Turning on (Mathematics as the Engine of) a Thinking Curriculum: Challenges and Opportunities in Singapore and Wider Asia

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Abstract: This paper aims to address educational authorities in Asia, at the national, school, and instructor level. It consists of three parts. First, we identify three central educational objectives that are universally recognized as essential to good education, as well as some of key tools to deliver these objectives. Second, we note the main obstacles preventing Asian education systems from meeting these objectives (the challenges). Third and last, we comment on the concrete tools available to remedy the situation, at management and teacher level (the opportunities). All academic subjects in school could contribute to achieving the objectives, but this paper will demonstrate that mathematics has a particularly workable and straightforward strategy at its disposal to kick-start the desired changes. The observations and recommendations in this paper are blunt. They are based on the author's work in Singapore and Indonesia for the last 15 years, first as a visiting Dutch PhD student in mathematical physics, then as a teacher of local and international students, at primary, secondary and (adult) university level, as the editor of the first independent guide on the International Baccalaureate Diploma Programme, and finally as corporate trainer at, and owner of, an experiential learning resort in Indonesia (where company CEOs share their own assessments on the virtues of Asian education). While the comments by default apply to Singapore (and to a large extent to other highly developed Asian countries such as Korea, Taiwan and Japan), rather than backing this up with extensive research data, readers are invited to simply ascertain to which extent the comments apply to their own educational environment.
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1. Three universally accepted educational objectives

Below we list three central educational objectives that are accepted as valid by the vast majority (if not all) of educators who have had the benefit of trying them out and contrasting them to alternatives. The objectives are: good educations should *engage* both student and teacher; good education should *enable* both student and teacher (to develop a wide skills set, to think for themselves and to apply the material learned to both existing and new situations); and good education teaches the student to effectively *process* and in turn *disseminate information*. Many of the other objectives that one sees listed regularly, such as promoting IT, critical thinking, problem or project based learning and so on, are *tools* or specific *skills* to achieve these objectives but should not be confused with the objectives themselves (more on this in section 2).

Objective 1. Good education should engage both student and teacher individually.

In alternative language, this is also phrased as 'education should be *student-centered*'. Of all objectives, this has got to be the most important one. If the students (and the teachers) do not experience a personal active interest in the lesson material (because they do not feel the material is relevant to their own lives or interests), and the system neither elicits nor rewards individual responses, there is little room for genuine motivation, the key driver of progress.

Asian education systems are not alone in failing to meet this objective, but they have gone much further than the rest of the world in enforcing the complete opposite: a fully *system-centered* education model. (Disclaimer: there are of course institutes in Asia that do things differently, and we will refer to some of those later on, but in this paper our default observations are general in nature).

The British A-levels, the French national examination, and the American AP are also examples of somewhat system-centered education models in the sense that a central paper examination is used to measure most if not all of student performance, but in all these countries individual teachers are nevertheless almost fully autonomous: they decide individually how to teach the years preparing for the central exam, and they are in complete charge of their classes and internal assessment. As such, good teachers in these systems still have opportunities to put the individual student in the centre.

In many schools in Asia, however, not only is *all* assessment uniform, but the regular school-wide tests even demand that every teacher follows the same scheme of work. Having fun in the class room is regarded as 'not serious' and unproductive, mastery of 'objective' content is regarded as superior to mastery of harder-to-measure but much more important skills, and 'objective' school-wide or nation-wide assessments are viewed as superior to individual teachers' assessments. To meet the standards, the emphasis is on 'hard work' and drilling routines, both in and out of school. Even artistic performances are held to objective standards instead of being a celebration of creative individuality. The Asian model has placed both student and teacher firmly outside the center. Instead, the system is at the center. The teacher's role is to deliver it, the student's role is to receive it and master it.

This system has generated a rat-race, fueled by parents' concerns for their children to attain 'the highest standard'. The original rationale of Asian education authorities for insisting on standards was this: to achieve high-quality education for all, and to identify and groom an elite (reminiscent of the system in France). The rat-race, however, has by now generated its own dynamics. It has largely replaced the original rationale by a counter-productive 'market-generated' rationale: rigid system-wide standards must be set to fend off parents who are paranoid their children might be disadvantaged unless everyone is held to exactly the same standards and everyone receives exactly the same opportunities. Anything less than this is considered ‘unfair’ according to recent Asian societal norms.

The damage of this ‘Asian model’ on a personal level is considerable. Some of the harmful effects are well-recognized by the parents, who are in particular very concerned about the high stress levels the system generates. But the damage goes much further. The relatively good school exam results in mathematics (the most easy-to-standardize subject of all) have been attained at the cost of other knowledge. The drilling routines are obviously harmful to would-be creative and innovative thinkers, and, more generally, to the (by necessity) majority of students who do not perform well in the system. Once students fail the standards, there are few alternative avenues for them to excel and claim credit in the education system (unlike in many Western education systems, where students can take pride in the areas of their personal strength). Even for those who attain the highest standards there is no peace: they are constantly reminded of their individual ranking in the cohort.

The adverse consequences for students’ overall self-esteem and self-confidence are predictable and clearly visible for any foreign instructor teaching at local universities or schools. This lack of self-confidence pervades society: even the most talented of my local teaching colleagues will assume without question that teachers at international schools are ‘better’ than local teachers.

Another alarming consequence, at least in Singapore, is the fact that students do not listen, do not take notes, and only do homework under threat of penalties. After all, since the only thing that matters are the exams, and all the important information to pass those exams will be given to them on revision sheets, why bother paying attention in class? If students have questions, the default strategy is to ask their friends in class instead of the teacher, leading to noise levels in class that are astonishing for teachers coming from foreign education systems. The students move from classes where they do not listen to tutorials where they are too tired to listen and thus enter a vicious circle that succeeds in very little except keeping stress levels very high. By contrast, students in international schools hardly employ tutors because they make good use of class time and teacher assistance.

Oddly enough, this reality is completely at odds with existing perceptions at both local and international schools: most people routinely assume that Asian students are much better disciplined than international students. One couldn’t be further from the truth.

The public at large is also largely unaware that, apart from the personal misery the ‘Asian model’ causes, it is not very productive either. Again, there are some widely held perceptions to the contrary. The local press regularly publishes favorable comparisons with some of the world’s worst education systems, such as the public education system in the US.

Comparisons with the better functioning national education systems in continental Europe are harder to find. Take the oft-cited alleged comparative strength of Asian education, especially in mathematics and science (where its standards are supposed to have produced superior results). In reality however, university science standards are very low, and pure mathematics and theoretical science is hardly taught. To give an example, at Singapore's National University the standard physics curriculum does not even feature Einstein's Relativity Theory, considered a standard must-teach first-year course in any Western university physics curriculum (it is only offered as an honours course). The usual excuse for this breathtaking omission is that 'the topic is not relevant for applications'. Even if one were to accept this dubious explanation (the fact that the students find it too difficult comes closer to the mark), the truly shocking fact is this: *The school system has clearly not succeeded in producing students curious enough to be interested in one of mankind's most seismic advances in knowledge.*

Similarly, the alleged strength in science fails to re-materialize at the research level and in the work sphere: national Asian productivity levels per hour worked are not particularly high (OECD, 2000). An immediate objection of many people to this claim would be: but what about the university rankings? Do not some Asian universities rank amongst the world's best? Suffice it to say that there are few researchers who take the publicly touted rankings seriously, with a widely held view amongst top scientist that the university and individual rankings have actually seriously compromised the concept of quality. Shanghai Jiao Tong University has a famous university ranking that attempts to address some of the most obvious shortcomings of most ranking systems. Apart from some Japanese universities, no Asian university makes the top 100, (academic Ranking of World Universities, 2006). Despite Singapore's universities' respectable showing on the Shanghai index, when physics Nobel laureates and other academic luminaries come to town for a week of public lectures, the last people they meet on such trips are local academics, who are discouraged to meet with the great men for fear they would be in the way. This further demonstrates that the previously mentioned lack of self-confidence permeates all levels of (educational) society.

To give a last example in terms of business: the highly developed Asian countries rank near the bottom in terms of high value private entrepreneurship, see the executive summary of (GEM, 2005). A system obsessed with measuring everyone against the same standards, predictably, does not encourage individuals to stand out and take risks; instead it produces people who like to play it safe and go by the book.

Progress in business and in science depends on critical and skeptical analysis and unrestrained imagination, two areas that are hard to assess in a system-centered model, and hence indeed systematically under-developed in Asia.

Objective 2. Good education should enable both student and teacher (to explore and develop a wide range of skills, to think for themselves and to apply the material learned to both existing and new situations)

Unlike the previous objective, which clashes culturally with ‘the Asian model’, there are no such problems here, as the world has generally come to accept that in this time of rapid change, the keyword for survival is the ability to adapt and innovate.

While Asian education has accepted this objective as valid, its very systems stand in the way of achieving it. The system-centered model enables students to pass the end-of-school exam and little else, simply because it is impossible to formulate one-size-fits-all exam-based standards for creativity and innovation.

Objective 3. Good education teaches how to process and disseminate information

Again, there will be few educators disagreeing with this objective. It is generally recognized that the world is experiencing an information avalanche, and that students should be able to discern what is important and what is not, what is reliable and what is not, and where to find the information they are looking for. Equally important will be to subsequently analyze and process the information thus gathered and then disseminate this in a form that reaches the intended audience effectively.

As a closing remark in connection with the comments on objective 1, it is worthwhile to mention that there is good research-based evidence as well for the claim that the Asian focus on science and mathematics (as the subjects that lend themselves best to central assessment) is not a beneficial strategy. Research in Holland has shown that the strongest university students in Chemistry were not those with elevated high-school Chemistry grades, but those with high *overall* school grades. In other words, to excel in science one should be interested in the entire world, not just in the world of science – an observation that will surprise few good scientists. The more general interests exhibited by the student, and the more holistic their approach to learning, the greater chances of success at university.

For the last few years running, the most successful national education system (in terms of science, math and language) is Finland, which has put in place concrete measures to meet all the objectives listed in this section, see e.g the OECD’s PISA report (OECD, 2003). Finland’s educational successes are not limited to school exam results: after implementing the educational changes about 20 years ago the country has emerged as a global technology leader despite its small population size. This paper will argue that the Asian countries are in a position to do the same, provided they are willing to make the necessary bold moves.

2. The tools of the trade: how to deliver the objectives

Below we list some of the key *tools* employed and specific *skills* to be developed to meet the three objectives listed in the previous section.

Tool 1. Technology

To begin with one of the most widely used (but in our opinion overrated) tools, we briefly discuss the use of *Technology*, in particular computer software and graphical calculators. The major potential contribution of IT is towards objective 1. It gives the teacher a powerful extra tool to engage the students and hold their interest. IT can further be fruitfully employed with objective 3, as teachers can invite students to research information on the internet in class (or to generate data with the scientific software), giving the instructor an excellent chance of teaching some important research and information-gathering skills.

It appears however, that many schools see IT as an objective in itself (this is totally wrong, see below) or as a tool to teach presentation skills (which is largely wrong). IT in itself should emphatically *not* be an across-the-curriculum objective, simply because many of the IT skills we learn today will be useless tomorrow. To give an example, it will be just a matter of years before typing will become largely unnecessary as all computers will recognize speech, and one can easily imagine that in 5 years from now one can design a webpage by dragging a thumb over the screen. So the real skills, the ones that matter, when we produce for instance a web page or a PowerPoint presentation are ‘design’ and ‘presentation’, not ‘WebPagePro’ or ‘PowerPoint’. Likewise, one could argue that PP additionally teaches the students to summarize information, but this very important skill can be more effectively taught without PP. Asking the students to design their own home-page can be a marvelous tool to meet objective 1. The idea that their own diary is on-line is incredibly motivational for many students, as it puts them smack in the center of education. But one should not forget that it is this aspect that is really important, not so much the software they use to produce the page.

Of course the system should enable the student (objective 2) and part of this enabling process is familiarizing the student with the fact that we live in an age in which information technology is vitally important. So the system should make sure that students are comfortable with the major pieces of popular software of their day, but this is rather easily done and does not merit the many hours that some schools currently spend on it, wrongly focusing on the ‘Technology’ bit instead of the more important ‘Information’ bit.

To give another example, many schools pressure teachers and students to use PowerPoint or other software in class. While it is appropriate that a school insists that teachers are familiar with the tools of their trade, it is counter-productive to demand, as some schools do, that a certain percentage of the lessons be done in PowerPoint. That choice should be the teacher’s to make. Anything less infringes on their autonomy and thus violates objective 1. Apart from wasting the time of the presenter, the effect of using PowerPoint, if not very carefully monitored, could well be to obstruct a good lesson, because rather than reacting to the individual reactions of the class and giving the students the opportunity to shape the direction of the lesson, a pre-packaged PP presentation risks removing the student from the center.

Finally, within mathematics, it is this author's opinion (after having tried a large number of software applications with my students over the last 10 years, both at school and at university level) that the only mathematical software packages on secondary school level truly worth employing are spreadsheets and Omnigraph. The possible advantages of other software simply do not merit the time lost in order to understand the features of the software.

In view of the above comments, it is not surprising that the literature is rife with seemingly contradictory papers, some claiming that IT is useful in education, while others say this is dubious. Every good educator knows that, yes, IT can be great if it serves the educational objectives outlined above, and, no, it will be counter-productive if it does not.

So, rather than pushing teachers to use IT just for the sake of it, schools should push their teachers to ask: how can I design (the use of IT in) my lessons to meet objectives 1, 2, and 3?

Tool 2. Problem-Based Learning (PBL)

Problem-based learning (PBL) or *design-led* education was pioneered by universities in Continental Europe and the US, based on the idea that in real life, one starts with a real problem that needs to be solved using a whole *holistic* range of knowledge and skills. This technique is not straightforward to apply, but for those who have tried it is difficult to go back, as it is a fantastic tool to address all three educational objectives at once (we will show very concrete examples of this in section 5). It is possible to find projects whose successful completion will demand mastery of all the skills the course seeks to impart. It is possible to choose the projects in such a way that they are relevant to the student and such that they allow for plenty of personal expression an input (objective 1). By its very nature, PBL teaches the student to produce new knowledge (objective 2), and finally, in order to be successful, the students will need to learn how to ask the right questions, find the relevant answers, and present their results in a manner that is acceptable to the intended audience (objective 3).

The universities that pioneered these methods (such as TU/e and Carnegie-Mellon) are amongst the world's best. Feedback from industry on their efforts has been very good and consequently their methods have found wide-spread following. The author was lucky enough to be able to freely experiment with PBL at a Singaporean branch of a US university (as a Professor of Mathematics and Physics) and at NTU, one of the national universities (as the Coordinator of Critical Thinking) for 5 years, and I should put my cards on the table: I firmly believe PBL is a supreme tool.

That is not to say it is easy to apply. It surely takes time to get used to, and mistakes will be made along the way. In view of this steep learning curve, it is not surprising that few school systems dare to fully rewrite their curriculum to facilitate this tool, but it should be noted that those who do, have plucked the fruits of their labor. We are not only referring here to the universities mentioned above, but also to Finland, which has made problem-based learning a central tool in its education system. Closer to home, in Singapore, Temasek Polytechnic was one of the first institutions to make PBL learning a central aspect of their teaching with noticeable results: the relative level of self-confidence is high and students speak well.

What this paper will argue is that, even when schools are hesitant to take a deep plunge right away, mathematics and physics are superb subjects to introduce and incorporate this concept smoothly by creating series of holistic mini-problems (see section 5).

Tool 3. Employ holistic learning.

Holistic learning, the attitude to look a variety of dimensions and perspectives of the topic at hand, and not just those dimensions relevant to the subject in which it is broached, requires confidence on the part of the teachers: they must be comfortable talking about issues they may feel are not strictly speaking within their academic expertise. Take statistics as an example: many teachers stick to colored balls, beans, coins and other items that could not possibly excite any student. But statistics has an incredible influence on our lives. Politicians, engineers and marketers vitally rely on (and occasionally manipulate) polls and surveys every day. It is these enormously important uses and abuses of statistics that feature daily in the news and in people’s lives that mathematics teachers should discuss. Let the class do a survey amongst themselves to determine if smoking affects average grades. The results (yes, smokers have significantly lower grades) surprise almost everyone, which means you’ve got everyone’s attention (objective 1). Is this result true? The mathematics says so if your sample is big enough. You don’t believe it? Please, do a google search (objective 3) Amazing, the internet backs up your backyard survey! So then, what does the correlation mean? Can we conclude there is a causal effect or not? How could we test for or against causality? Students will stake out strong positions (objective 1). A mathematics teacher who is able to facilitate this discussion will see the students gaining truly new insights (objective 2). The lesson will meet objective 3 as well because resolving the confusion and different opinions will require a clear exposition of ideas and arguments.

It is clear that the more a system is examined via central subject-based standards, the less it will be able to teach holistically, leaving students with completely disconnected strands of knowledge: a picture of some individual trees but no forest in sight.

Teachers do not gain overnight the confidence they need to teach holistically, but for instance those who have experience with the International Baccalaureate (IB) programme know that one year of teaching its TOK (Theory of Knowledge) course is enough to get going. Of course ‘mistakes’ will be made: language teachers may say nonsense about mathematics, and mathematicians may express dubious opinions on the social sciences, but that is no big deal (in a student-centered system). School should be a reflection of real life, and not give the false impression that for each issue there is one ‘correct’ answer, while all other answers are ‘wrong’. What is important is that the students understand that no issue or subject is an island, that there are many perspectives, each yielding different insights, and yes, that there are many prejudices and false beliefs (also amongst teachers) and that they therefore should develop the habit of consulting various angles if they really wish to resolve a problem (objective 2).

Tool 4. Never give up teaching Basic Information Skills

For every academic subject, objective 3 (processing and disseminating information) is vital, yet the mistake (made around the world) is that language lessons are seen as the exclusive corner in which to address the objective. As every academic knows only too well, school leavers have great trouble finding relevant information, taking notes, and summarizing, the basic skills needed to find and process information, and they have equally great trouble communicating their findings. There is no doubt about it: *every* academic subject should set time aside to ask students to summarize ideas, let them find information on their own, and ask them to present their work to the class, both off the cuff and in more formal formats. Because such efforts are best assessed by individual teachers, rather than through system-set standard assessments, this further stresses the need to move away from system-centered learning.

A great example of the effectiveness of employing a strategy emphasizing the basic information skills is College Mara Banteng, Malaysia, the world’s best IB school in terms of examination results. Their grades at the end of the two-year IB Diploma programme shot up by around 15% after the school introduced an intensive 5 week course addressing these basic skills (van Loo & Morley, 2004).

Tool 5. Teamwork, Leadership and Community Skills.

It is by now pretty much universally recognized that it is vitally important to address inter-personal skills, both in smaller groups and in society at large. Developing individual leadership skills as well as team-work skills fits superbly in objective 1 (engaging the student). They are also absolutely necessary to achieve objective 2 (enabling the student, since the vast majority of work in real life will require working together with others and being sensitive to cultural expectations different from your own). Finally, these skills squarely address objective 3 (as students will find out that good planning and team work require clear organization, information, and communication skills).

The Singapore school and university system is trying to promote these skills but predictably faces significant hurdles, as such skills cannot be quantified easily with rigid standards. Some schools strongly encourage this kind of work, but leave it voluntary in the end. Others have chosen to make it mandatory for those who wish to join certain elite clubs within the schools. Nanyang Technological University (NTU), feeling it could not sufficiently assess these skills through its examination system, tried linking student-housing to a (deeply unpopular) point-based system for extra-curricular activities. But it doesn't need to be this way. Singapore's new university, Singapore's Management University (SMU), has had considerably more success with their bold move to require and assess students on their class participation (the final exam only counts for 50%, and the other 50% is a mixture of class participation and projects): SMU students are far more confident than their peers at the two older national universities, and can hold their own in public exchanges, even in guest lectures from foreign luminaries.

Tool 6. Critical Thinking.

The phrase Critical Thinking has become a fashionable phrase in education today, but there is little consensus about what it actually means. One of the reasons for this confusion is that it involves at least four quite distinct skills or tools, each equally vital for a well-rounded education that meets the objectives listed in section 1.

Critical Thinking as in Problem Solving. One of the essential skills students need to acquire is the ability to solve a general problem by *deconstructing* it and then *synthesize* all the various bits knowledge that they have learned (in order to meet educational objective 2). In popular language, this is often known as 'common sense', but the fact of the matter is that this skill is not common at all and needs to be taught explicitly. Students need to learn to look at real-life questions, which typically do not come equipped with a standard answer format. Current examination questions all too often refer to a single particular topic discussed in class, fully ignoring the fact that real-life questions are multi-topical as a rule.

Subjects that lend themselves naturally to address such real-life problem solving skills are mathematics, (social) science, and business. The tricky part of teaching this aspect of critical thinking is that there is no technical standard format to acquire these skills, posing a problem for system-centered educational models. Lots of exposure to real-life problems (PBL learning) and lots of discussions debating the merits of each other's solutions (thus meeting objective 1 and 3 as well) is the best way forward. Section 5 features concrete suggestions on how to start introducing this skill into classrooms.

Critical Thinking as in Critical Analysis. Sometimes known as *Critical Reasoning*, this is a completely different skill, very relevant to objective 3 (finding, analyzing and processing information). Students need to be able to *analyze* an existing media piece. Is the case clearly stated? Are the arguments in favor clearly identified and validly argued? This involves the subject of *fallacies* too (Labossiere, 1995). Have counter arguments been properly addressed and dealt with? Is the paper well-referenced? Following this, students will recognize the answers to such questions as: Is there evidence of bias on the author's part? And so on. Through learning to analyze existing texts critically in the sense sketched above, students can also learn to produce themselves texts that withstand critical scrutiny.

Subjects that lend themselves particularly well to teaching this skill are writing courses, philosophy, and the social sciences, especially history. This skill is more technical in nature and easy to assess via a paper examination. It is perhaps for this reason that it receives most academic attention amongst all four areas of critical thinking listed here, That special emphasis is wrong. The problem is that this skill does not produce *new* knowledge (i.e, it does not address objective 2); what it does is help stating the case clearly (a part of objective 3). Important, for sure, but only a part of the body of skills that make up critical thinking.

Critical Thinking as in Being Open to new ideas. This skill concerns a vital *attitude* that all students should develop (in order to be successful in objective 2). There must be a clear recognition that mankind has often been spectacularly wrong in the past and that people – the students themselves included – are still frequently wrong today. A good way to acquire this attitude, which automatically addresses objective 1, is to address some of the big modern issues that face people today as they relate to the students individual lives (morals, religion, role of law, culture, politics, language, role of media, arts, science – a subject like the IB's *Theory of Knowledge* does this very well). Only by demonstrating to students that many of their own personal convictions are based on quicksand or cultural bias of some sort will they acquire the healthy attitude of recognizing that it is very easy to go wrong, and will they become truly open to new ideas and ideas from others. This attitude can and should be explicitly taught in all classes.

Needless to say, there is little room in a system-centered model to reward students for progress made in this vital attitude.

Critical Thinking as in Constructive Skepticism. To recognize what is 'right' and 'wrong' and the inherent limitations of these concepts, students must be intimately familiar with the most powerful tool mankind has developed to distinguish between the two: *the scientific method*, whose phenomenal achievements over the last centuries are based on a simple principle: constructive skepticism and the ability to recognize which claims are open to testing and which are a matter of judgment.

This skill is most naturally taught in science classes, psychology, sociology, economy and business, and philosophy. It is a vital tool to develop objectives 2 and 3, as we use it first to analyze existing information for quality and gaps (objective 3), and then to phrase hypotheses that can genuinely expand our knowledge (objective 2). It is remarkably easy to assess against objective standards and could thus be taught in almost all education models, but the sad reality is that around the world, it is still very poorly developed. The recent discussion in the US on evolution versus design theory revealed an astonishing lack of popular understanding of what science is. Witness also the regular news clips featuring politicians who elevate the alleged strength of moral convictions over insights gained scientifically.

It is impossible to make true progress (objective 2) if one is not aware of mankind's most successful tool to distinguish right from wrong: the scientific method. Had scientists accepted the standards of some of today's politicians, we'd be lucky to drive bicycles today. As it is, we've been to the moon and beyond.

3. Challenges for education in Asia.

As we have argued above, the tendency in a good number of the developed Asian countries to embrace a system-centered model (instead of a student-centered model) has serious consequences. First, the system cannot be sustained if a country aspires to join the knowledge-based global economy. Second, it produces a population that lacks confidence, and has no love for learning. Third, it prevents us from effectively meeting the objectives 2 and 3 that are recognized as valid around the world, Asia included (the need to enable students and the need to make them information-savvy). Fourth, it prevents us from delivering many of the skills that are universally thought necessary, and from employing tools that are rapidly gaining reputation, section 2.

So what prevents us from changing the current system-based models into a student-centered model (objective 1)? In this section, we will argue that the challenges are mainly of a cultural nature (and in the next sections we will demonstrate how these can be overcome). The challenges have common roots but it is helpful to separate them first by the various stakeholders: first, the *parents* are subject to the modern Asian paradigm that 'fairness' demands a systems-based education model. Second, the lack of self-confidence we've mentioned earlier prevents *teachers* from demanding more ownership in their classes. Finally, e*ducational authorities* regularly share this lack of confidence in their teachers and thus often don't offer it, let alone promote it. On top of this, and woven throughout society, is the challenge of *management systems that conflict head-on with the consultation culture required by objective 1*. Below we will elaborate on each of these challenges.

One may wonder why we don't mention students amongst the challenging stakeholders here, but that is because students are the least problem of all – they are ready for change, so they actually fall under the opportunities, see next section.

Challenge 1. The parents are said to resist changing a systems-based education.

Historically, one of the reasons for embracing tough central standards was a genuine desire to set high global standards and to quickly groom an elite, a system employed fairly successfully in France. In Asia, however, this policy set in motion a counter-productive rat-race, where parents want 'the best for their kids', and consequently yell foul whenever the slightest 'unfairness' in the system is perceived.

At least, this is the story one often hears in answer to the question 'why not give the teacher more autonomy and move away from central standards'? Our view is that this perceived pressure from parents is largely a myth. We have personal experience with a good number of teachers across Asia who have insisted on teaching their classes in 'Western style'. None of them ever had a problem with parents demanding strict standards. To the contrary, the parents, well aware of the enormous stress the national systems generate, are positively delighted to hear enthusiastic stories from their children. If they contact such teachers, it is to tell them to keep it up. In addition, to take Singapore as an example, those institutions that have made concrete steps to try to move away from the system-centered model have not suffered any backlash. To the contrary, the SMU (Singapore management University) is rapidly gaining a reputation as Singapore's best university, on account of their modern teaching methodology which stresses the importance of communication, and which sets aside 50% of the grade for project work and class participation. Hwa Chong also sets 50% of the grade aside for classroom assessment (as opposed to 100% by central exam) but it is still considered to be one of Singapore's finest schools. Singapore's Republic and Temasek Polytechnic are much talked about – invariably in positive terms – because of their innovative teaching methodologies stressing PBL. The New NUS high school, which has developed its own curriculum based on critical thinking and problem solving, and which teaches regular classes in just four days of the week, managed within just two years to clinch the top positions in the various highly prized mathematics, science and language competitions. Lastly, in 2006 the Anglo-Chinese School, one of Singapore's most prestigious schools, became the first Singaporean school to run the IB, a student-centered education system. It had a massive enrollment of well over 350 students in its first year, making it in one stroke one of the biggest IB schools in the world. All of this demonstrates that parents are not afraid to try change, and that they have little reason to be.

So challenge 1 is an easy challenge. It's simply not there.

Challenge 2. Teachers lack the confidence to adopt new methodologies

As we have mentioned earlier, the lack of self-confidence seeded by the Asian education system is real. Even obviously very talented teachers themselves will say that they lack the skills to teach the way their international colleagues routinely do. Of course this is complete nonsense. Those local teachers who find jobs in international schools are just as good as their international colleagues. They may need some time to settle in, as is to be expected for any professional who starts a job in a new environment, but they cope just as well. The perception has real consequences nevertheless. Even Asian schools that give their teachers a lot of freedom and push them to use it, lament that very few teachers take them up on this. But since the problem is purely perception-based, it can be solved, as we will argue in the next section. What needs to be done is force teachers into it, piecemeal, until the confidence is there. With the right lesson materials and support, this can be done easily.

Challenge 3. Educational authorities are reluctant to trust their teachers

The Asian model has led to excesses that would be utterly unthinkable in the Western world. No teacher wants to be singled out for 'not doing well'. This means that if teachers have access to exam material, many will tailor their pre-exam lessons closely to the exam. To prevent this astonishing self-defeating scenario, an even more astonishing cure is adopted: important internal exams are not shown to the teachers! The obsession with standards even leads some schools to demand that a single teacher grades all scripts across the entire year group so as to 'ensure fairness'. The real problem, however, is not with the teachers but with the system, which – if you strip away all the PR fanfare – essentially only recognizes exam grades as performance indicators. Of course exam grades are also important in international schools, and good results will be proudly paraded by such schools if they have them, but the difference is that good exam results in non-Asian schools is mostly seen as a team-effort and a result of sound policies. Exam results of individual teachers – as long as they are not consistently far too low – are much less of an issue, as performance is measured against a far more holistic basket of performance indicators (one of the most important of which is student-satisfaction). In much of Asia, by contrast, the obsession with quantifiable standards doesn't just hound the students, it hounds the teachers too. Some schools go as far as to withhold bonus payments from teachers who rank in the bottom in terms of exam grades!

More vivid evidence of the lack of trust in teachers is the habit of many schools – again utterly unthinkable in other parts of the world – to demand that teacher files be handed in to the head of department every week. The official rationale for this is, again, the 'need to maintain standards'. Of course, the whole exercise becomes a farce in which most teachers just make the thing up in order to file something that looks OK, and everyone knows it. But still, standards must be observed, so everyone keeps up the pretense.

In the highest echelons of government, at least in Singapore, the problem of lack of self-confidence is well recognized and the government is exhorting schools to experiment more. But governments could certainly help by explicitly banning the schools from collecting teaching files, and by letting everyone know that such documents are personal private files, just like elsewhere in the world. In government schools, promotions should be visibly awarded *not* to those teachers who know exactly how to go by the book (as is now often the case) but to those teachers who actively experiment with new ideas, even when these experiments sometimes fail – as they will from time to time.

Challenge 4. Asian management models conflict with objective 1

In many parts of Asia, respect for authority and hierarchy is an important societal feature, and one often points to Confusius to explain its origins. The true picture is of course much more complicated than this simple statement, with some of Asia’s largest countries, India and Indonesia, being thriving democracies where leaders are held to task by a watchful electorate. Even ‘Confusian-heritage’ countries such as China are seeing an exploding number of popular demonstrations, and Hong Kong and Taiwan recently witnessed mass demonstrations on scales rarely seen in the West. Nevertheless, on a company or organizational level, there is a clear difference between, say, East Asian countries and Western countries. By and large in Asia, bosses make decisions. They generally do not seek consultation from their staff since this is perceived as a sign of weakness. Conversely, staff does not give feedback to the top, let alone critical feedback, as this is regarded as a lack of respect. Bad decisions simply get reversed, often without explanation. For Westerners, this is hard to understand, because in Western culture, changing decisions all the time is seen as a sign of incompetence.

This paper is not the place to discuss the very interesting (self) perceptions between East and West, nor to discuss the societal merits of such values, but the point we do wish to make is that this Asian value is in deep conflict with objective 1. Objective 1 calls for the student to be put at the centre of the education. This task is primarily overseen by the teachers, who are thus also in the best position to observe what works and what not. Their opinion should thus be sought constantly by the school in order to achieve a successful program. To have a people-centered system thus requires a change of management methods, from top-down decision making to consultative decision making. Also, if teachers are expected to teach their students to become critical and innovative thinkers, they must be able to lead by example, and thus insist on their own right to provide critical feedback.

4. Opportunities for education in Asia.

We will begin this section by addressing how the challenges in the previous section can be met, and we will then list some special opportunities that are specific to Asia.

As we have argued above, the parents will not be an obstacle to change. But we can go further: as a matter of fact, they are a great *opportunity* for change. Asia is fortunate in the sense that society cares greatly about education, and that governments are willing and able to spend real money on it. In that sense they are in a similar position to Finland 20 years ago, when that country set out to become a world-leader in technology and managed to do that in less than 15 years. The education system adopted by Finland is radically student-centered: teachers are fully autonomous; there are no class rankings of students; progress is measured relative to the individual student by the individual teacher; PBL learning is a central tool; and there is only one central exam, at the very end of high school. Such national success stories can be used to great effect to convince the population in Asia. The great respect that Asian people have for famous international educational institutions can be used effectively as well: both governments and schools one can recite the successes of institutions that have embraced the objectives and tools listed in this paper. Parents are, furthermore, evidently very sensitive to the feelings of their children, the students, who must be the greatest opportunity for change. A happy student will make a happy parent. Currently, it is a very sad, and damning, fact that the vast majority of Asian students do not like school. But one needs only to visit an international school to witness plenty of happy Asian students. No surprises there: if the education engages the student, the student will be engaged.

As to overcoming challenge 2 (teachers lack of confidence), for those who are not yet convinced by the (easily verifiable) fact that local teachers can and do shine in international schools (where they are largely autonomous in their classrooms) we could point to some institutional success stories. An important reminder of the ability of Asian schools to do well in all of the above is provided by Mara College Banting, Malaysia, the most successful IB school in the world. This school has combined the best of East and West and added in some revolutionary ingredients of its own: student-led learning; classes only on 4 days in the week from 9 AM till 1 PM; one day set aside for extra and core-curricular activities; and a rigorous course in the basic information skills (van Loo & Morley, 2004). Of course India has long produced centers for theoretical mathematics, physics and computer science that are amongst the very best in the world. It is less well-known that in leading global software design competitions (such as TopCoder Open and the Google India Code Jam) the top prizes are often clinched by Indonesians, (TopCoder 2006). Such sustained successes are not possible without good teachers, so what needs to be done is to foster an environment that produces such good teachers. Below we will describe in detail a process to create such an environment that will allow teachers gain confidence gradually but quickly.

Overcoming challenge 3 (lack of confidence by schools in their teachers) needs leadership from the top. Asia is fortunate in this respect (ironically partly because of the relative absence of a consultative process) that it can push through changes quickly. Governments need to aggressively support those institutions that push for change (as Singapore has recently started doing). They further need to abolish administrative procedures that imply a lack of trust in teacher's professionalism, and instead focus on actively supporting and promoting those teachers who show independence, initiative and ingenuity.

Overcoming the deeply rooted societal top-down structure in favor of a consultative structure (challenge 4), at least in the educational sector, is of course not an easy task, especially since the less consultative management boards are quick to quote Asian values in order to resist change. On the other hand, Indonesia is an example of a country that went from authoritarian rule to full and responsible press freedom and (local and national) democracy in the space of just a few years, so evidently it can be done. School boards resistant to change can be put on the right track by a number of fairly straightforward central government policies: all it takes is sending around monitors who spot-check that school and department meetings are conducted in a consultative manner, setting and example by interrupting the meetings to solicit feedback if need be. Promotions should be visibly awarded to those who encourage and/or provide constructive feedback.

To overcome ‘Confusian objections’, the authorities could make use of the extraordinary respect that science commands across Asia. The very rapid progress in science in modern history is due to the scientific method in which *creative imagination* and constructive *skepticism* (criticism) play the central roles: scientists need imagination to formulate new hypotheses, and the scientific community subsequently helps solidifying and recognizing good hypotheses by testing them till destruction. Only if a hypothesis withstands a concerted effort to prove it wrong will the hypothesis make its way into the body knowledge of science. Without this vital ingredient of skepticism or criticism, science would not be where it is today. But to develop imagination we need to let go of rigid standards and allow for much more individual input. Healthy skepticism can only thrive in a consultative environment where ideas can freely be discussed, independent of societal rank or position. Currently, science in Asia is typically taught as a fixed set of rules, ignoring the fact that progress has often come in quantum jumps through the imagination and skeptical analysis of talented scientists who did not accept the status quo. “Questioning authority is good, refer to the scientific method” should be the new message across schools in Asia.

One can further make use of the fact that deep down, everyone knows already that the current top-down system is not productive. Everybody has personal experience with the pointless meetings where bosses can talk nonsense for hours in a row. The overwhelmingly adopted trick is to stay quiet in the hope it’s over sooner. But in my experience as a company trainer, it is evident that people are delighted to be able to give feedback to their superiors, once they are convinced this won’t be held against them. Such a development would not hurt business either. One of the major complaints from company bosses is that their staff is unwilling to furnish them with critical feedback. Questioning a teacher or a school policy has never paid off, and this attitude carries forward in the workplace. Employees either follow protocol to the letter, even if it is evidently nonsensical, or, if the protocols do not provide a standard answer, they will seek approval from a superior first for every move they make, even the most insignificant ones. The obvious consequence is that company bosses spend a huge amount of time dealing with minor issues.

In the next section, we will offer a specific strategy for educational authorities to spread the change quickly and effectively through the grass roots.

5. Making the changes – a proposal for an easy teaching strategy that delivers.

In the preceding pages, we have established the need for educational change, and we have concluded that the organizational and societal challenges to such a change can all be overcome. What we have left out so far is this: once organizational hurdles have been removed, how do we get teachers to embrace these new objectives and employ the new methodologies?

This may seem like a monstrous task, but in fact it is not. Experience all around the world has shown that teachers can adapt quickly to new teaching methodologies. To give an example, most teachers who start teaching the IB for the first time will adopt the new methodologies within a year or so, especially in a conducive environment (it takes a few years if the whole school starts from scratch). Subject teachers in the IB who are asked to teach the Theory of Knowledge course (where they are asked to connect all strands of human knowledge) find it often daunting and scary the first year, but for a majority, it quickly turns into their favorite course to teach.

But to ensure success, we need a support structure that links the methods of the past to those of the future. That support structure can be built, as we will argue below, by freeing up 10% of teaching time to deploy the most encompassing tool of all, PBL (Problem-based Learning), in the form of a series of mini-problems in science and mathematics centering on *estimation*. To give the reader a clear idea what we are talking about, we give here a list of concrete examples from both mathematics and physics. The examples are specific to Singapore (to illustrate how these problems can be formulated to put the students at the centre), but they can obviously easily be adapted to other countries and individuals. The problems listed below are further mostly relevant to teenage or university students, but again, one can easily devise similar problems for younger students.

- How many hairs do you have on your head?
- How many chicken do we import every day into Singapore? How big a building would we need to breed all the chicken Singapore consumes? Would Takashimaya shopping centre (South East Asia’s largest shopping complex) be big enough?
- If we fill the whole classroom with coke cans and each of us can take one drink every day, how long can we drink?
- If we seal the whole room hermetically, how long can we breathe before the air runs out?
- How much money does the McDonalds on the corner make? And what about your favorite disco?

- If all 6 billion people in the world would come to Singapore, is there enough place for all of them to stand?
- How much money is the Singapore government earning out of cigarette taxes?
- And how much do they gain from GST (Goods and Service tax) and alcohol taxes?
- (class project) Singapore's total annual budget is around 25 billion. Can you account for how the government receives that amount? (This is a wonderful exercise necessitating much ingenuity and internet research. Filling the gaps will lead the students to truly interesting macro-economic insights about their own country).
- For each of the students: propose your own business and convince the class through a cost-benefit analysis that they should invest in your business. Class to act as critical potential investors.
- The world raised a billion dollars for the tsunami victims in Aceh. How much is that, really? – translate this figure to a scale on which we can actually comprehend its impact.
- Singapore says it has a water problem. Do you understand why? (nothing drives home the world-wide looming water disaster as forcefully as finding out for yourself).
- If the polar caps melt, how far would the sea-level rise? How come your estimates are different from the official estimates you've found on the internet?
- There are 6 billion people in the world right now. How many babies are born every second?
- Invent and execute a home experiments to test Newton's $F = m.a$ law. Can you explain the (unavoidable) failures? (It is infinitely more instructional to see the law 'fail' and then come to understand that it really does work after you fix the systematic errors, than to do an impersonal and uninspiring laboratory experiment that works. Plus students do come up with great ideas, like pushing their parents' car round a parking lot, using a weight scale to measure force etc. Figuring out why laws fail and how to fix the home experiments can be a highly non-trivial exercise, but students will come up with proposals that will allow for plenty of profound teaching points).
- Try measuring the acceleration of free fall, g, by dropping objects from a high floor, using wristwatches or hand phones to measure time. (These are fantastic exercises, because the initial results are bound to be totally wrong – prompting very interesting discussions on how to fix this – and it allows students to experiment with various curve fitting tools of Excel spreadsheet software etc. It is also a great way to give students a true appreciation of the amazing precision attained by scientists of previous centuries).
- Find a way to test Archimedean buoyancy laws at home.
- Using a water-hose and a bucket, measure the atmospheric pressure.
- More generally, anytime a home experiment with home equipment can be done, choose it over a standard laboratory experiment. The skills inherent in a laboratory experiment will only be appreciated after students have tried their own experiments first.
- How *fast* can you throw a baseball? (Leaving the method of finding the answer totally open, one will find that students will come with solutions involving estimation, computer

simulation, projectile motion or Calculus, video footage, catapult boards etc. Asking the class to understand *why* we can throw so fast will lead them also to understand why a soccer player can kick so hard, a golf player can hit so far, and a karate expert can slam through wood, so each student can apply the results to their own favorite sport).

- Is there a relation between smoking and grades? (see section 2, tool 3)
- Is there a relation between foot size and swimming times? etc etc. All such kind of problems should be done by collecting data in school first, and then analyze and process those data and compare the students' own results to internet data.
- Can we mathematically model the initial growth of SARS in Singapore? Look up the daily statistics on the internet, do some curve fitting with Excel, and comment (a natural introduction to the so-called logistic growth model, so important in Biology, which can elicit many interesting discussions about the limits of exponential growth, sustainability, false promises by investment agencies etc etc).

Obviously, this list could go on forever. Once one gets the hang of it (starting with easy questions), it is very easy to find a list of such problems in most topics in mathematics and physics, ranging from the quick and fast to the more elaborate, see also the mathematics and physics chapters in (van Loo & Morley, 2004). By doing such problems, alone or in groups, using the internet or not, presenting and debating them, we develop just about every skill and objective mentioned in this paper. The problems can easily be chosen to be contemporary (just open the newspaper to find a new problem every day) and can clearly be tied to students' personal interest.

Are such experiments and estimations important from a scientific point of view? They couldn't be more so. Quoting the advice to students from one of last century's foremost physicists John Wheeler (the mentor of Richard Feynman and the man who gave the world the word *black hole*): 'never do a calculation before you know the answer'. Professional scientists live by this rule: they don't embark on detailed work unless they first have some estimation assurance that confirms they on the right track. It is hard to find an activity for school children more scientific in nature than the problems above. The mathematical estimation problems like those listed above are often referred to in the scientific community as *Fermi puzzles*, named after the Nobel-prize winning physicist Enrico Fermi. Fermi posed such problems to his colleagues during their long drive to work in the Los Alamos atomic bomb project. (His problems were also noted for their irreverence, another feature that could be adopted to good effect in class). In any case, if it's good enough for Nobel prize winners, it's surely good enough for our students.

It is easy to integrate the teaching of such problems into the (Asian) education system. Large sets of problems similar to the ones listed above could be generated nationally or school-wide first, specific to the various age groups. Teachers who are not (yet) comfortable making their own problems could then pick and choose from this list. The problems require literally zero preparation time. In fact, they work best if teachers do *not* prepare and just pose the problem to the students. That way, teachers will have no bias and are more open to whatever approaches and solutions the class comes up with. Assessment can be done through a peer-based assessment system where students grade each other. Such systems work remarkably well with students (from all cultures). It turns out that everyone recognizes good quality work, so the much-feared 'fair assessment' issue won't be an issue, provided the teachers assert their authority in the initial stages. The reason we mention this is that school teachers around the world routinely employ this technique successfully, but that some universities have reported problems with it. The problems stem from the fact that students, if not restrained by the teacher, are sure to give their friends high grades, certainly during the first runs. School teachers typically have little problems asserting their authority to stop this habit in its tracks: a stern warning that everyone will get low grades, and a challenge to under-achievers to publicly explain why they deserve the same grade as high achievers will do, and after such an initial correction, students quickly come to relish a system that empowers them and excels in fairness. University teachers, however, are less inclined to act as managers and to assert their authority and will thus find it much harder to make the peer-grading system work. After making sure the peer-grading system is firmly in place, schools need to make sure that such assessments really count, so they should set aside at least 20% of the overall grade for it.

The current answer of Singapore's mathematics curriculum to encourage the development of much needed thinking skills is the recent reintroduction of an old idea: Euclidean geometry. We firmly believe this is not the best idea. While it is true that this topic is suitable to coach thinking skills and the concept of proof, it is supremely irrelevant to applications and it does not relate to students personal lives. Whatever skill a teacher could impart through the teaching of Euclidean geometry can also be imparted, but much better, through discussion of the estimation-type problems such as the above.

To free up curriculum time, educational authorities should begin by taking out some of the current curriculum content that does not comply with the educational objectives set out in this paper (in most education systems, that frees up 20 – 50% easily: what's the point of APs, GPs, trigonometric identities that mathematical researchers or scientists are not aware of and never use, Bayes formula, Poison distributions, and a whole raft of similar technical topics that are hardly ever used by professional scientists and do nothing to enhance thinking skills?). Using the time thus freed up, one has plenty of time to do projects such as the above. In fact, one will find that the time 'lost' doing these problems is gained back manifold because of students' rapidly increasing confidence. One could start with a modest 10% of curriculum time first. Set aside three weeks in the beginning of the year so as to concentrate solely on problem-solving. After that, one could sprinkle these problems throughout the year.

Students love doing these problems. Many of those who do not perform well under traditional instruction are often surprisingly strong the moment the subject matter comes to life (and their successes will subsequently spark rapid progress on the traditional front as well), so teachers will quickly come to love it too. Teachers and students realize very quickly that there are many different correct solutions to the same problem, and after only a little while, one finds that students will come up with ideas the teacher never thought of. Students feel proud and empowered and teachers will learn it’s not a problem to not know the answer, and to leave certain questions open. Within a short time, teachers will then acquire the confidence to set their own problems instead of relying on the suggestions provided. The popularity of such courses in mathematics and physics will force other subjects to step up to the plate and make their lessons more relevant to the student as well. An irreversible grass roots movement will be created.

Utopia one might ask? Ask the people of Finland.

In science education, in addition to the PBL approach sketched above, time should be set aside to explicitly teach the scientific method, and to thoroughly explain how widely applicable it is (stressing its merit not only in the natural sciences but in the social context as well). The course should contain plenty of interesting real-life contemporary societal examples to make students understand the difference between an opinion and a testable hypothesis, and how to dissect an issue in terms of testable hypotheses (science teachers should not be afraid to apply these principles to matters like war, abortion, capital punishment, law, morality, politics, religion, and so on!). The good news within the Asian context is that this skill is very easy to assess via standard examinations (thus posing no great difficulties for the education system to adopt) while on the other hand it does provide the main key to the development of critical thought. The instruction in the scientific method should be coupled to a true, interesting and exciting history of science, highlighting the individual battles many of the world’s most successful scientists were involved in to gain acceptance for their theories, and highlighting the imagination and constructive skepticism that underlay these efforts.

6. Conclusions and recommendations.

In order not to be left behind in the constantly changing global economy, Asian education authorities need to move from a systems-centered hierarchical model to a student-centered consultative system. The key to success is two-fold: the creation of a grass-root movement that carries the changes from ground-up, and the advancement of policies by the educational authorities (at national and at school level) to support this movement from the top.

Specifically, our recommendations are as follows:

1. Starting with mathematics and physics, educational authorities should remove all syllabus content that does not support the objectives set out in this paper. The Finnish national high school curriculum – and other continental European curricula – would be good places to look for examples.
2. A list of PBL problems relevant to nation and school should be produced, from which teachers *may* choose if they want to (but they should be encouraged to set their own problems). At least 20% of the final grade should be set aside for assessing progress in the PBL skills. Assessment to be done through presentations and peer-grading (with teacher acting mostly as referee).
3. In science and mathematics education, in addition to the PBL problems, the *scientific method* should be taught explicitly, showing its wide societal application. In addition, the exciting history of science should be highlighted, focusing on the importance of the unrestrained imagination, constructive skepticism, peer review, and transparent communication, which have together made science arguably mankind's most successful endeavor.
4. Governments should follow the rest of the world and firmly abandon administration routines that imply a lack of trust in their teachers, such as weekly scrutiny of teacher files. Instead they should be seen to actively promote teacher autonomy, and to (be seen to) promote those teachers who show independence, initiative and a willingness to experiment to make classes more enjoyable (despite the unavoidable failures such teachers will face from time to time!).
5. Governments should concretely promote a new way of working in schools, where top-down decision-making gets replaced by consultative decision making (citing the scientific method as rationale to explain the change). As these changes are likely to be resisted by middle managements in schools, governments should be vigilant and monitor that meetings at all levels be consultative, and that students will enjoy true representation in schools, with a significant vote on matters important to them.

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