TITLE OF PAPER:

TOWARDS A RESEARCH-INFORMED PHYSICS CURRICULUM FOR SECONDARY SCHOOLS

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Abstract

What is the extent of educational research outcome filtering down to teacher education and to teacher practice in classrooms? How do teachers maximize their professional development from research outcomes in their subject areas? How do teachers upgrade their professional practice with direct involvement in research? These are questions with no easy answers pertaining to the purpose of educational research.

The practising teacher may instead ask: Why not bring research outcomes and research-informed practices directly into my subject curriculum? A move towards a research-informed curriculum within schools could help to shorten the timeline for well-established research outcomes to benefit teacher classroom practices and student learning. It could also provide a platform for suitable customization of a subject curriculum with research-based assessment and review by the users - the teachers themselves.

This paper proposes an approach in

1. redesigning a secondary school physics curriculum with the infusion of research outcomes into pedagogical and assessment practices, and
2. encouraging teacher involvement in research practices to support the review of the physics curriculum implementation.

Some issues of the physics curriculum redesign to be explored include

1. physics education research outcomes useful for a physics curriculum,
2. benefits of redesigning the normal curriculum into a research-informed curriculum,
3. teacher-readiness in redesigning and implementing the revised curriculum, and
4. student-readiness for research-informed practices.

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Objectives

The objectives of this paper are

1. to propose a redesign of the physics curriculum to infuse educational research outcomes into pedagogical and assessment practices, and
2. to explore the issues related to this curriculum redesign.

Motivation

Based on my own teaching experience and observation of the trends in the educational field, I feel that it is no longer sufficient to understand how well we've taught or how well our students' have learnt or how effective is our teaching practice, just based on our professional experience or anecdotal evidence. We have to move towards the use of systematic research instruments or methods to evaluate our teaching and our students' learning.

Teachers often learn new ways of improving the curriculum, "more effective" teaching strategies and assessment practices via various channels. These channels may include the attending of workshops, courses or conferences, the reading up of books, journals or the internet, the discussion with colleagues, from department reviews, or through one's own teaching experience.

In most instances, the learning of these new "improvement" techniques may be on an ad hoc basis. The learning process may be made compulsory by the department or the school. Without subsequent follow-up or application in the school, the learning may not be

sustainable in the long term. It may also involve "new" or "better" methods promoted by individual practitioners or popular speakers, but whose values are yet to be verified by educational researchers.

Instead of "ad-hoc" or "directed" instances of curriculum improvement efforts, whose values may be questionable, why not systematically incorporate curriculum improvement based on current professional knowledge in the field? First, this means carrying out a search and review of current knowledge and ideas derived from research outcomes and/or professional studies, both from external sources (in the literature) and internal sources (from teachers' own educational research). This is followed by integrating the knowledge into the curriculum content, as well as into pedagogical and assessment practices.

Redesigning the Physics Curriculum

Figure 1 shows a simple framework illustrating the central role of the learner embraced by the curriculum, pedagogy and assessment. Redesigning the normal physics curriculum refers to infusing educational research outcomes (from external research literature and internal teacher-initiated research, e.g. action research), into the curriculum, as well as into pedagogical and assessment practices, as represented by **Figure 2**.

Figure 1 Normal Physics Curriculum

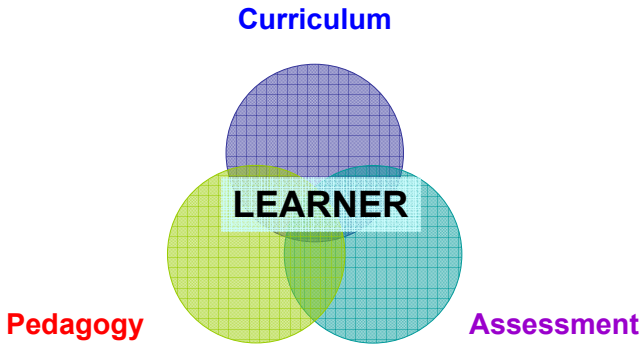
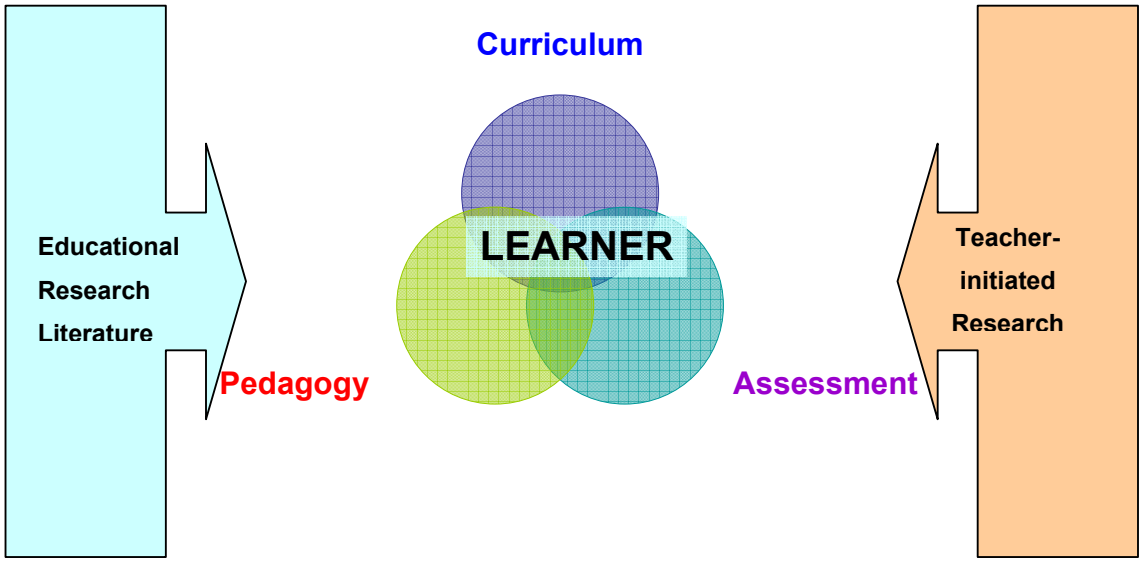


Figure 2 Proposed Research-informed Physics Curriculum



Redesigning the physics curriculum would change the characteristics of the curriculum with respect to pedagogical strategies, diagnostic and assessment practices and the curriculum review process. These changes are summarized in **Table 1** below.

Table 1 Comparison of Curriculum Characteristics

Normal curriculum (based on GCE O level syllabus)	Proposed Research-informed curriculum
1. The list of topics to be covered may or may not have a list of common learning misconceptions or learning difficulties, which are 2. obtained on an ad hoc basis from teacher experience, workshops, colleagues, books, etc.	1. Topics covered would be linked to a comprehensive list of common misconceptions or learning difficulties highlighted by research, and 2. obtained systematically from a review of research materials from educational research literature, or teacher-initiated research.
3. It may or may not have a list of pedagogical strategies.	3. It includes a list of pedagogical strategies to be employed for different topics based on research.
4. The assessment includes quizzes, tests, and exams.	4. The assessment also includes diagnostic tests to determine learning difficulties/misconceptions on different topics for each batch of students.
	5. It encourages the conduct of teacher-initiated research on learning difficulties or misconceptions identified, and the effectiveness of intervention strategies.
5. Curriculum is reviewed and changes are made based on teachers' experience and knowledge.	6. It also uses research outcomes (whether external or internal) to review the curriculum and to make informed decisions on changes.

Why Re-design the Curriculum?

What are the benefits of redesigning an existing curriculum into a research-informed curriculum? Physics educational research (PER) has amassed a significant amount of knowledge on teaching and learning (Dancy & Henderson, 2005). Many research-based curricula developed at American research universities are being adopted by departments at other types of institutions (Loverude, 2004). Much of these research-based physics knowledge can be found on the internet. A good source is "PER-Central" which gives a collection of information and resources on PER, from mostly American universities as well as universities engaged in PER from other countries such as Australia, Israel, South Africa, U.K., South Korea and Sweden. There are also PER resources in print. "Five Easy Lessons" (Knight, 2004) describes learning difficulties and teaching strategies distilled from PER, and "Physics Teaching using Physics Suite" (Redish, 2003) discusses PER findings, and provides lesson resources and diagnostic tests.

Willinsky (2001) used the analogy of "evidence-based medicine" to call for a similar approach of "evidence-based education" in giving teachers' ready access to the vast amount of educational research to help them in their efforts to improve teaching and learning. Willinsky suggested the setting up of an online educational research portal to "increase and improve access to all of the available evidence", so as to "expand the opportunities for learning and exchange all around." Brusling (2005) reviewed the literature surrounding the discussion of evidence-based practice in education, an idea borrowed from the health sciences. He concluded that there is still much room for educational researchers to work on providing a cumulative empirical evidence for effective practices, based on research of the randomised control trial (RCT) kind. He concluded there are issues with the transfer of evidence-based practice to teaching and teacher education, but he has no doubt that there is a

need for improvement in the dissemination of "research results and interpretations of what they might mean for policy and practice".

By systematically reviewing and infusing the research-based outcomes into pedagogical and assessment practices, this would help

1. to provide teachers with evidence to pursue certain pedagogical or assessment practices,
2. to shorten the timeline and improve accessibility of well-established research outcomes to benefit teacher classroom practices and student learning,
3. to make research-based learning through the curriculum a sustainable effort for teachers,
4. to provide teacher researchers a platform to share their research efforts, and
5. to give teachers responsibility for their own professional development

Some examples of these PER outcomes include knowledge on misconceptions in physics topics, difficulties with terminology, effective pedagogies for different topics, the use of Information and Communication Technologies (ICT), laboratory demonstrations and the use of diagnostic tests for various physics topics.

Discussion of Potential Issues

Are Teachers Ready?

Are the teachers ready to redesign their existing curriculum and implement a research-informed curriculum? Factors to be considered include the teachers' knowledge, the amount of content to be covered in the curriculum, the availability of time and the norms in the teachers' academic department.

Teacher knowledge

Teachers' background knowledge and their perception of the impact and values of educational research (Everton, Galton & Pell, 2002) may have a bearing on their readiness to redesign the curriculum. Everton, et al. (2002) used a survey to find out what teachers

perceive as the impact and values of educational research. Such a survey may give an indication of teachers' readiness to work on redesigning the curriculum.

Davies (1999) wrote about his interpretation of evidence-based education as one in which "educationalists at all levels need to be able to:

1. pose an answerable question about education;
2. know where and how to find evidence systematically and comprehensively using the electronic (computer-based) and non-electronic (print) media;
3. retrieve and read such evidence competently and undertake critical appraisal and analysis of that evidence according to agreed professional and scientific standards;
4. organise and grade the power of this evidence; and
5. determine its relevance to their educational needs and environments."

Taber (2007) proposed a set of questions to ask when we evaluate the claims made by educational researchers:

1. How do they know?
2. How confident can I be that the claims are justified by the evidence?
3. What kind of evidence would be needed to support such a claim?
4. Do these findings have a limited range of application (e.g. age, subject)?
5. How could I find out if these findings apply to my professional context?

Teacher competency in the evaluation and use of educational research resources could be nurtured through training at various levels. Teacher pre-service and in-service training could include educational research as a component of their training.

Diezmann (2005) presented the case for training teachers with high level research skills. To him, a "teacher researcher" is a reflective professional who engages in inquiry to identify and address the problems faced in the profession. Diezmann took a step further and proposed a "scholarly teacher" who exhibits professionalism in both teaching and research.

A concerted effort could be made in the promotion of educational research training and sharing at cluster level, and at other school-based platforms. Teachers could also be encouraged to pursue higher degrees which usually involved training and practice in educational research methodologies.

In Singapore, research in education has been promoted in schools since 2006 through the Ministry of Education (MOE) with the training of teachers called Research Activists (RA). These are teachers from selected schools who are "coached in conducting research and applying what they learn to the prototypes they are implementing" (MOE, 2006). There is also an observed trend of an increasing number of local school teachers conducting educational research (e.g. action research) and sharing at local and international conferences, with support from local educational research workshops and training materials (Soh, 2006).

Finland was the highest-performing country on the PISA 2006 science scale, an internationally standardised assessment (Programme for International Student Assessment). It has implemented research-based teacher education and its education system strongly promotes research and evidence-based practice (Niemi, 2009). It could serve as a learning model for Singapore.

Content Coverage and Time Constraint

If there is high expectation to cover a lot of material in the syllabus, the teacher may decide against the use of research-based methods geared towards deeper understanding, but which may require more preparation effort (Dancy & Henderson, 2005). The teacher needs to consider a careful balance between the amount of content to cover and the quality of learning, within the context of MOE's framework of Teach Less Learn More (TLLM).

Teachers are sometimes too busy with large teaching loads and/or other responsibilities to have time to integrate research-based methods into their curriculum (Dancy

& Henderson, 2005). Off-loading could be considered for teachers who are involved in educational research. Development of research-informed curriculum could be incorporated as part of professional development or departmental review. Teachers could also take advantage of MOE's concept of white space (MOE, 2005) which is "10% to 20% of curriculum time" freed up through content reduction for teachers to explore pedagogical and "assessment methods to better meet the needs of their students."

Department norms

In a department, if traditional instructional methods are more common than those integrating research-based method, it is harder for a teacher to apply the latter, with minimum support or without any role model (Dancy & Henderson, 2005). Vulliamy and Webb (1991) studied how teacher research efforts in a tertiary institution contribute to the processes of professional development and change within schools. Their data generally endorsed "the increasing body of literature which argues that for teacher research to effect change throughout the school then the culture of the school must be one which values critical reflection on practice and the sharing of ideas".

School or department leaders need to promote an openness to explore research-based practices. Teachers involved in educational research or curriculum design could make a case for a worthy pursuit of research-based practices. Collaboration among like-minded colleagues could provide the necessary support to redesign the curriculum and evaluate research-based materials.

Are Students Ready?

Trial sample

Many research-based curricula developed at American research universities were tested with specific populations of students with particular characteristics. Loverude (2004) studied the effectiveness of research-based curriculum at a university which has a diverse

student population. The research-based instructional materials appear to be effective in some cases. In others, there is disappointing student performance. Loverude suggested that the mixed results could be due to:

1. Deficiencies in the implementation of the curricula, as there were modifications in the use of the course materials due to constraints of time and group size.
2. The academic background of the students involved, as some students gave feedback on the difficulty of the materials encountered.

One question used in evaluating educational research materials is: "Do these findings have a limited range of application?" (Taber, 2007) Teachers need to adapt research-based materials (including diagnostic tests) according to their teaching and learning context and their students' background before implementation.

Student resistance

Dancy and Henderson (2005) found that teachers with PER-compatible beliefs about teaching and learning, may still resort to largely traditional instructional practices due to student resistance. Some students do not like research-based instructional methods which require them to interact with each other and think independently.

A way to lessen student resistance is to expose them gradually and early to teaching and learning practices common in research-based pedagogies, e.g. student interaction or discussion activities, and the use of critical thinking skills.

Conclusion

Redesigning the curriculum into a research-informed curriculum means

1. bringing research outcomes directly to the classroom teachers,
2. encouraging evidence-based practice, and
3. providing a basis for teacher-initiated research.

Recent and Current Studies

I have completed a short study on students' use of blogs as online journals for their physics projects. I am analysing the data obtained from my students' use of an asynchronous discussion forum (online) based on social constructivism to learn about electrical circuits.

Future Plans

With further knowledge of research-informed curriculum and evidence-based practices in education, I would refine the proposed research-informed curriculum model. The existing physics curriculum would be redesigned in phases to incorporate research-based outcomes from existing PER literature as well as our teachers' research findings. In the long run, I hope to persuade my colleagues and the school management that this is a task worthwhile for further investment of time and effort.

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