see stars at the same position. Some students explained that people in different latitudes will view the same stars but in different positions while other students believed that they will see different stars.
- Half of the students (53%) were able to mark the zenith and horizon on the clear plastic dome correctly, but only 8 students (27%) drew a meridian correctly (by drawing a circle passing through the North, zenith and South points). The remaining students gave alternative explanations, such as the meridian is a circle passing through the East and West points, or the meridian is a circle passing along the horizontal. Less than half of the students (23%) knew that the North Celestial Pole (NCP) direction is close to the North Star. None of the 30 students were able to

plot the position of the NCP from the perspective of an observer in Bangkok on the clear plastic dome.

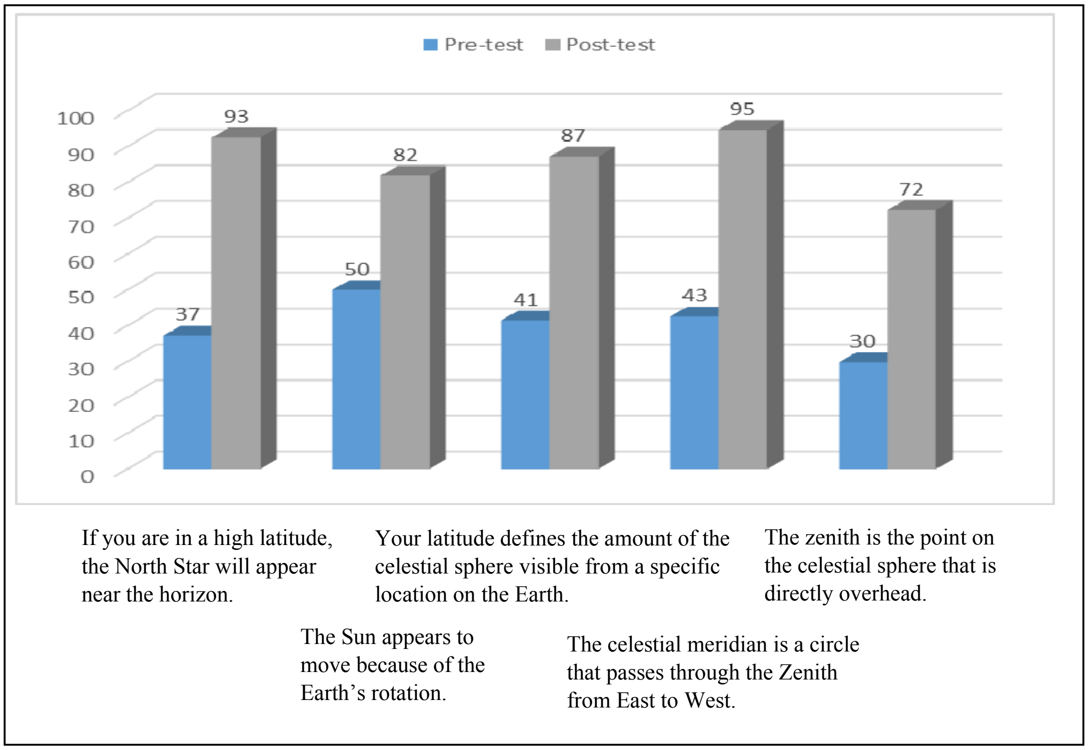

Figure 2. Percentages of students who responded correctly to questions of the celestial sphere topic before and after instruction for each item. The correct answer for some is No.

- Nine students could explain that the North Star's angular height from the horizon is equal to the latitude of the observer, and they could draw the North Star seen at Bangkok at an angle from the horizontal of about 15 degrees (correct answer). The remaining students had alternative explanations; for example, some students drew the North Star's position at the horizon and other students drew the North Star's position near the zenith.

After students explored the celestial sphere by using the MCS model, they plotted positions on the celestial sphere and learned that the Earth's rotation causes apparent celestial motion. The results of the post-interview indicated that:

- Most of the students (93%) understood that people in different latitudes will see a difference in positions of stars; only two students (7%) still believed that people in different latitudes will see stars in the same position.
- All students could mark the zenith and horizon on the clear plastic dome correctly. Most students (80%) drew a meridian from North passing through the observer's zenith to the South correctly; only four students still drew a meridian passing through the East and West points. Most of the students (83%) could correctly plot the position of the NCP from the perspective of an observer at Bangkok on the clear plastic dome.

- Most of the students (87%) could correctly draw the North Star's angular height from the horizon at about 15 degrees. The remaining students drew the North Star's angular position from the horizon at 75 degrees (lower than the zenith by 15°) and only one student drew the North Star position at the horizon, as illustrated in the following excerpt:

R: Where is the North Star position?
S11: The North Star is at the horizon (He drew the North Star at the North direction point on the horizon).
R: Why did you draw the North Star at the horizon?
S11: I knew that the North Star point to the North direction, then I think the North Star and the North position are the same position.

Astronomy coordinate system.

The pre-tests indicated that half of the students (50%) knew that the location of the stars changes with location of the observer on the Earth and time. More than half of the students (63%) knew that the altitude of a star is measured in degrees above the horizon but only 44% of students knew that equinoxes and solstices occur when the Sun is at particular points on the celestial sphere.

After instruction using the MCS model, most of the students (68%) realized that horizon coordinates are not fixed on the celestial sphere and more than half of the students (76%) indicated that the location of the stars changes with location of the observer on the Earth and time. More than half of the students (72%) knew that the lines of both right ascension and declination stay fixed with respect to the stars.

In terms of interviews, students' initial ideas with respect to the following questions were determined: "How do we identify the position of the object on the celestial sphere? Explain the position of the Sun in the morning (6 a.m.) of the summer solstice of the observer at the Equator in the horizontal and equatorial coordinate systems."

Pre-interview data indicated that:

- More than half of the students (57%) knew that the altitude of a star is measured in degrees above the horizon, perhaps because they had prior experience with horizontal coordinate systems in grade 9. However none could explain the position of the Sun in the morning of the summer solstice in term of horizontal coordinates correctly. Only four students were aware that the altitude of the Sun is 0 degrees; they struggled to explain the azimuth of the Sun.
- Most of the students had only partial understanding of the equatorial coordinate system, eight students knew that right ascension and declination are the coordinates of stars in the equatorial system but they could not explain how to find the right ascension and declination of the Sun at the summer solstice.

Post-interview data indicated that:

- Twenty one students (70%) were able to correctly describe the azimuth and attitude of the Sun in the morning (6 a.m.) during the summer solstice, and nine students understood that the altitude of the Sun is 0 degrees yet remained confused in terms of finding the azimuth of the Sun.
- Eighteen students (60%) correctly explained the right ascension and declination of the Sun on the celestial sphere at the summer solstice. Seven students (23%) were able to explain the declination of the Sun correctly but struggled to explain its right ascension. Four students

(13%) were able to explain right ascension correctly but could not explain the Sun's declination.

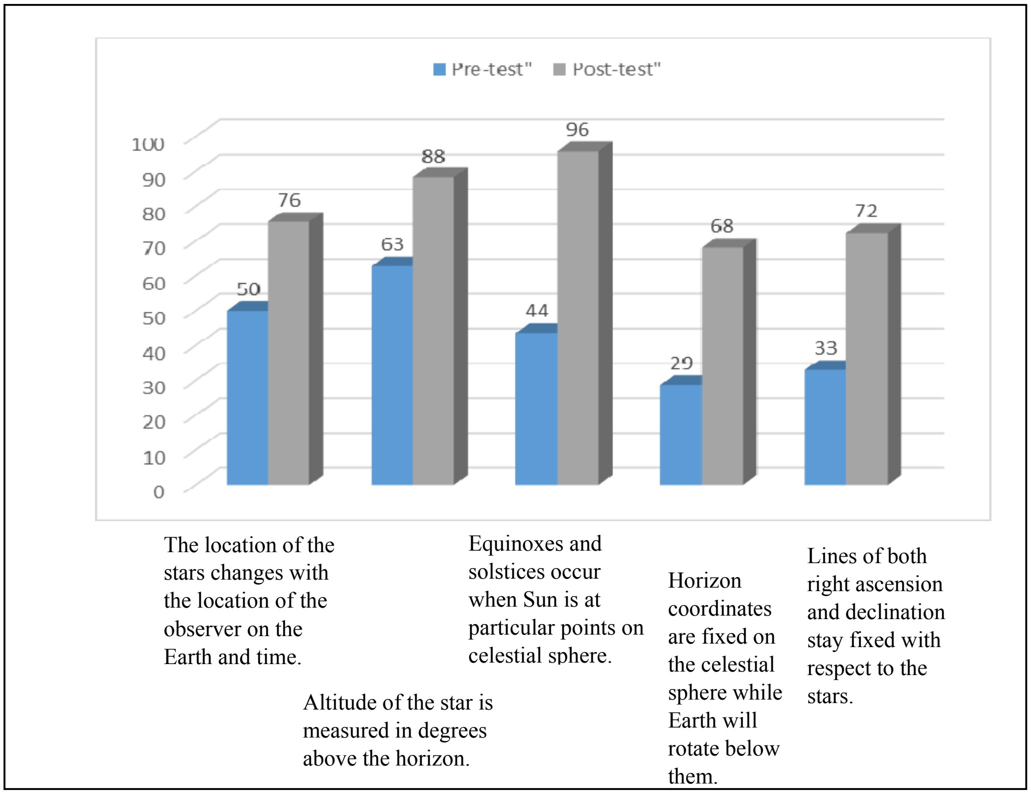

Figure 3. The percentages of students who responded correctly to questions on the astronomy coordinate system topic before and after instruction for each item. The correct answer for some is No.

Path of the Sun.

The pre-test indicated that only 37% of students knew that the summer Sun's apparent position 23.5° above the celestial equator is related to the tilted rotation axis of the Earth. Most of the students (74%) believed that the Sun passes directly overhead at noon every day, and students (84%) also believed that the Sun rises in the exact East and sets in the exact West every day. Only 19% of students understood that the Sun's altitude is different depending upon the location on the Earth and time.

After instruction, students demonstrated a clearer understanding of the Sun's path change; all students answered correctly that the Sun does not pass directly overhead at noon every day, and 94% understood that the Sun does not rise in the exact East and set in the exact West every day. However, 28% of the students still did not realize that only two days of the year have 12 hours of daylight.

The pre-interviews revealed students' initial understanding about the path of the Sun in response to the following questions: "If you stay in Bangkok (latitude 15°N) during the vernal equinox day, draw the apparent path of the Sun in the sky starting from where it appears to rise until it sets. Explain the Sun's position change during the day. Is the Sun directly overhead at noon? How does the Sun's path change with respect to the different latitudes of an observer?" Students were provided with a clear plastic dome to represent a celestial sphere to use and demonstrate their understanding about the Sun's path. Students had to draw the line to represent the Sun's apparent motion in Bangkok on the clear plastic dome and explain the Sun's positional change during the day.

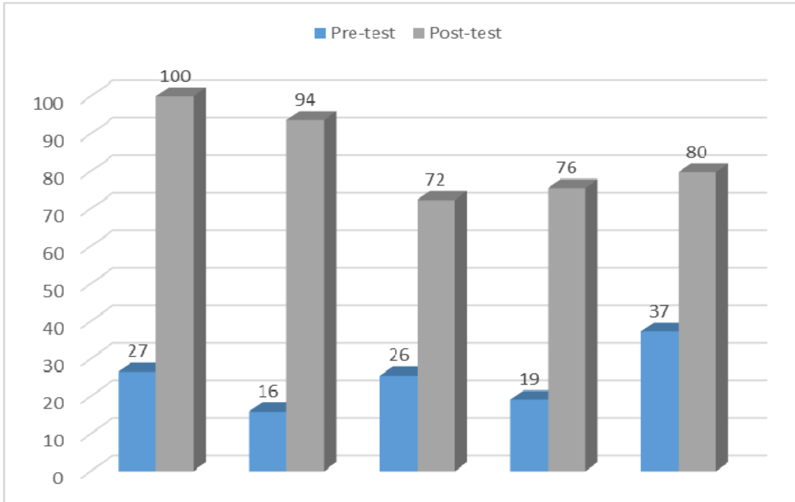

Figure 4. The percentages of students who responded correctly to questions of the path of the Sun topic before and after instruction for each item. The correct answer for some is No.

Tracking as drawn by students on the clear plastic dome.

- The greatest proportion of students (57%) drew the Sun's path as a straight path through the zenith.
- 10% of students drew the Sun's path shifted towards the South.
- The remaining students drew the Sun's path shifted towards the North.

Some students were inconsistent in their understanding of how the maximum altitude of the Sun changes during the year. The excerpt below illustrates students' initial ideas with respect to the path of the Sun in response to the question:

S1: I knew that the Sun's path at Bangkok does not pass overhead but I don't know why? I think we lived in the North hemisphere then the Sun's path should be shifted towards to the North.
R: How about the Sun's position at noon, do you think the Sun is directly overhead?
S1: No, the Sun is not directly overhead at noon. I think the Sun is below the zenith a little bit.

For the Sun's rising and setting positions, most students (83%) believed that the Sun always rises in the East and always sets in the West. Some students (10%) knew that the sunrise and sunset points move but could not explain how they move. Students expressed uncertainty and were not able to fully explain their answers; most of the students were confused about the Sun's rise /set positions. A probable explanation for their confusion may be related to the use of language in elementary science when students are typically taught that the Sun 'rises in the East and sets in the West':

R: Where are the sunrise and the sunset positions?
S1: The Sun rises East and sets West.
R: Is the sunrise exactly East and sunset exactly West every day?
S1: Yes, I saw it rise in the East and set in the West every day.

The responses of students during the post-interview indicated that most of them (43%) realized how the Sun's path changes, the position of the Sun in the sky at noon and at sunrise and sunset positions.

- All students knew that in Bangkok (15°N) the Sun is not directly overhead at noon every day.
- Twenty four students (80%) drew the Sun's path shifting towards the South and more than half of them explained the Sun's altitude at noon correctly (they could explain that the Sun's highest position at noon is 75 degrees above the horizon).
- The remaining students provided alternative explanations, such as the Sun passes through the zenith or the Sun's path shifts towards the North.
- All students drew the sunrise and sunset positions at the equinox correctly (the Sun rises directly East and sets directly West). Students' understanding of concepts related to the Sun's path is illustrated in the following excerpt:

R: Why did you draw the Sun's path shifting towards the South; please explain?
S1: Because if we lived in the North hemisphere then we can see the Sun's path shift towards to the South.
R: How about the Sun's position at noon, do you think the Sun is directly overhead?
S1: No, only people at equator can see the Sun directly overhead at noon every day.
R: How about the Sun's altitude at noon from the perspective of people in Bangkok?
S1: The Sun is 15 degrees below the zenith.
R: How do you know the Sun's altitude at noon is below the zenith is 15 degrees?
S1: Because the Sun's altitude below the zenith equals the latitude of the observer.

Seasons.

The pre-test score indicate that only 46% of students responded correctly that seasonal change is caused by the tilt of the Earth's axis. Most of the students (77%) believed that in winter, days are shorter than nights because the Earth is far from the Sun, and most of the students also believed that June is hotter in Bangkok than December because the Earth moves near the Sun. Most of the students (68%) knew that the Sun's path in summer is longer than in winter, but only 19% of students knew that the Sun's path is tilted southward in the winter for the northern hemisphere.

After instruction using the MCS model, there were still areas in which many of the students did not demonstrate a complete understanding of the cause of seasonal change; 82% of students knew that seasonal change is caused by the tilt of the Earth's axis. However, some students (27%) still believed that in the winter, days are shorter than nights because the Earth is far from the Sun. Most of the students (90%) knew that the Sun's path on the sky in the summer is longer than in winter, but some were still confused about the Sun path's direction.

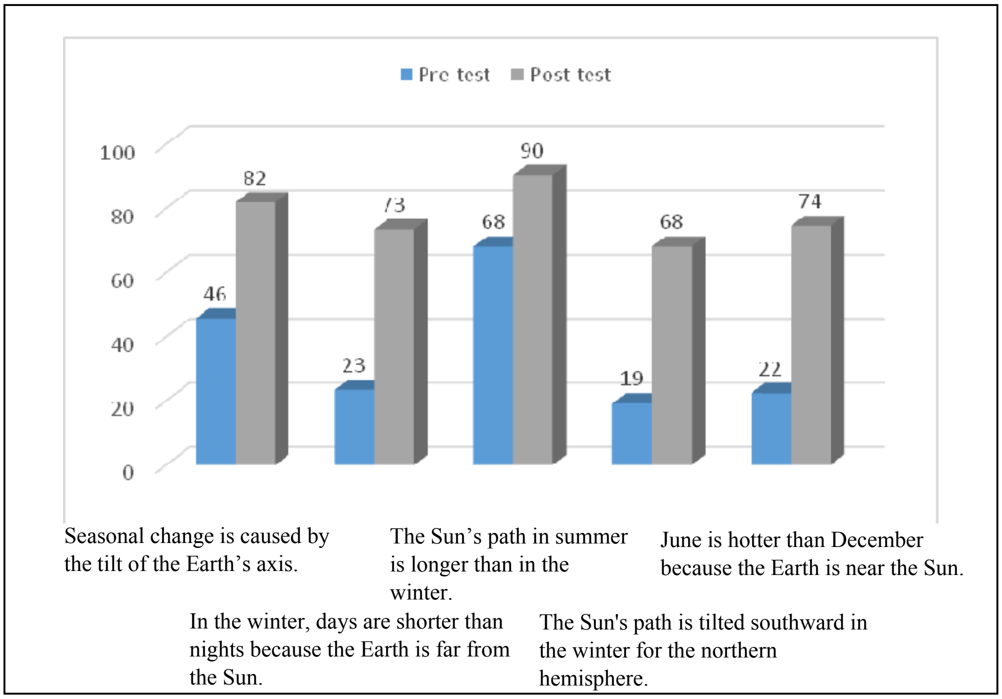

Figure 5. Percentages of students who responded correctly to questions about seasons before and after instruction for each item. The correct answer for some is No.

Cause of seasons

- The Earth's axis is tilted.
- Distance between the Earth and the Sun.
- The Earth's axis flipping back and forth as the Earth moves around the Sun.
- Inaccurate explanation for the cause of seasons.

Path of the Sun

- Students draw four Sun paths shifted towards the South correctly.
- Students draw four Sun's paths shifted towards the North.
- Students draw the Sun's path through the zenith in the summer.
- Students draw the same path every day.

Sunrise and Sunset positions

- The Sun rises exactly East and the Sun sets exactly West.
- The Sun rising north of East and setting north of West in the summer.
- The Sun rising south of East and setting south of West in the winter.
- The Sun rising north of East and setting south of West.

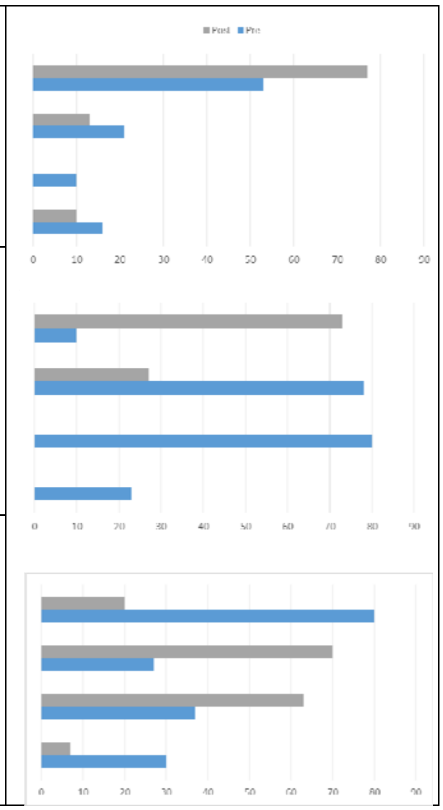

Figure 6. The students' explanation about Sun's path change.

The pre-post interview data with students about seasons included the following questions: "What is the cause of seasons? Draw the Sun's path change in one year at Bangkok on a clear plastic dome during this day (vernal equinox, autumnal equinox, summer solstice or winter solstice). Is there any difference in the path of the Sun between summer and winter? Explain."

The pre-interviews about students' initial understanding of seasons indicate that 87% knew that the change of the seasons is caused by the Earth's axis being tilted, but there are inaccurate explanations. Fifty-three percent of the students explained that when the Earth's axis points towards the Sun in the summer, the Earth gets more energy than in the winter, when the axis is pointed away from the Sun. The remaining students believed that the distance between the Earth and the Sun causes the seasonal change. They explained that the Earth orbits the Sun in an elongated elliptical shape and sometimes moves closer to the Sun (summer) and sometimes moves farther from the Sun (winter); see Figure 6. Some students (10%) explained that the change of the seasons is caused by the Earth's rotational axis flipping back and forth as the Earth moves around the Sun. None of the students used information about the angle of the Sun's light rays hitting the Earth to explain changes in temperature. The students' initial ideas about the apparent motion of the Sun demonstrated that most had a very limited understanding of the Sun's path change between summer and winter. Eighty percent understood the Sun passing –or not--through the zenith in summer. They did not know that the Sun's path changes its direction every day. Students' initial ideas about seasonal change are illustrated in the excerpt below.

R: What is the cause of seasonal change?

S8: Because the Earth moves around the Sun in an elliptical orbit then some time it is far and sometime is close the Sun. When the Earth's axis tilted toward the Sun, it will be summer. When the Earth's axis is away the Sun, it will be winter.

R: Can you explain why the Earth's axis is tilted toward the Sun it will be summer?

S8: Because we live in the northern hemisphere when the Earth's axis tilted toward the Sun, the northern hemisphere is closer to the Sun than the southern hemisphere. Then people on the northern hemisphere will have summer and people in the southern hemisphere will have winter.

During the interviews, some students could not explain how seasons occur in Thailand. They don't have experience with spring and fall seasons.

R: Then, how many seasons are there on the Earth? (Thai textbooks typically depict four seasons as a universal standard. This is problematic.)

S8: Four seasons; there are summer, fall, winter and spring.

R: How about the Sun's path. Do you think the Sun's path changes every day?

S8: Yes, it changes.

R: How about the Sun's path change during fall and spring seasons?

S8: I don't know about the fall and spring seasons.

In terms of post-interview responses about the cause of seasons, 77% could explain that the tilted Earth's axis causes the seasonal change and could explain that in the summer the Earth's axis points more towards the Sun so the Sun's rays hit that part of Earth more directly, causing changes in temperature on the Earth. Most (67%) provided clearer explanations about the cause of seasons and could explain the relationship between the Sun's path change, Sun's altitude, the length of day, and temperature on the Earth's surface. Most of the students (70%) drew the Sun's path shifting towards the South in the summer correctly. Twenty two students (73%) drew the Sun rising north of East and setting north of West in the summer and the Sun rising south of East and setting south of West in the winter.

DISCUSSION

Most of the students in this study improved their understanding of how the Sun's path changes and how the seasons come about by using the MCS model in a 5-E learning cycle instruction approach. All students had some prior knowledge of the reference points on the celestial sphere such as zenith, horizon, meridian, zodiac and the apparent motion of the stars, but most of them had only partially accurate understanding from prior instruction. Students struggled to understand concepts related to the celestial sphere and the apparent motion of stars because they did not have many opportunities to make direct observations of astronomical phenomena. In one interview, a student explained that "I know the North Star position can tell the latitude of an observer but I have never see the North Star on a real sky." Barnett et al. (2005) note that students develop scientific understandings as a result of their own observations, when they use models to explain phenomena. Plummer and Krajcik (2010) note that teachers should extend instructional time to include both the planetarium and classroom instruction, or observations of the actual sky, to improve students' understanding of celestial motion.

In terms of the Sun's path change, for many students this was their first introduction to the topic. Most of them lacked an initial understanding of the Sun's path change and the Sun's altitude and sunrise and sunset positions. In Bangkok, Thailand, latitude 15 degrees North, there is only a slight change in the Sun's path near the zenith across the seasons, and the Sun's altitude in the summer appears near the zenith point so most of the students perceive that the Sun's path is directly overhead at noon every day. Students also believe that the Sun rises due East and sets due West every day because they can't observe firsthand the shift of sunrise and sunset positions. The teaching of astronomy in Thailand traditionally does not encourage students to do activities related to the position of the Sun, such as observation of the shadows to find the position of the Sun, or use of the compass to check the Sun's rising and setting positions during each season.

All students have studied the cause of seasons as a topic since the elementary level, but most of them initially struggled to explain this concept when asked to apply knowledge with their own context. In the Thai science curriculum, students have to study four seasons; summer, fall, winter and spring. Yet, in Thailand, seasons are generally classified into three seasons; hot season, cool season and rainy season, although there does not seem to be much difference in the temperature between summer and winter except in the North of Thailand. Some students thought that Thailand received equal amounts of sunlight so Thailand should not have seasons. Bongkotphet (2009) found that students did not know what spring and fall seasons were like since they do not meteorologically occur in Thailand. It is important for teachers to give students basic information about fall and spring seasons. Teachers should discuss the effect of monsoons on the seasons in Thailand in order to help students formulate an explanation for seasons in the Thai context. In addition, prior to this study, most of the students had alternative conceptions about the cause of seasonal change. Some students knew that the tilted Earth's axis caused the seasonal change, but they did not elaborate or provide further explanation. They could not explain that if the Earth's axis tilted more towards the Sun, then the Sun's rays hit the part of the Earth in the Northern Hemisphere more directly than in the Southern Hemisphere, and it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.

After using the MCS model students learned that the tilted Earth's axis caused the Sun's path change. They understood that this was related to the differing length of day through the year and was part of the explanation for the changing seasons. Further, students could explain that the Sun's altitude varies with the seasons and the location of the observer on the Earth, causing the Sun's altitude to be higher in the sky during summer than it is during the winter.

IMPLICATIONS AND FUTURE RESEARCH

Most of students in this study had alternative conceptions about the Sun's path changing with seasons; they had limited observation of the Sun's path change over a year based on their own experiences. Although the MCS model helped them to improve their understanding of the Sun's apparent motion, it seemed to be most effective when student experimented with the model, observing phenomena by themselves rather than with simple teacher demonstration. In future studies, the researcher should establish long term observations, activities or experiments involving observations of the Sun's positional changes and support students to build personal explanatory models of their own. Teachers should engage students in explaining scientific understandings through modeling and presenting their own model in the classroom. The strength of the MCS model is it allowed students to view the Sun's path change phenomenon from different perspectives (latitude) of the observer, which can be difficult to view in the sky.

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APPENDIX A

Usage of the Mini-Celestial Motion Model

The MCS model is used to demonstrate the Sun's apparent motion as viewed by observers on the Earth. Each student group can observe the Sun's path change by setting a latitude for observation on the MCS model (Figure A1).

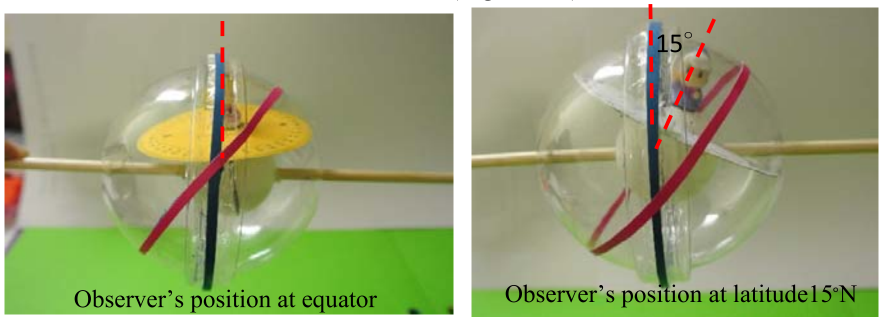


Figure A1. The MCS model of the observer at the Equator and latitude 15°N.

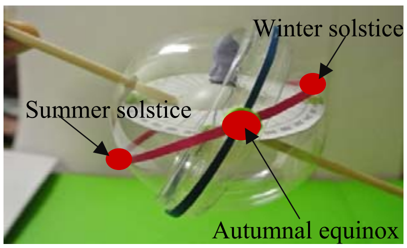


Figure A2. The Sun's apparent position at the vernal equinox, summer solstice, and autumnal equinox and winter solstice days.

The MCS model can be used to observe the Sun's apparent motion at the vernal equinox, summer solstice, autumnal equinox and winter solstice days by setting the day from which students want to make observation (Figure A2). For example, if they want to observe the Sun's apparent motion on the vernal equinox day, they should turn the Earth's axis until the Sun at the vernal equinox is aligned with the East side of the horizontal plane inside the model (Figure A3) and use a non-permanent pen to mark the Sun's position on the clear plastic dome. Students should continue to turn the Earth's axis counterclockwise and observe the Sun's position change until the Sun is aligned with the West side of the horizontal plane and record the Sun's position. Students should draw a line to connect the Sun's position on the clear plastic dome (Figure A4).

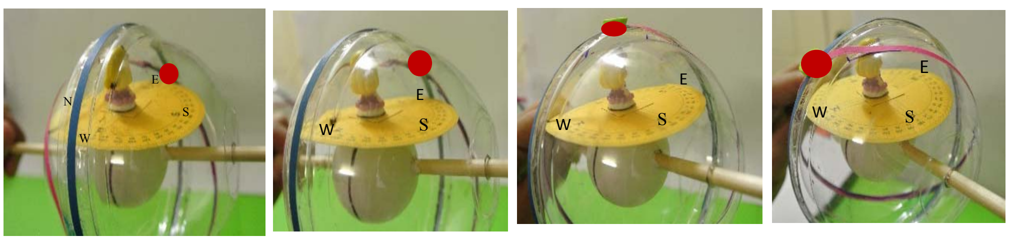


Figure A3. Using the MCS model to demonstrate the Sun's apparent motion change during a day.

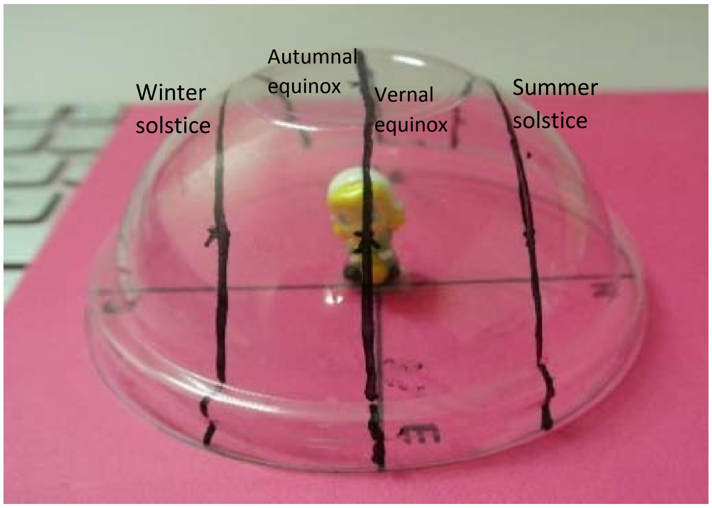


Figure A4. Showing the Sun's path change for people at the Equator.

Method of Constructing the Mini Celestial Sphere Model

We used a plastic ball (diameter 2-3 cm) to represent the Earth and a clear plastic dome to represent the celestial sphere.

1. Holes were drilled into the middle of the plastic ball, and chopsticks inserted to represent the rotational axis of the Earth;
2. A line was drawn around the circumference of the plastic ball to represent the equator line (Figure A5).
3. A cardboard circle was used to represent the horizontal plane of the observer on the Earth. The cardboard circle was divided into four equal parts to illustrate directions on Earth; the cardboard circle was glued to the top of the plastic ball (Figure A6)
4. The plastic ball was enclosed by two clear plastic domes, one representing the northern hemisphere and one the southern hemisphere.

Figure A5

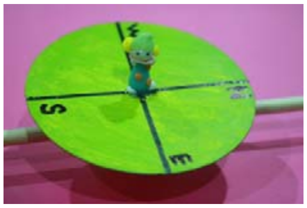


Figure A6

5. Sticker tape was placed on the clear plastic dome parallel to the Earth's equator to represent the celestial equator. A different color of sticker tape was placed on the clear plastic dome at an angle of about 23.5° from the celestial equator to represent the ecliptic (Figure A7).

Figure A7

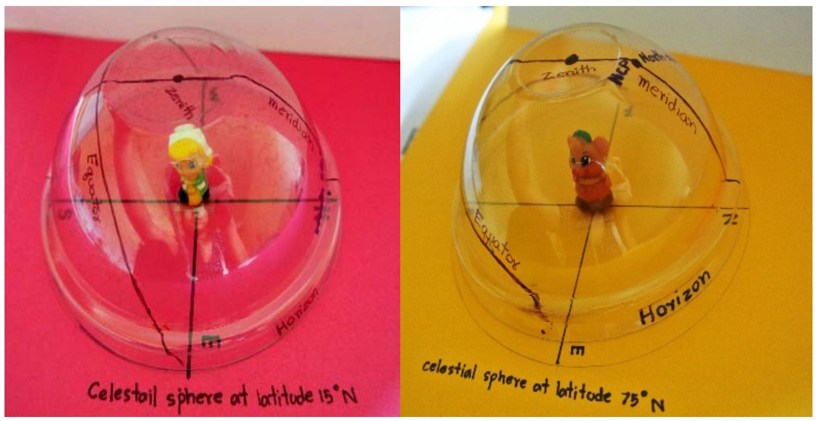
APPENDIX B

Nature of the Instruction Using the 5-E Learning Cycle

The instructional cycle consisted of four lessons designed according to the 5-E learning cycle model. The 5-E learning cycle consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills (Bybee et al., 2006). In lesson 1, students explored the celestial sphere. Lesson 2 introduced the idea of astronomical coordinate systems. The focus of Lesson 3 was on the understanding of the path of the Sun. Finally, in Lesson 4, students explored the cause of seasons.

Sample Lessons Designed Based on the 5-E Learning Cycle Model

Lesson 1: The celestial sphere, 5-E learning cycle activities	
Engagement	1. Teacher asks essential questions and discusses the celestial sphere with students: - Why do we see a sky as a half sphere? - Is the stars' movement in the sky a product of their physical movement, or of the Earth's movement? - Do you think people in different locations on the Earth have the same celestial sphere? Explain. (each group discusses the questions using a globe) 2. Teacher shows a picture of the sky in a different locations (latitude) on the Earth at the same time (Malaysia 4°N, New York 42 °N, Australia 38°S). Each student group discusses what is similar or different about the spheres in different locations. 3. Each student group thinks about a question that they want to learn about the celestial sphere individually and then shares it with their group. 4. Teacher writes all the questions generated by each student group on the white board and selects questions this for student to explore.
Exploration	5. Students explore the questions with peers by using the stellarium program and internet (Stellarium program http://www.stellarium.org/). Stellarium program is a free downloadable program. It depicts a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope. 6. Each student group (choosing a different latitude for the observer on the Earth) observes the reference position on the celestial sphere by using a stellarium program and plots reference positions of the direction, horizon, North Star, north celestial pole, zenith, meridian, equator line on the clear plastic dome.
Explanation	7. Each students group shares their clear plastic domes with the class. 8. Students discuss what the sphere would look like when observed from different locations on the Earth and explain why the altitude of the North Star depends on the latitude of the observer on the Earth.

	Students discuss the answers to the previous questions.
Elaboration	9. Teacher asks the question: - Can you apply your knowledge of the celestial sphere to explain astronomical phenomena? (For example, star's position, star's apparent motion, direction) - How can you find the direction and your position if you get lost in the forest?
Evaluation	10. Students demonstrate their understanding by drawing a diagram of a celestial sphere as it would appear from Norway (75 degrees north) and compare with Thailand (15 degrees north) (Figure B1).  *Figure B1.* Examples of the celestial sphere for the observers at 15°N and 75°N.

Lesson 2: Astronomical coordinate systems, 5-E learning cycle activities

Engagement	1. Teacher asks the essential questions : - How do we identify the coordinates of people on the Earth? - How do we identify the coordinates for locating objects on the celestial sphere? - What are the reference lines on the celestial sphere? 2. Students explore reference lines on the celestial sphere by using a Stellarium program and recording their ideas on the white board. (Stellarium program http://www.stellarium.org/. The stellarium is a free downloadable program, depicting a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope.) 3. Teacher and students discuss the celestial equator and the ecliptic line on the celestial sphere.
Exploration	4. The teacher demonstrates how we can identify the ecliptic line in the celestial sphere by using a globe to represent the Earth and the laser pointer to represent the Sun's position, illustrating the apparent position of the Sun on the celestial sphere. One student should hold a globe that is rotated on its tilted axis while slowly orbiting the Sun. The teacher aims a

laser pointer at the equator on the day that the Earth's axis points neither towards or away from the Sun. Students observe the position of the laser pointer (Sun's position).

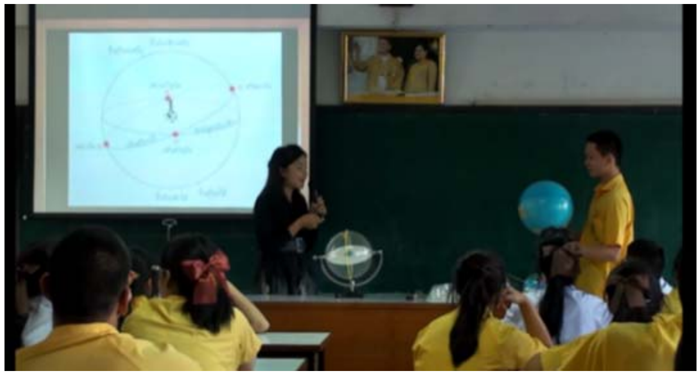


Figure B2. Student demonstrates the Earth orbiting around the Sun.

5. The student holds a globe and orbits around the Sun slowly.

6. Students observe the laser pointer's position (Sun's position) on the Earth's surface when the Earth's axis points more towards and points more away from the Sun.

7. Teacher and students discuss the Sun's position (when the Earth's axis points neither towards nor away from the Sun, the Sun's position intersects with the celestial equator. When the Earth's axis points towards the Sun, the Sun's apparent position is 23.5° above the celestial equator. When the Earth's axis points away from the Sun, the Sun's apparent position is 23.5° below the celestial equator).

8. The teacher explains the ecliptic on the celestial sphere and positions on the ecliptic (the vernal equinox, summer solstice, autumnal equinox and winter solstice).

9. Teacher poses the question "How do astronomers define the locations of astronomical objects on the celestial sphere?" and has students study observations in the Stellarium program.

10. Students and teacher discuss astronomical coordinate systems. Teacher explains to students how to find azimuth, altitude, right ascension and declination of stars.

11. Each student group constructs their own the MCS model (each group should select a different latitude for observation), see Figure B3.

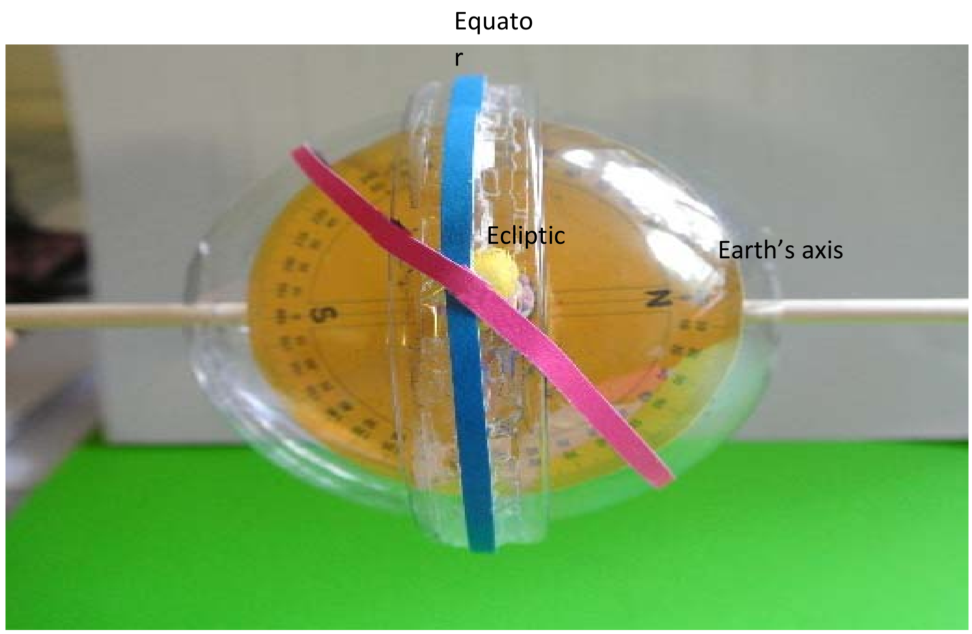


Figure B3. The MCS model

12. Each student group chooses 2-3 stars on the star chart, puts data into the worksheet (Figure B4) and places stickers which represent stars on the MCS model (Figure B5). They label the right ascension and declination (equatorial coordinates) of the stars on the MCS model (students have to understand how to define right ascension and declination of stars in order to place stickers on the MCS model correctly).

Star	Star's position	Horizontal coordinate system		Equatorial coordinate system	
		Azimuth	Altitude	Right ascension	Declination
Star 1	aligned with East side of horizon				
	Middle of sphere				
	aligned with West side of horizon				
Star 2	aligned with East side of horizon				
	Middle of sphere				
	aligned with West side of horizon				
Star 3	aligned with East side of horizon				
	Middle of sphere				
	aligned with West side of horizon				

Figure B4. Worksheet to record stars' positions.

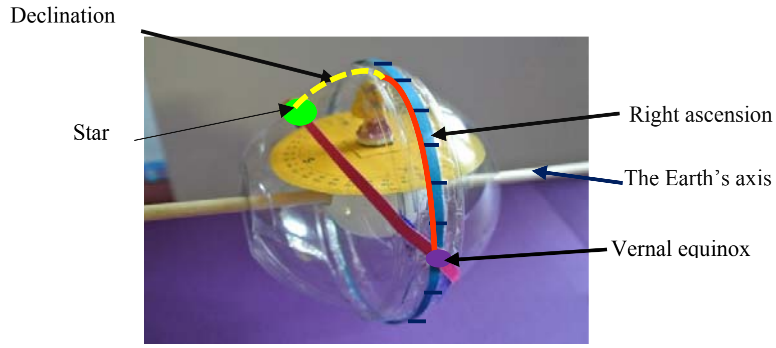


Figure B5. Using the MCS model to estimate the right ascension and declination of a star.

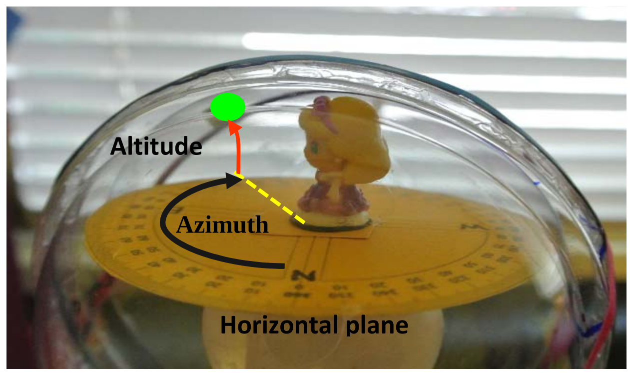


Figure B6. Using the MCS model to explain azimuth and altitude of star.

13. Students turn the Earth's axis in the MCS model (representing the Earth's rotation) until a star is aligned with the East side of the horizontal plane inside the model and record Azimuth and Altitude (horizontal coordinate system) on a data sheet (Figure B6).

14. Students continue to turn the MCS model until the star is at the middle of the sphere, and then the star is aligned with West side of the horizontal plane. They record the azimuths and altitudes of the star at the two spots.

Explanation	15. Each group of students shares their observations with the class and compare their observations with other groups. 16. The teacher and students discuss the horizontal coordinate system and equatorial coordinate system. The horizontal coordinate system is the simplest way for giving location of stars on the celestial sphere. The equatorial coordinate system is a fixed coordinate, used to describe how the location of a star doesn't change with location on the Earth or with time.
Elaboration	17. Students explain strengths and weaknesses of the horizontal coordinate system and equatorial coordinate system.
Evaluation	18. Teacher asks the essential question: assume you are a person who lives at the equator on the Earth's surface. You see a star that has right

	ascension 0 h and declination 0° directly overhead. If you want your friends who live at latitude 45°N and 45°S to observe the same star with you at the same time, how do you tell them about azimuth and altitude of star at each place?

Lesson 3: The Sun's path change, 5E learning cycle activities

Engagement	1. Teacher asks the essential questions: - Does the Sun's apparent motion change every day? Explain. - Is the Sun's position at noon directly overhead every day? - Does the Sun rise in the East and set in the West every day? 2. Teacher uses Youtube video https://www.youtube.com/watch?v=XkeFXkjaLHE to demonstrate the Sun's path change as viewed from New York during vernal equinox, summer solstice, autumnal equinox and winter solstice days. 3. Students discuss why the Sun's path changes. Each student group observes the Sun's path change by selecting a latitude for observation on the MCS model.
Exploration	4. Students use the MCS model to observe the Sun's position change on the vernal equinox, summer solstice, and autumnal equinox and winter solstice days. 5. The students use the non-permanent pen to mark the Sun's position and draw the Sun's path on the clear plastic dome.
Explanation	6. Students present the Sun's path change of their location on the Earth and compare it with another location. 7. Students discuss the following questions: - Why does the Sun's path change every day? - Why is the Sun's path of the observer in each location on the Earth different? - Why do the Sun's rising and setting positions change? 8. Students share their ideas with the class based on their answers, the teacher explains the path of the Sun to summarize the concept.
Elaboration	9. Students use the MCS model to explain the Sun's path change in Bangkok (15°N).
Evaluation	10. Students draw the Sun's path from observation locations at 60°N and 40°S on vernal equinox, summer solstice, autumnal equinox and winter solstice

Lesson 4: Seasons, 5E learning cycle activities

Engagement	1. Teacher asks essential questions: - What is the different between summer and winter? - What is a cause of changing seasons ? 2. Each student group discusses the questions and writs their answer on the white board.

Exploration

3. Students examine how much the flashlight angle can warm a cardboard.

4. Students record the initial temperature on two cardboards.

5. Students do an experiment by aiming a flashlight, at two pieces of cardboard with thermometers, laying on the ground, the light located 50 cm. away, at different angles(one flashlight perpendicular to the cardboard, one tilted flashlight), see Figure B7.

6. Students measure the area over which the flashlight beam strikes and record the temperature of the thermometer 20 min. after.

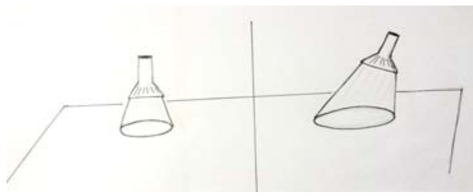


Figure B7. Flashlights illuminating different amounts of areas on cardboard pieces, showing effects of tilt.

7. Students discuss how much energy falls on each square meter of the cardboard and the changing of temperature.

8. Teacher uses a globe and flashlight (representing the Sun) to demonstrate the Earth's rotation and revolution around the Sun. Teacher points the flashlight to a globe that is moving around the Sun, and students observe the changing light intensity on a globe.

9. Students discuss the change in sunlight striking places on the Earth's surface at different latitudes.

10. Students use the MCS model to observe the Sun's path change on the vernal equinox, summer solstice, autumnal equinox and winter solstice days (each student group should select a different latitude of observation).

11. Students observe the Sun's path and draw the Sun's path on the clear plastic dome.

Explanation

12. Students present the Sun's path change of their location in summer, winter, fall and spring.

13. Students observe the relationship between the Sun's path change and the changing of temperature on the Earth's surface.

14. Teacher asks follow-up questions:
   - Is the direction of the Sun's motion the same in summer and winter?
   - What is the length of the Sun's path change in the winter compared to the summer?
   - What is the Sun's altitude change in winter compared to summer?
   - Does the position of the Sun vary with the seasons over time?
   - Does the Sun change position when observed day to day at the same time from the same observer point?

	- Why is it hotter in our location in June than in December? 15. Students discuss their answers based on their observations with the MCS model.
Elaboration	16. Teacher proposes a situation that if they need to use solar panels, how should they set the direction of solar panels in your latitude to get more solar energy during summer, winter, fall and spring (student choose different latitudes of observers on the Earth)
Evaluation	17. Student respond in writing to the question: Are there differences in the path of the Sun between summer and winter in Bangkok, Thailand (15°N)? Explain.

STATUS OF EUROPEAN PLANETARIUMS DISCUSSED AT THE 2014 SYMPOSIUM OF PLANETARIUMS

Dario Tiveron, *Fulldome Database*, Padua, Italy

Abstract: A symposium of planetariums discussed the status of the field in France, Germany and Italy. Key points are that in some countries, family visits are predominant rather than school and teachers, and that the economy impacts the ability of families to spend money for admissions, more than the effect of government funds for budgets.

Keywords: Public - Planetariums – Economics – Technology in Education

The May 2014 Symposium of Planetariums in Lucerne, Switzerland, a new event in the planetarium scene, brought together affiliates from three different European associations: Association des Planétariums de Langue Francaise (APLF, France), Gesellschaft Deutschsprachiger Planetarien (GDP, Germany) and the Associazione dei Planetari Italiani (PlanIt, Italy). A most interesting talk there brought together on the stage representatives of each association who spoke about what the planetarium scenario is like in each of their countries.

The GDP, represented by Björn Voss, is the biggest association of the three, with about 300 members (people, not planetariums, represented; besides planetariums, there are amateur astronomy associations, vendors and production companies) of what GDP calls 'a huge potential that hasn't been disclosed yet'. Their main goal is to increase networking and have stronger collaborations within the community. The Italian association, spoken for by Gianluca Ranzini, its president, has about 60 members. The French association, represented by Marc Moutin, has a membership size between the latter two associations.

THREE COUNTRIES IN NUMBERS

In the talk, moderated by Lucerne's Planetarium director Daniel Schlup, various interesting factoids were stated:

Both Germany and France each welcome about 1.2 million planetarium visitors annually, with Italy seeing a much smaller audience, about 400,000.

Germany and Italy consider school audiences to be very important for their activities, with students accounting for up to 50% of the entire attendance. Such a high percentage from schools is believed to be due to teachers not feeling confident enough to teach astronomy in classes; they'd rather let planetariums take care of it on their behalf. All three presenters agreed with this statement.

The situation in Germany is a bit worse, in regards to the quality of astronomical education in schools, due to recent negative developments that are making astronomy progressively disappear from school programs.

Also, Germany has a new and steadily increasing segment of young adults who enjoy hanging out in planetariums, leading planetarium managers to invest in and develop specific offerings for this age group.

On the other hand, according to Moutin, the majority (>50%) of visitors in France are families, rather than schools, with parents enjoying learning new things together with their kids.

The number of planetariums in each country is about 100 in Germany, about 150 in Italy, and almost 160 in France. Unfortunately only a few of each country's planetariums are affiliated with each national association.

The majority of the French and Italian planetariums are small dome theaters with fewer than 35 seats available. Germany has a much wider distribution of bigger installations, with about 10 domes bigger than 18 meters. Still, as you can see in the image below, each country has a lot more older, optical-mechanical systems than digital ones, although we can expect at least some of them to convert to digital in the next future.

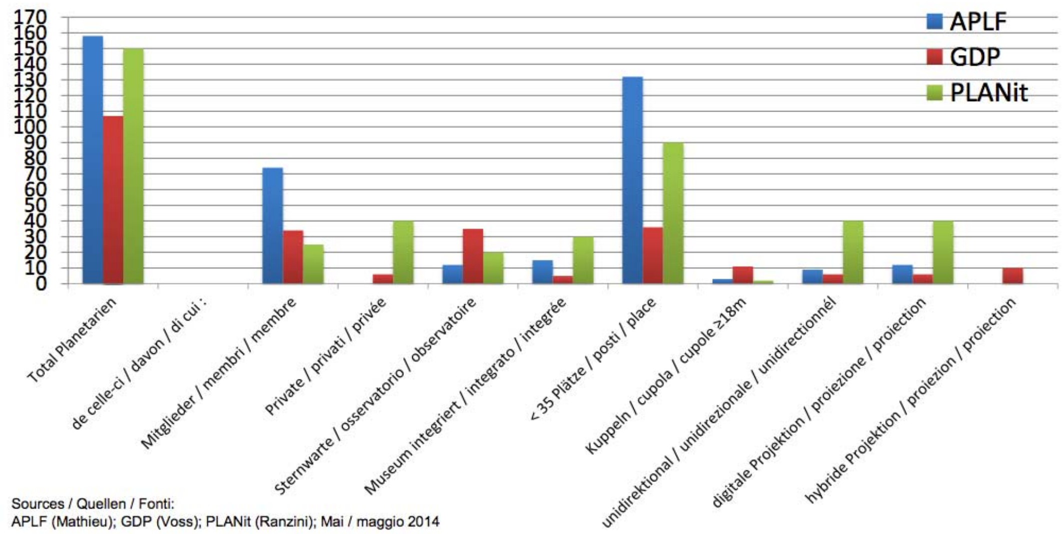


Figure 1. Number and type of planetariums in France, Germany and Italy. Credit: Daniel Schlup, Swiss Museum of Transport.

BAD ECONOMY IMPACTS EVERYONE

It should come as no surprise that there was a very strong agreement among all three association presidents about the current economic crisis impacting the planetarium business. The main concern was about the constantly decreasing personal incomes, as well as the lack of both private and public funding. Even the Swiss had to fight a bit in order to gain the required budget to upgrade the system in Lucerne, which was successful mainly because it was highly supported by visitors' feedback. Interestingly, Italy's PlanIt association was still able to continue its annual project of inviting an American planetarian to Italy, to stimulate young students and high school teachers by showing them different ways to teach astronomy in class. Very recently, the association also introduced an annual competition that gives monetary awards to Italian producers who make either fulldome or flat films on astronomical topics.

The representatives of the three associations unanimously agreed on one point: each association needs to make an extra effort towards engaging planetariums to take part in their national planetarium communities, by offering new reasons for them to be part of them.

Dario Tiveron is a planetarian in Padua, Italy and a leader in the fulldome production scene; his email is dario@fddb.org .

ASTRONOMY IN THE PARK: LINKING CULTURAL HERITAGE AND DARK SKIES

Daniel Brown, *Nottingham Trent University*, UK

Abstract: This article outlines the impact of a project carried out by Nottingham Trent University in collaboration with the Peak District National Park Authority and the Peak District Dark Sky group. The project focussed on engagement with audiences not normally involved with astronomy, unconventional locations for astronomy, and utilizing simple observational skills side by side with advanced astronomy equipment. Visitors experienced how light pollution spoils the night sky and impedes a complete experience of some ancient sites within the Peak District National Park. The events triggered emotional responses from participants and they developed a motivation to help reduce light pollution.

Keywords: Public - Dark Skies - Light Pollution - Cultural Heritage - National Parks - Skyscape

INTRODUCTION

Dealing with light pollution has become a very popular topic, and has led to the introduction of Dark Sky Reserves and similar initiatives to preserve and promote the importance of dark skies. We have carried out a local project based around a National Park in the heart of England that focused upon light pollution education by highlighting its impact on exploring astronomical objects within the local cultural heritage. The project triggered a strong response, including an emotional attachment to the subject of light pollution, and creating an urge for action. The project intentionally used the landscape and ancient monuments -- several standing stone circles -- within the Peak District as an outdoor classroom. This went hand-in-hand with discussions on the historical relevance of these sites, archaeological methodology, and conservation.

In the past, research into learning and teaching has illustrated that non-traditional learning and teaching environments are ideal to maximise the impact of a delivered session (Braud & Reiss, 2004, Rickinson et al. 2004). This is achieved through placing the learning outcomes into a realistic context. The Astronomy in the Park project allowed people to see the impact of light pollution caused by the local community in a way not normally perceived, for example, during a cross country walk at night time. The locations and time of day also created more engaged participants through the informal atmosphere, where participants found they could chat with members of our team rather than carrying out an intense question and answer session. Additionally, a night time outdoor environment removes participants from their usual everyday surroundings, creating the need to be part of a group (Brown et al. 2013). Such innovative environments that are more open to walkers and hobby archaeologists are also ideal to reach audiences that would not normally engage with astronomy, and are sometimes classed as difficult to reach (e.g. younger than 30 or older than 65, from black and minority ethnic groups, or disabled).

To further maximise engagement with the topic of light pollution we linked it with local cultural heritage and ancient prehistoric monuments. Examples of such monuments could be stone circles comparable to Stonehenge that were placed consciously by their builders into a landscape to achieve maximum impact. However, such monuments are not only located within a landscape, but also in a skyscape context (see Silva (2014) for more details regarding skyscape); as such, landscape, monument and participant engage with the sky above, including stars, Sun, Moon and planets.

For us to understand the meaning of a monument many millennia old, it is essential to explore and experience the skyscape surrounding the monument (Brown 2014b). This becomes especially relevant when realising that both the monument and the landscape will have considerably changed as time passed. However, the sky above will have remained virtually unchanged (neglecting precession), allowing us to view what the builders of these monuments would have seen. This has one significant caveat, as it relies upon preserving the dark skies over these sites; without them, we would lose this window into the past and destroy our cultural heritage. This realisation is the key motivator behind our light pollution education work (Brown 2014a).

DARK SKIES IN THE PEAK DISTRICT

The Astronomy in the Park project is based around the Peak District National Park and targets light pollution. The Park was the first of Britain's fifteen National Parks; their distribution and size is illustrated in Figure 1. Founded in 1951, it is an asset of national, regional, and local importance, and plays a special role in the centre of England. Being in close proximity, i.e. one hour's drive away, to the largest population centres in England (including Manchester, Birmingham and Sheffield), it offers access to a large fraction of the population. The downside is it results in a National Park that is penned in on all sides by considerable light pollution, as shown by the light pollution map in Figure 2. Light pollution is indicated through coloured shades of red (high) towards blue (low). This light pollution is constantly encroaching on the park, as shown in recent studies carried out by the

Figure 1. The distribution of National Parks (green regions) throughout the United Kingdom. Solid black dots represent Dark Sky Communities and black regions Dark Sky Reserves or Parks (in several cases this is identical with a National Park) as recognised by the International Dark-Sky Association. Open dots are Dark Sky Discovery Sites (listed by Dark Sky Discovery, STFC).

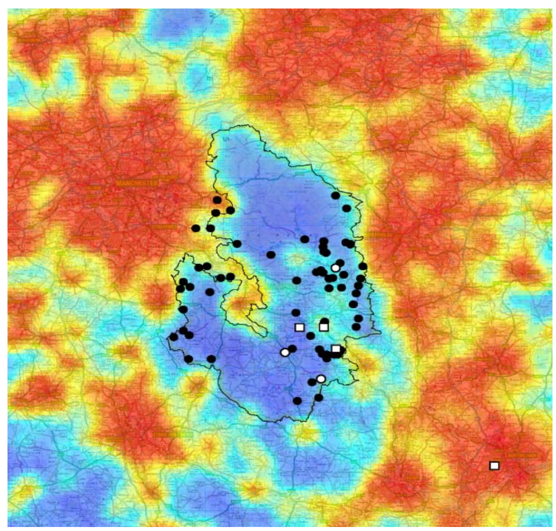


Figure 2. Light pollution distribution in and around the Peak District National Park, edited from PDNPA (2013). The National Park boundaries are highlighted by a solid black outline. Coloured shades indicate light pollution levels, blue for dark skies and red for bright skies. Solid dots display the location of prehistoric monuments. Open dots are locations of three light pollution interpretation sites; the most northern is Surprise View. Open squares indicate light pollution education event sites.

Peak District National Park Authority (PDNPA, 2013). To add to the external factors, the park contains many large villages and a town, making this National Park one of the most populated in the United Kingdom (UK).

The main purposes of National Parks are to conserve and enhance the natural beauty, wildlife and cultural heritage of each park, and to promote opportunities for the understanding and enjoyment of their special qualities by the public. One of the recognised special qualities of National Parks is the ability to experience dark skies at night, supposedly unhindered by light pollution. To support this special quality in light of the challenging environment of the park, the Astronomy in the Park project set out to establish a sustainable light pollution education project for the general public.

For example, to achieve a Dark Sky Reserve or Park status (both international projects), strict lighting audits and planning regulations need to be put into place, ensuring preservation of dark skies (IDA 2013). Due to the highly populated nature of the Peak District, this route was a difficult one to follow, and not an outcome that could be achieved initially. Additionally, the establishment of such a region has to be heavily supported and driven at a council or park authority level.

The Dark Sky Discovery project, a national initiative, was a result of the International Year of Astronomy (2009) and was realised in 2012 (Male 2008). The project aimed at establishing many smaller locations that allow the observation of the night sky. These Dark Sky Discovery Sites (Dark Sky Discovery 2013) cover the entirety of the United Kingdom, as illustrated in Figure 1, and have, as of 2014, reached nearly 100 locations (STFC 2014). However, they displayed a lack of coverage in the Midlands region of England; the only existing Dark Sky Discovery Site there has been established by our group as a result of our project.

To also illustrate the impact of light pollution during our activities, we chose locations that offered a vista that included light polluted and unpolluted views. We also tried to embed the experience of moving from lit areas to the dark nocturnal landscape in order to evoke an emotional response identified by Brown (2014a) as a vital educational tool.

PROJECT AIM

Given the rich cultural heritage of the region, including landscapes shaped by ancient societies, together with highly accessible dark sky locations, our project focused on two main objectives: firstly, carrying out small scale events to engage the general public with light pollution at ancient monuments; secondly, developing sites to explore light pollution within the context of the landscape and cultural heritage. A typical small-scale event is discussed at length in Brown (2013), and was located in a village hall close to an ancient monument; the locations are indicated by open squares in Figure 2. The event included an inflatable planetarium with a tour of the night-sky to develop basic naked eye astronomy skills such as understanding the changing rising and setting location of the Sun on the horizon, and over the seasons. This was used as a hook to analyse the astronomical knowledge of ancient societies and ancient methods to find North, such as the Indian-circle. Visitors were then guided onto the ancient site, where we allowed for a critical discussion in-situ of light pollution within the

Figure 3. A group of visitors exploring the ancient Nine Ladies stone circle at Stanton in Peak.

village and beyond. On location they were introduced to the history of the landscape and of the monument itself (Figure 3). Local astronomical societies were present to supply additional information on basic astronomy skills and also allow visitors to explore some of the fainter astronomical objects using small telescopes. During the entire event, visitors were able to experience how our cultural heritage is not only defined by the landscape and monument, but also by the stars above and, therefore, the skyscape.

Three light pollution exploration sites were determined during the project that either included ancient monuments on the horizon or were in close proximity to such monuments. We developed permanent interpretation boards that were seasonally updated (Figure 4). The light pollution map in Figure 2 illustrates the location of our three sites identified for light pollution exploration and identifies them as open dots.

Figure 4. This is Surprise View in the Peak District National Park in the United Kingdom, within its landscape context. Note the quality of the path leading from the car park, past the panel and towards the viewpoint. It allows free and safe access for all members of the public. Surprise View has recently been designated a National Dark Sky Discovery Site.

Additionally, the three locations at which we carried out promotional events are indicated through open squares. All the sites and locations are at dark locations, but are in the proximity of some local light polluters, for example, the town of Bakewell or the city of Sheffield.

LIGHT POLLUTION INTERPRETATION PANELS

A close up of a light pollution interpretation panel located near a prehistoric burial site at Minning Low is shown in Figure 5. Each interpretation board illustrated what could be observed during each season at one to two hours after sunset. Furthermore,

Figure 5. This is a close-up of the permanent interpretation panel located close to Minning Low, one of the three light pollution exploration sites in the Peak District National Park in the United Kingdom. The permanent interpretation panels are seasonally updated, illustrating astronomical objects that are easy to observe, but suffer from light pollution.

the design included a striking astronomical image of an object that can be easily observed with the naked eye, if conditions allowed including if the sky is sufficiently dark, e.g. the Andromeda Galaxy. A brief description of the object was included, stating that the image has been gathered by an observing facility that has STFC and UK funding. Through these images,, visitors become aware of in what astronomical projects the UK is involved, and how fascinating these objects are. The sky chart gave instructions on how to locate the object, making it possible to observe it there and then.

To make the sky charts relate to the surrounding landscape and support the skyscape experience, we included a realistic visualisation of the landscape on site. Along the horizon, major settlements were marked, including the light pollution domes. We also included the changing rising or setting positions of the Sun to further encourage visitors to engage with the local skyscape and become more aware of the skies above them. Images of the landscapes were gathered by pre-16 Nottingham Trent University (NTU) placement students and imported into the free Stellarium planetarium software. Through this involvement of NTU students, we ensured a wider impact which also resulted in a commendation for the Green Gown Award 2013 in the category of Social Responsibility for our NTU Astronomy Placements: A Placement in Time (EAUC 2012). Quick Response (QR) codes allowed visitors to access further information online, including a planetarium landscape for each site via free mobile phone apps. We chose Stellarium as a visualisation tool given for its potential to explore the skyscape experience, as outlined by Brown (2014c).

The information on the panel described the impact of light pollution, but never points out any communities responsible for the light pollution on site. It was left to the visitor to explore for themselves where the light pollution originated from, and be amazed by how bright their own village can appear at night.

PROJECT IMPACT

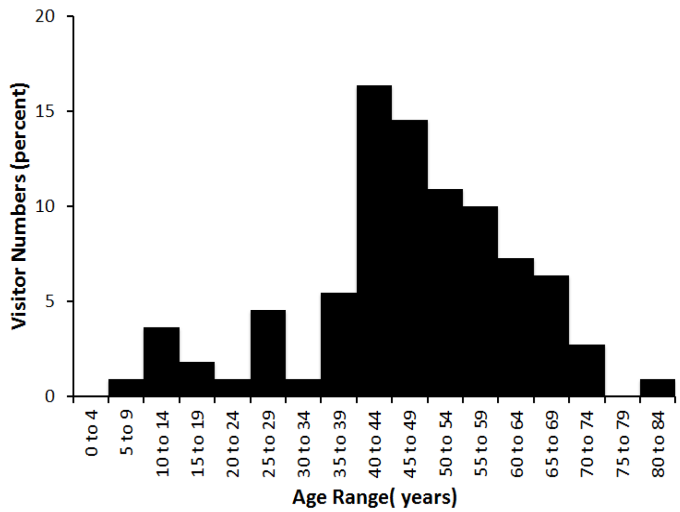


Figure 6. The visitor number in percent plotted against the age in bins of 5 years. The total number of participants providing their age was 110. The data illustrates the wide range of ages engaging with the project, including hard to reach audiences with ages below 30 years and above 65 years.

During our project we interacted with more than 4,000 visitors in various locations, including an invitation to present our work at the Midlands BBC stargazing live event in 2012. The project also reached out to wider audiences by indirectly interacting with visitors through the interpretation panels (since the locations of the three dark sky interpretation panels are popular amongst tourists and locals), resulting in a high foot traffic. The impact was monitored through evaluation forms (an example is given in the Appendix)

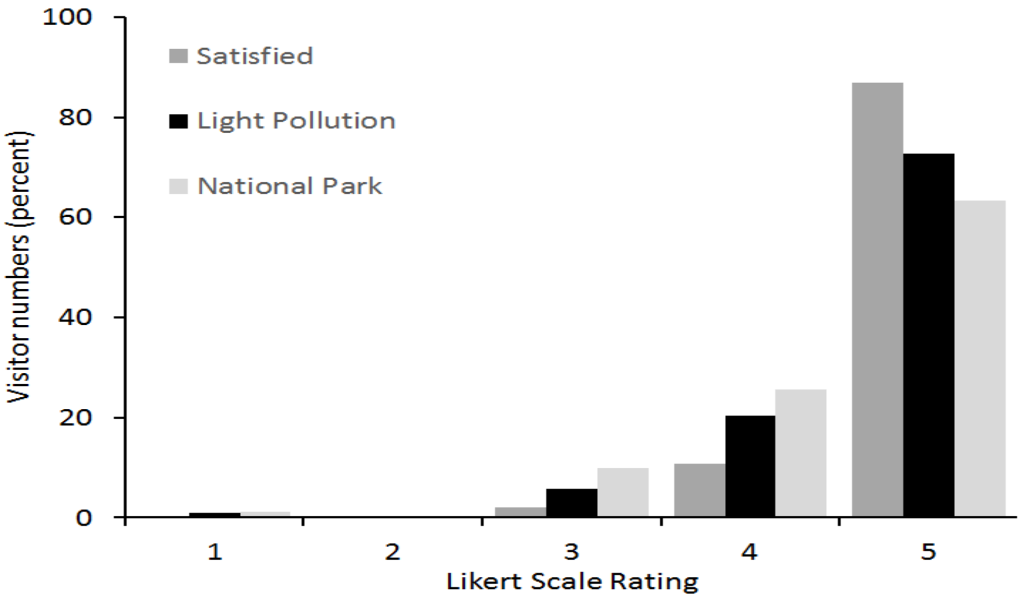


Figure 7. The response frequency is plotted against a Likert Scale from 1 (learnt nothing or unsatisfied) to 5 (learnt a lot and very satisfied) for the three analysed responses: Overall satisfaction with the events (dark grey), have participants learnt anything about either light pollution (black), or the special qualities of the National Park (light grey). The total sample of responses for these questions was 104.

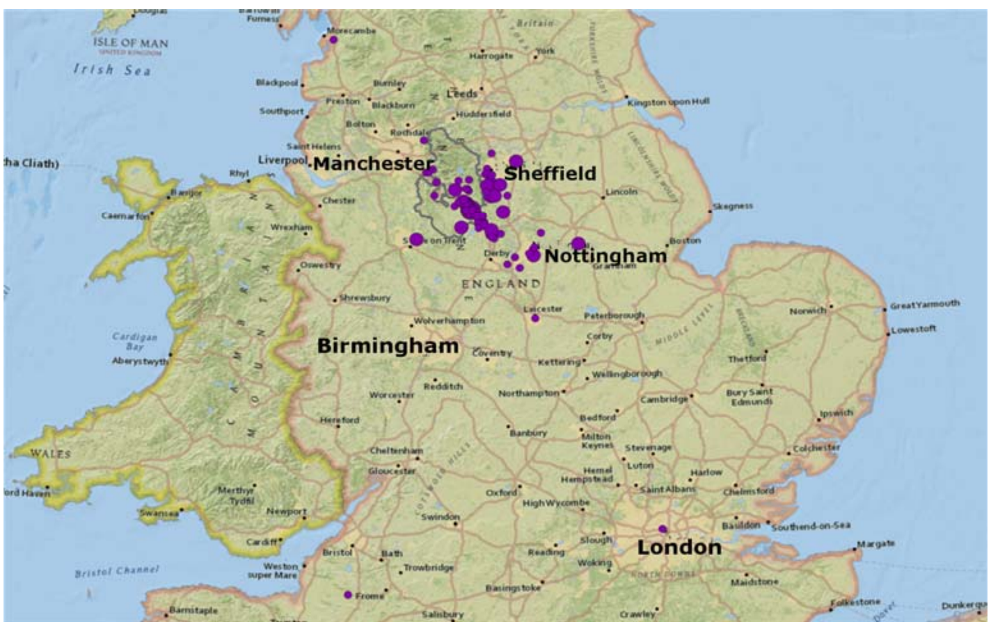


Figure 8. Distribution of our 110 participants across England as determined by their postal code. The larger the circle, the more participants lived at this postal code. It is clearly visible that a large fraction of visitors originate from outside of the Peak District National Park.

at specific events at Stanton in the Peaks and Bakewell, which constituted a mix between interactive light pollution and skyscape exploration, as well as planetarium and exhibition events. Unfortunately, given the limited time and resources, feedback could not be gathered at the location of the interpretation panels. Through this feedback we gathered information from 110 visitors who volunteered out of the directly engaged 400 visitors at the smaller events. The overall age distribution is shown in Figure 6, indicating that we have covered a very wide age range, but we did predominantly target an audience older than 40. It is also seen that we have interacted, to some extent, with secondary school aged participants. With respect to difficult-to-reach audiences, we managed to engage a 12% share of those under 30 years as well as 10% older-than-65 years; 2.7% identified themselves from Black and Minority Ethnic Groups, and 5.5% had self-identified long-term limiting illnesses or diseases (disabled).

Evaluation data displayed in Figure 7 showed that our events were well received (with a 4.9 out of 5 satisfaction rating), and that visitors felt that they had learned a large amount, both about the special qualities of the National Park and astronomy (with a 4.6 out of 5 education rating). We also enquired if the participants were interested in finding out more about astronomy or the cultural heritage of the region; the majority of respondents left the activities with the intention to find out more about history (86.3%) and astronomy (92.7%). The overall distribution of the origin of the participants (shown in Figure 8) reveals that we attracted members of the public from within the National Park, but also outside the wider Peak District, in some instances as far afield as London.

However, these are only raw statistics, and we intended to generate an emotional response and an urge for action. To illustrate the response we analysed the general comments provided by 64 (58%) of the 110 participants. Comments included calls for *what can be done to reduce light pollution* regarding a local Sainsbury supermarket, as well as *(it) inspired us to look at the stars more and try to help stop light pollution as much as possible*. Visitors enquired as to how they could personally combat the effects of light pollution or make sure unwanted light is reduced in their neighbourhood. Feedback forms are not an ideal format to record an emotional response from visitors engaging with our events, and results in capturing our rather incomplete picture. Semi-structured interviews would provide a better format.

Given our initial findings, Brown (2013) carried out a more detailed analysis of light pollution education as one example of education for sustainable development, specifically focussing upon critical place-based learning. A case study approach was chosen and semi-structured interviews were carried out with seven individuals engaging with our project. With respect to the above mentioned emotional responses, the interviews were coded and the results summarised over all seven interviewees with respect to what emotional response the event itself had, as well as the emotional impact of the location. This more robust analysis confirmed the previous anecdotal findings, with interviewees describing the event with phrases such as *enthused*, *keen to engage*, *interest* and *provokes thought*. The emotional response the locations caused was described as *interesting*, *potential*, and *amazement*. The sense of awe and wonder caused by feeling in touch with the sublime is illustrated by one visitor:

> *And it felt as though you were, if the skies were clear, yes you could have been in touch with the solar system I suppose. You could have seen thing, you could have really seen things.*

The impact a location or place can have, through removing visitors from their everyday environment and establishing ideal conditions for transformational learning, is also illustrated by another visitor:

> *When you were up there, you couldn't see, or I didn't notice the village or see it, so I didn't know which way to head. It was quite an interesting experience, to be lost but not really.*

The substantiated interest and deep impact has allowed the project to generate a long lasting legacy. One of the light pollution sites, at Surprise View, has become a National Dark Sky Discovery Site, one of a growing number within the Midlands of the UK. This was triggered through our intensive work at the site (Brown et al. 2012), resulting in several resources (Brown 2012) that lead to a successful proposal (PDNPA 2012); additionally the National Dark Sky Discovery Project invited key members of our project to assist in their further work in the region (Hillier 2012).

To respond to the eagerness for action among the general public, we are developing a Dark Sky Community Award that will allow local communities to take ownership of projects to reduce light pollution in their immediate locality. This award is seen as an approach to ultimately achieving an International Dark Sky Reserve Status from the International Dark Sky Association.

CONCLUSIONS

The Peak District National Park is not a wilderness; it is an area of 555 square miles of mostly privately owned land, inhabited by approximately 38,000 people in 20,000 dwellings. Since the National Park is a lived-in and working landscape, artificial light is prevalent. We believe that directly engaging with individual communities, rather than the entire National Park, will result in communities becoming emotionally involved in reducing light pollution, especially as astronomy and light pollution have such a high media profile. This project not only interacted directly with 4,000 visitors and analysed the impact upon a sub-sample of 110 participants, we also created unique light pollution interpretation panels that used the experience of observing to engage participants with light pollution. These sites offer a huge potential for educating the public, confirmed through the nomination of the site "Surprise View" as a Dark Sky Discovery Site, tapping into topics so far not covered by other Dark Sky Discovery Sites. It is hoped that this enthusiasm will spread to other communities throughout the National Park, and that the Peak District will remain an excellent location from which to enjoy dark skies.

ACKNOWLEDGEMENTS

We would like to thank all members of the Dark Sky Group involved and the many NTU work placement students. We would also like to thank John Tanner, who was heavily involved in developing an initial draft of this paper.

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APPENDIX A

An example evaluation form used for the cultural heritage and light pollution events in the Peak District National Park, United Kingdom.

Have your say

Astronomy in the Park

PEAK DISTRICT NATIONAL PARK AUTHORITY

Thank you for taking the time to fill in this survey, the information we collect will be used by the Peak District National Park Authority and its partners to improve our service to you.

REF: ______ office use only

Q1 Date of visit ______

Q2 Overall, how satisfied are you with this event?

unsatisfied ☐ ☐ satisfied ☐ ☐ very satisfied ☐ don't know/NA ☐

Q3 How much have you learned about what makes this National Park special as a result of this event?

nothing ☐ ☐ a little ☐ ☐ a lot ☐ don't know/NA ☐

Q4a Are you a visitor to the National Park?

☐ Yes (go to Q4b) ☐ No (go to Q5)

Q4b Are you staying overnight?

☐ Yes ☐ No

Q5 How did you travel here?

☐ Bicycle ☐ Car ☐ Motorbike ☐ Train
☐ Bus ☐ Coach ☐ On foot ☐ Other

Q6 How did you find out about this event?

☐ Radio ☐ Internet ☐ Newspaper
☐ Televsion ☐ Word of mouth ☐ Other (please specify below)

______

Peak District National Park Authority, Aldern House, Baslow Road, Bakewell, Derbyshire DE45 1AE
Tel: 01629 816200 Fax: 01629 816310 Email: customer.service@peakdistrict.gov.uk

www.peakdistrict.gov.uk

Q7 How much have you learned about the impact of light pollution as a result of attending this event?

nothing ☐ ☐ a little ☐ ☐ a lot ☐ don't know/NA ☐

Q8 As a result of this event, are you interested in finding out more about ancient history?

☐ Yes ☐ No ☐ don't know/NA

Q9 As a result of this event, are you interested in finding out more about astronomy?

☐ Yes ☐ No ☐ don't know/NA

Q10 Do you have any general comments?

☐

Q11a Do you live in the United Kingdom?

☐ Yes (go to Q11b) ☐ No (go to Q11c)

Q11b What is your full postcode? ____________________ (go to 12)

Q11c Which country do you live in? ____________________

Q12 In what year were you born? ____________________

Q13 Are your day-to-day activities limited because of a health problem or disability?

☐ Yes ☐ No

Q14 What is your ethnic group?

☐ Asian British Indian	☐ Black British Caribbean	☐ White British	☐ Mixed White Black African
☐ Asian British Bangladeshi	☐ Black British African	☐ White Irish	☐ Mixed White Asian
☐ Asian British Pakistani	☐ Black British Other	☐ White Other	☐ Mixed Other
☐ Asian British Other	☐ Chinese	☐ Mixed White Black Caribbean	☐ Other

If you are under 16, please ask an adult to sign here to show that you have permission to complete this survey. ____________________

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Instructions for Authors

The *Journal and Review of Astronomy Education and Outreach (JRAEO)* seeks to publish the highest quality articles that advance the understanding of astronomy teaching and learning and are likely to have a significant impact on the field of astronomy education and outreach. *JRAEO* welcomes manuscripts from authors around the world and from all theoretical frameworks and research methodologies.

Types of Manuscripts

You may submit a variety of materials for publication in *JRAEO*, provided they are not currently under consideration by other journals, nor previously published. Manuscripts can be in but not limited to any of the following type:

Research: All articles in *JRAEO's* Section A are peer-reviewable scholarly research. We accept quantitative, qualitative and mixed methods research articles. All undergo rigorous double-blind reviewing and are held to the same high standards for sample sizes, statistics, inference making and so on.

Articles should discuss the importance of the study to the field. A relationship between the study and previous work is generally needed. Methodology should be reported concisely.

All other articles are placed into *JRAEO*'s Section B. These include:

Commentary [Hypothesizing]: Invited or unsolicited 'white papers' on a topic of interest to the astronomy education, formal or informal, communities.

Ideas [In the Astronomy Education Universe]: These are items that may be of value to teachers or to those seeking research ideas, but are not necessarily peer-reviewable materials. Among these are ideas that have been tried out in classrooms as in-house experiments that could be more rigorously investigated later.

General features: Similar to those found in the editor's column [Field Observations] that take a more informal look at some item of interest to the community.

Other types of articles may be accepted.

While many articles have practical considerations for a teacher, *JRAEO* does not currently accept most practitioner articles, such as how-to-do or resource list stories. These may be submitted to a Hermograph sister publication, *The Classroom Astronomer* (www.classroomastronomer.com) .

Language

The language of the journal is English. We accept articles using both American and British English conventions. Articles from non-native English writers are also accepted, in English, though we request that all possible attempts to perfect the writing be done before it is submitted. We will do our best to make linguistic corrections unless doing so effectively and substantially rewrites the text. An additional abstract in the other language is welcome.

Formatting and Submission

Articles should be pre-formatted in APA style, in any version as far back as version 5. We have some "local" rules as well. The list of these is maintained on the *JRAEO* website, but include such things as having two spaces after a full stop (a period, question mark, exclamation point, or colon), certain subheadings which can be bold, and a space follows a URL and then the period, etc.

Articles can be submitted at any time by emailing them in a zipped, archive file to JRAEO@toteachthestars.net. An Article Submission form, also found on the website, which contains contact information, preferred keywords, and other information, must be submitted at the same time.

Being an all-digital publication, there are no size limitations in terms of word count or page numbers. However, you have a better chance of a quicker acceptance if the author 'writes tight.' Superfluously worded articles may be sent back for rewriting even before the peer review process begins. Implications, backed by supporting evidence, are paramount.

Data tables should be easy to read and with all, and only, appropriate information. Color images (in graphs, graphics, or photographs) are welcome. All figures and tables should be sent in separate files though they may be also included in the text for help in final placement.

In addition to the instructions listed on the Information for Authors page, changes and current information can be found on the website at www.jraeo.com. If the first author is a subscriber, there is a reduced page charge/open access fee. Being a subscriber is *not* to be construed as a right to be published. To reduce the page fee, *the first author* must be a subscriber *before* the article is submitted.

Review

All Section A articles are reviewed in an anonymous double-blind peer process by at least two reviewers. Some Section B pieces are reviewed double-blind by one reviewer. The editors often raise questions, and partially edit the submission both before and after the peer review process in order to improve the submission's quality and its chances for acceptance.

As a journal with a publication schedule, and thus, deadlines, we try to put accepted articles into the next issue, but this is not guaranteed. We also try to have articles reviewed and sent back to the author(s) within about 10 days from submission. Authors need to make corrections and return the revised manuscript in no more than a week to ten days after receiving the reviewers or editor's corrections. Late returns can mean a change in publication schedule of the article, or rejection of the article.

DR. LAWRENCE KRUMENAKER is the Editor of *JRAEO*. Dr. Krumenaker has deep roots in the astronomy education community, having been an astronomy and physics instructor since the 1980s at various universities and colleges. His Ph.D. was in science education from the University of Georgia. The 2008 dissertation was entitled "The Status and Makeup of the Modern U.S. High School Astronomy Course in the Era of No Child Left Behind," which generated three articles in *Astronomy Education Review*, and others in *The Science Educator* and *The Planetarian*. His current research involves astronomy education in other countries.

Krumenaker has worked in journalism since the late 1980s, having started at ABC's *20/20* show as a researcher of science stories. He has been published in numerous astronomy, science, and computer magazines, and is currently the publisher and editor of *The Classroom Astronomer* magazine. Krumenaker is a member of the National Association of Science Writers and the International Science Writers Association. As an astronomer, he does stellar spectroscopy, from time to time, of cool and emission-line stars. One of his key research results was the discovery of the Milky Way's only microquasar, SS433.

DR. KRISTINE LARSEN is the Assistant Editor of *JRAEO*. Astronomy education and outreach have been the central focus of her decades-long career, beginning in 1981 when, as a college freshman at Central Connecticut State University, she began working as a planetarium lecturer and observatory assistant. While completing a Ph.D. in Theoretical Physics at the University of Connecticut, she returned to her alma mater as a faculty member in 1989, where she currently holds the rank of Professor in the Physics and Earth Science Department and serves as Faculty Coordinator of the Copernican Observatory and Planetarium. She teaches courses in introductory astronomy, observational astronomy, and astrophysics, as well as courses for pre-service teachers and interdisciplinary courses for both the University Honors Program and First Year Experience Program.

Larsen's scholarly work focuses on the intersections of science and society, especially science pedagogy and outreach, the history of women in science, misconceptions of science, and depictions of science in literature and film.

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Section A – Research

Section B – General Articles

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