Recent Developments in Physics Education In Canada.

Work in physics education can take many forms. Some is research-based, such as the modeling of students’ conceptual understanding and cognitive processes. Some work focuses on designing and developing best instructional practices (pedagogies, curricular materials, laboratory activities). Some focuses on the preparation of future teachers or outreach activities for the public. Attention to physics education helps sustain healthy undergraduate and graduate enrollment in physics programs and helps prepare –and maintain - a vibrant community of professional physicists in academe and industry. In this special issue, we showcase some recent developments in physics education since the previous update 5 years ago ( T. Antimirova et. al., Physics In Canada **65** (1), 19-22 (2009)). In this article we present an overview of physics education in Canada including papers on Physics Education Research (PER), best teaching practices and teacher preparation.

There is a clear and growing interest in physics education among Canadian Physicists. While the overall membership in CAP has been static, membership in the Division of Physics Education (DPE) has grown by more than 50% in less than 10 years. The DPE sessions at the CAP congress are normally held in the larger halls and often overflow the capacity of the room. There were only two DPE sessions at the 2005 congress. In 2013 there were 5 regular sessions plus a joint session with CEWIP. These are in addition to the special plenary talk given by the recipient of the CAP medal for excellence in teaching. In the last several years, CAP congress featured invited talks with high-profile speakers like Nobel Laureate Carl Wieman who has turned his attention to improving Physics/Science education. While Wieman gave the Herzberg Memorial Lecture at the 2007 CAP Congress in Saskatoon, Harvard professor Eric Mazur - the father of Peer Instruction - delivered a plenary talk at the 2008 Congress in Quebec City. Last year, the plenary talk was given by Edward (Joe) Redish, an internationally recognized PER scholar and the founding director of the renowned PER group at the University of Maryland.

Within this context of interest and growth of physics education in Canada, the editor of Physics in Canada (Béla Joós) and of its education corner (Rob Thompson) suggested this special issue at the 2013 CAP Congress. The objective is not to provide a set of papers that paint an exhaustive picture of Physics Education in Canada. Each paper in this issue presents a brief sampling of interesting work done in different institutions across the country. We simply provide a snapshot of a select number of recent developments in Physics Education in Canada. We received a total of 25 proposals. All articles were refereed by at least two reviewers. Ultimately we ended up with selecting twenty articles covering the following areas:

I- Physics Education Research in Canada

The field of PER in Canada is relatively new and growing. Doctoral programs in PER are found at the University of British Columbia, the University of Calgary and Concordia University in Montreal. We also received articles in PER outside of these institutions that indicate a widespread interest in the field. While these are particular examples of initiatives sampled across Canada, at the same time they represent emerging trends and show the direction in which Canadian PER is going.

In a paper by Harlow et al, students’ attitudes about science are explored in conjunction with the breadth of courses and students’ interactive engagement. They find that student engagement positively shapes their attitudes and views on the nature of science. An interesting PER study is presented by Williams *et al.* and assesses whether students interacting during peer-instruction activities respond to peer-pressure. They find that the combined effect of random guessing and students who voted but did not participate in the peer interaction process was substantial. In another quantitative PER study, Harrison quantifies the uncertainties associated with final grades in physics courses and finds that they are at least 4% and probably much larger. A paper by Wang & Kalman (winner of the 1999 CAP Medal for Excellence in Teaching Undergraduate Physics), describes how to improve students’ understanding of physics. They describe how students’ beliefs about the nature of knowledge and knowing (i.e., epistemic beliefs) in physics have important effects on how they learn physics. They go on to describe three learning activities that were designed to advance students’ epistemic beliefs. Day et. al. consider how a good invention activity should present a readily interpretable goal and engaging scenario to the student. Holmes examines the well-studied notion that women are under-represented in the physical sciences. Finally two graduate students Khanam (Concordia university) and Sobhanzadeh University of Calgary) focus on using reflective writing activity and laboratory exercises to help students understand the scientific conceptions covered in introductory physics courses.

II- Implementing Physics Education Research-informed pedagogies

An interesting implementation of a studio-physics program for grades 11 and 12 is carefully described and thoroughly documented by York Mills high school teacher Meyer. Many of the large learning gains documented in the PER literature are replicated and at times even surpassed. Whittaker (a 2013 winner of CAP teaching prize for High School and Cegep teaching) and Charles describe in another paper how research can inform classroom design. The paper builds on research findings showing that the central focus in classrooms should not be on the teacher but students and their social interactions (include peer-to-peer interactions and novice-to-expert interactions). In another paper by Charles et al, the construction of a community of practice composed of post secondary science instructors is described. The aim of the resulting SALTISE consortium is to support the implementation of pedagogical innovations. Aligned with the idea of implementing, replicating pedagogical innovations and making them sustainable and lasting, this issue features a number of papers that document the implementation of PER-informed pedagogies in various contexts.

III- Preparing future physics teachers

Two articles describe a growing focus on the preparation of future physics teachers. In a paper by Milner-Bolotin (winner of the 2010 CAP Medal for Excellence in Teaching Undergraduate Physics), a course aimed at future physics teachers brought PER results into the classroom and challenged future teachers to design PER-informed conceptual resources for physics teaching. In another article on the preparation of future physics teachers, Bullock describes his attempt to help future physics teachers develop strategies for using PER findings in their future work as secondary school teachers.

IV- Physics Outreach in Canada

An example of outreach initiative is providedby Bluteau & Barkanova. The paper describes an initiative to share Bluteau’s experience as a student participating in an honours summer research program at CERN. When he returned, Bluteau delivered outreach presentations at local Nova Scotia high schools about his time at CERN, particle physics, and physics as a career option. The authors argue in favour of the student-driven, students-delivered outreach.

V. Active learning and engaging students

A great deal of attention has been paid in the recent years to reforming introductory physics classes, while innovations in the upper division courses are still long overdue. Hawkes (winner of the 2000 CAP Medal for Excellence in Teaching Undergraduate Physics) focuses on the implementation of the original seven principles of effective undergraduate education at the upper level undergraduate physics courses. The paper argues in favor of designing upper level physics courses that more faithfully replicate the work of professional physicists.

At the undergraduate level, there is often sizable overlap between introductory physics and calculus. In a paper by O’Meara et al., a new course is described where Mathematics and Physics are now being taught in an integrated fashion that demonstrates how they support and enrich one another. This initiative is an exciting opportunity to enhance first-year science education and stimulate growth in existing programs.

The shift toward more formative assessments is a trend it today’s education.

An article on quizzes as learning experiencesby Ives provides an example of this trend. His article describes a weekly quiz implementation which incorporates peer interactions in the form of follow-up collaborative group quizzes, and additional formative assessment through post-quiz reflection assignments.

Technology can bring new opportunities to the classroom. Using videos and video analysis for physics teaching is still relatively new in Canada, although it is quickly gaining popularity. The article by Lenton and Adams discusses student-generated videos and their role in the physics classroom. They describehow two distinct video creation activities (videos analyzing real-world motion and videos explaining physics concepts) helps to engage students in active learning in their institution.

VI. Other initiatives

Michal considers a set of lab activities based upon the hardware and physics of magnetic resonance imaging, while Adams & Chen consider using studies in photonic-related fields in a waves for modern physics course. Rieger et. al. consider having students perform some experiments at home and bring the data to class for discussion and analysis.

Growth in the Canadian economy requires a cadre of technically trained personnel. Mathematics and science education throughout the country need to be improved dramatically if Canada wants to remain competitive in the 21st century. Canadian students do not perform badly in international comparisons of mathematics and science reasoning, but their ranking has slipped (OECD, 2009; TIMSS, 2007).

Student dropout in physics courses is a loss that must be stemmed. We conjecture, that if we pay more attention to improving physics education, then we can expect more success in the understanding of the subject by our students, which in turn should result in scientific research by future graduate students that would advance the Canadian economy.

We hope you enjoy finding some ways to improve your own classrooms as you read through the following articles. Sincere thanks to all authors for their contributions.

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Guest Editors