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ATINER's Conference Paper Series
ENGEDU2016-2146

How to Keep Science and Technology Curricula for the Senior Phase (RSA) Relevant to 21st-Century Demands on Teaching and Learning

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This paper should be cited as follows:

de Kock, J., and Greeff, A. (2016). **" How to Keep Science and Technology Curricula for the Senior Phase (RSA) Relevant to 21st-Century Demands on Teaching and Learning",** Athens: ATINER'S Conference Paper Series, No: **ENGEDU2016-2146.**

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8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209 Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm
Printed in Athens, Greece by the Athens Institute for Education and Research.
ISSN: 2241-2891
01/03/2017

How to Keep Science and Technology Curricula for the Senior Phase (RSA) Relevant to 21st-Century Demands on Teaching and Learning

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Abstract

Satellites have penetrated every corner of our human existence and are pivotal in understanding the world. How is it possible that this major development of science and technology, during the past fifty years, is so poorly reflected in the classroom of the 21st-century? The data logging and satellite environment is one example of how we have started to engineer the world inside and around us at a breakneck speed. How do we develop the capacity for innovation and problem solving in the classroom in line with 21st-century science and technology? How do we prepare learners to be lifelong learners and active and informed citizens and prepare them for jobs not yet created? How do we adapt current teaching methodologies to a dramatic shift in the educational environment and use the latest technology to contribute to excellence in the classroom? The known TPACK-model, developed by Mishra and Koehler (2006), builds on the work done by Shulman (1987) and presents a valuable framework for educators and learners to engage in active, meaningful 21st-century teaching and learning on the following levels: Relevant content material that counts, the art and science of teaching at specific cognitive levels with or without technology, The use of technology in a confident way in and outside the classroom. This article focuses on the Content Knowledge domain of the TPACK-model. It explains how relevant and exciting topics are incorporated in the Senior Phase (13 to 15 year old learners), in a multi-cultural schooling system in South Africa, and creates a space to such an extent that teaching and learning occurs without deviation from the main structure of the curricula.

Keywords: 21st Century Teaching and Learning, Natural Science, Technology, TPACK, Senior Phase School, Middle School

Introduction

What does it take to prepare young learners to be successful scientists in the modern world? The answer to this question is not just an one-dimensional approach as ongoing discussions, various articles and current research shows us. Obvious outcomes are deep knowledge of a discipline and mastery and application of the scientific and/or technology methods. Combine this with the ability to think critically, solve problems creatively and in the process work collaboratively, communicate skillfully, with seamless integration of technology and we have a chance to prepare "The Scientist of the Future" according to the magazine Nature (2015). The argument is that creative thinking, problem solving, reflection (meta-cognition), persistence and other 'twenty-first-century skills' can, and should be taught and fostered through well-designed courses. Developing these skills enhances learners' abilities to master and retain knowledge and hopefully capture learners for the Science, Technology, Engineering and Mathematics environment.

Why the TPACK Model?

The Technological Pedagogical Content Knowledge approach (TPACK) provides a constructive framework for development of a relevant curriculum. The Pedagogical Knowledge (the art and science of teaching effectively - the "how" of teaching) is as important as the Content Knowledge (development of content that counts - the "what" of teaching) in collaboration with Technological Knowledge (understanding the impact and effective use of technology) (Doering 2009).

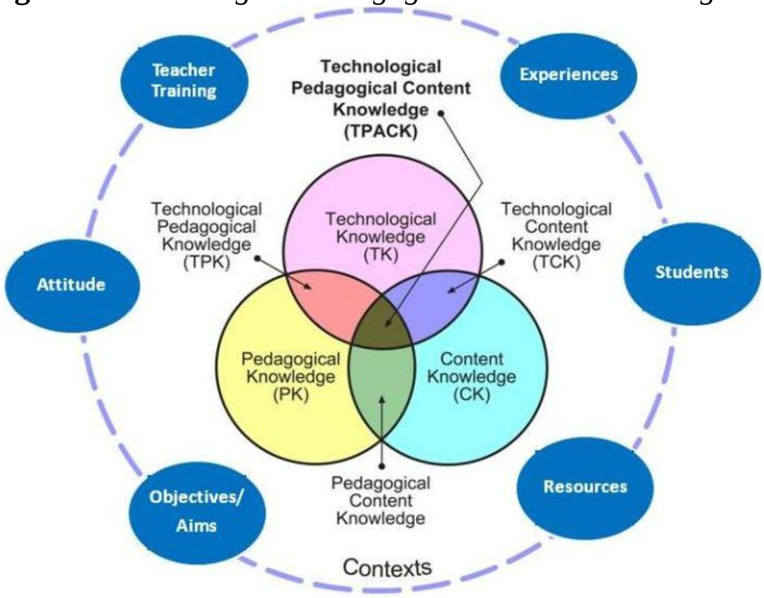
Content knowledge is seen as the volume of knowledge encompassed in a specific content learning area. Historically success was measured as how efficiently educators could transfer this knowledge to learners by rote learning techniques. The schooling system in South Africa abounds with excellent educators who have become experts in coaching learners to write a final exam and be credited for the success.

Over years it appeared that the *what* and the *why* of teaching is not enough for an effective classroom experience. **Pedagogical knowledge** (the *how* of classroom teaching) started to play a more important role. In the search to find an educational system to rectify huge educational divisions of the past and address the problems of learners from extremely different backgrounds, the focus on pedagogical knowledge was left well behind in South Africa with little interrelation between content and pedagogy.

Advances in technology started to have a more severe impact on classroom teaching since access to the Internet became the norm and laptops, tablets and smart phones ubiquitous consumer devices. This brought a third component to the education environment and a challenge to established teachers who are not always open to change. **Technological knowledge** by itself is not an effective way to teach but, the integration with content and pedagogical knowledge has become a valuable skill.

Mishra and Koehler (2006) coined the combined framework, technological pedagogical content knowledge and called it the TPCK model (the acronym subsequently changed to TPACK). This model strives to "capture some of the essential qualities of knowledge required by educators for technology integration in their teaching, while addressing the complex, multifaceted and situated nature of teacher knowledge".

Figure 1. *Technological Pedagogical Content Knowledge*



Source: Mishra & Koehler, 2006.

The strength of the TPACK model lies in its dynamic application in the teaching and learning environment. Different contexts influence the relevance of a domain with regards to the other two domains as shown in the graphic above. Learners are at different levels of cognitive development, from different backgrounds and experiences. Educators, on the other hand, do not have the same interests, even in the same learning area, received different training and have different attitudes towards education with variable resources. Equal application of the three knowledge domains provides an opportunity to effectively develop concepts and ensure that deep, meaningful learning stay at the core of everyday teaching and learning.

The Curro Approach

In the South African educational system learners are obliged to participate in a final written examination and give an account of knowledge and skills accumulated over twelve years of school. The last three years of a school career is occupied by the FET Phase (Further Education and Training Phase) where there exists little time to experiment or move outside a curriculum with fixed topics. Therefore, the Senior Phase, preceding the FET Phase, provides a golden opportunity to expose learners to relevant learning material, broaden their view on the modern science and technology world and capture their interest to choose subjects like Physical Science, Life Science or Technology.

South Africa has an abundance of research and development in learning areas which can be linked to the current curricula. Residential universities and research centres, as part of an international community in science and technology, provide articles, research papers and results to use in designing relevant learning material. South Africa’s Council for Scientific and Industrial Research (CSIR) annually publishes the latest information on research and development on a broad front in their Science Scope magazines. The recently published book *Innovation* by Sarah Wild (2015), speaks of a South Africa where science, technology and innovation are used to address local problems and thereby shaping a country through science and modern technology.
Senior Phase Natural Science & Technology encompasses different learning areas namely: Life and Living, Matter and Materials, Energy and Change, Earth and Beyond, Mechanical Systems (incorporating Communication and Design), Electricity and Control and Processing. These learning areas provide a vast canvas for engaging learners in the ever changing world of Science, Technology, Engineering, Mathematics and Medicine. Written across any chosen learning area are the effective use and seamless integration of the Scientific and Technology Processes during this phase.

Different questions were asked to **introduce** new relevant topics in the curricula, **substitute** irrelevant material or **enhance** existing learning material:

- Which topics in the current curricula are duplicated in any other learning area of the phase?
- Do topics exist where both Natural Science and Technology can benefit from the same activities?
- How relevant is a topic to increase essential knowledge?
- Does a topic add value to the current curriculum?
- Do learners realise why they need to perform a certain task or obtain certain knowledge and skills?
- Are learners engaged in the learning process?
- How effectively is modern technology incorporated in the teaching and learning process?
- Does a topic link to standard assessment guidelines in the FET phase?

Content Knowledge

The choice of multidisciplinary topics makes for a balanced presentation of the senior phase curricula. Following here are examples of relevant topics presented and developed as substitution, addition or enhancement to the Senior Phase curriculum.

Natural Selection and Evolution

South Africa abounds with the visual and factual presence of who we are as human beings, and where we come from. Facts around **Natural Selection** and **Evolution** is an essential part of Life Sciences in Grade 7 and creates a space for the latest findings and discoveries. The revealing of Australopithecus sediba and Homo naledi by professor Lee Berger changed the way anthropologists (and all of us) look at the family tree of Hominins in our world - The Skull in the Rock, (2012). Combined with the history and beauty of, and extraordinary life on the Galapagos Islands, this learning area fascinates even the most skeptic learner.

Fundamental States of Matter

From an early grade, learners are introduced to three states of matter: gas, liquid and solid. Seldom is the fourth state of matter, plasma, mentioned in textbooks as one of the **four fundamental states of matter**. According to Encyclopaedia Britannica on the WWW (2016) Sir William Crookes mentioned radiant matter in 1879 while the word “plasma” was already coined in 1928 (Hart-Davis 2009:141). Although plasma encompasses different grades of magnitude and can become a daunting topic, visible existence of basic plasma phenomena around us like lightning, flames, television screens, auroras and light bulbs, provide an easy way to extend the traditional three phases to four phases of matter in the classroom. An opportunity to create awareness of multiple other states of matter in the modern science world exists.

The Standard Model

In 1964, Particle Physics went to a next level. It turned out that protons and neutrons were not elementary particles after all. They consist of a new group of smaller particles, named quarks. Quarks, as a set of fundamental particles in **The Standard Model,** took shape in the early 1970s with the aim of explaining deeper aspects of physics. It has been shown to be a very good way of understanding visible matter and three out of the four major forces of nature (Jackson 2014:110). Still, little to none of this relevant atomic information is mentioned in any senior phase textbook or learning material. Learners leave the schools system with a total outdated concept of the atom. With an ongoing media information stream about modern physics, originating from CERN, a new approach is long overdue and **The Standard Model** has to be presented to senior phase learners in simplistic ways.

HIV Programme

The relevance of an endemic outbreak of a virus like HIV, Ebola or Zika, challenges the classroom environment whether the true nature of knowledge and research can be presented to learners without endangering anybody's health. The learning area of health, micro-organisms, adaptation and survival provides an opportunity to incorporate practical simulation programs in the Life Science, Grade 8. Curro Schools, in cooperation with a local company, Somerset Educational, implements a well designed **HIV-programme** focused on group work as a class methodology, simulating different health, social and medical issues around this controversial topic.

Space Weather

Since the Space Race started for supremacy in spaceflight capabilities, our awareness of **space weather** and the possible devastating effect on Earth, has emerged as an important topic of discussion and research. The effect of space weather, from a Natural Science and Geography perspective, closely links with satellite technology and data logging activities as learning areas. SANSA (The South Africa National Space Agency) is heavily involved in education of young people and their web site and information centres provide useful learning material for senior phase classrooms. Learning material about weather and magnetism on Earth is extended to weather in space and the sun's magnetism and its behaviour. This provides learners with relevant knowledge on the impact of the sun on our high-tech environment and lives.

Structures and Mechanical Systems

The use of sticks, grass, tooth picks, plastics or various recyclable material can just go so far in developing the concepts of **structures and mechanical systems** in technology. To fully understand the precise workings of gear systems, levers, axles and wheels, cranks and shafts, valuable skills are developed by using sophisticated building sets available on the market. Models designed by Da Vinci, centuries ago, encompass various aspects of the technology curriculum and is marketed by companies well known in manufacturing equipment for educational purposes. Building of different models test learners' capabilities to read instructions, perform an activity collaboratively, test a model (apply meta-cognitive skills) and communicate a final result. These skills, combined with the Technology Process, are applied in various ways to design totally new models.

Electricity and Electrical Systems

Electricity and electrical systems seems to be an area were learners show little joy in the learning material. To find learners engaged in electrical concepts and be excited about the subject is, from personal experience, a rarity! Series- and parallel circuits are presented, year after year, with little deviation from the basic concepts and calculations. Careful planning and coordination between Natural Science and Technology opens space for a more innovative approach. On the one side topics like electrostatics, electrochemistry and Ohm's Law form an important part of Natural Science, while on the other side Technology focuses on technical applications and construction systems. **Electronics** is introduced at an early stage. Here, the use of precision building sets, supported by software applications, engage learners in new and exciting activities to build real life electrical and electronic models and learn far more than just the repetitive series- and parallel circuits.

Nanoscience & Nanotechnology

Nanoscience and nanotechnology has dramatically changed the way we look at the macroscopic world due to characteristics and behaviour of materials and creatures on a billionth of a meter scale in the nano world. Why the fuss over nanoscience and -technology? According to the South African Nanotechnology Public Engagement Programme (SAASTA 2011), focussing on the Nano world is an enabling technology which has the potential to create new markets, create opportunities in existing markets and thus paving a way for the next industrial revolution. Although Nano science and -technology is a vast and challenging research area at tertiary level, basic concepts can be developed in the Senior Phase. Learners work with scientific notation in Mathematics and use this knowledge to visualise a world getting smaller and smaller. Various basic activities link to the Nano world using measurement in length, surface area and volume, activities in changing colour (photonics) and electronics. Valuable learning material is regularly released on the latest research by the National Research Foundation (NRF) and are used to update this valuable module.

Data Logging

Data logging presents itself as a topic to be incorporated across Natural Science and Technology in various learning areas like: data collection on natural selection, pH of liquids and food around us, electronic equipment to track satellites, measuring the sun's radiation, temperature changes in a classroom or fridge, luminosity of daylight, to name only a few. Various pieces of equipment and software programs are available to use in the process of collecting data. Incorporation of both the Scientific- and Technology Processes, to conduct activities, is a valuable tool to develop sound research skills: ask questions, collection of data, drawing of graphs, collation and interpretation of results, communication of findings and presentation of results.

Satellites

At the 62nd International Astronautical Congress, the prestigious annual conference of the IAF held in Cape Town in 2011, the then Minister of Science and Technology, Naledi Pandor told delegates that "South Africa's intention is to expand the investment in 'micro' satellites building on existing platforms". These 'platforms' were the Sunsat and SumbandilaSat two of South Africa's three satellites orbiting Earth as part of a global satellite and space program, built by Stellenbosch University and a Stellenbosch-based company, SunSpace. The FET Phase curricula offers no learning material concerning this important area of development and it leaves the Senior Phase curriculum to address the shortcoming in relevant learning material. Development of South Africa's first cube satellite (third satellite) by **F'SATI,** at the Cape Peninsula University of Technology, brought a valuable opportunity to integrate knowledge about satellites into the curriculum. Learners are constantly involved in everyday use of satellite related data: cell phones, GPS, television, weather forecasts and sharing of global images and information. Tracking of the **ZACUBE-1 (Tshepiso)** becomes routine and building and 'launching' of a CurroCube (a simulated example of a CubeSat) touches the vast possibilities to experience a satellite as the ultimate data collector while working with mega data.

Modern Materials

The introduction of **Plastic Materials** in the Senior Phase can be a tough topic due to the understanding of macromolecules from an Organic Chemistry perspective. Introduction of Organic Chemistry starts in late Grade 11 or Grade 12, Physical Science. More advanced polymer chemistry concepts like polymerisation, cross-linking, foaming and annealing can however be practically introduced in such a way that learners become familiar with how plastics behave rather than the theoretical detail behind these behaviours. Current learning material in the Senior Phase focusses only on thermoplastic and thermoset behaviour and repetition of the recycling topic, year after year, add little to a learner's experience.

The plastics program in the Curro School cycle consists of three levels:
Practical activities to produce **different kinds of plastic material**s and learn the differences between materials like rubber, polyurethanes and water based plastics.
This is followed by practical activities on **identification of different plastic materials** leading to the topic of recycling. Recycling can only be successful if a consumer knows how to differentiate between materials and apply recycling methods effectively.

In the final stage, learners are introduced to mould making, casting and embedding. The use of the Technology Process is essential to design, make and present a final product as part of an entrepreneurial task.

The motto is always: *"Ignorance and misconceptions about plastic materials are the biggest reason for plastic pollution – materials don't litter, people do!"*

Get out of the Classroom …

How do we inspire young people to start to explore STEMM areas (Science, Technology, Engineering, Maths and Medicine)? Curro Schools annually organises a Science and Technology tour for Grade 8 and 9 learners to see how Science and Technology shape our future. South Africa's metropolitan areas provide ample opportunities to expose learners to valuable examples of relevant research and applications. To see and experience a University campus, where young, enthusiastic senior students are busy with post graduate studies, has a huge effect on the choice of a career. Research centres like the CSIR, Particle Acceleration Centres, SANSA and national universities annually accommodate groups of learners and expose them to world class research not available to individual people outside the educational environment.

Conclusion

We live in a world where the education system has become obsolete and serious questions are asked about how to survive in a changing world. Leading thinkers in education repeatedly voice their concerns on various media platforms and forums that we still run an educational system developed for the industrial revolution and a mind shift is essential for a next generation to be successful in life.

The TPACK framework and more lately the Promethean document: *The Modern Classroom*, has serious implications for the training and development of teachers and the awareness of their metacognitive skills to implement technological, pedagogical and content knowledge in classrooms. To implement changes are not easy and teachers and parents often question whether it is necessary at all. Education, where a teacher is the main source of knowledge and the classroom environment as a one way lecture, with learners being passive listeners, has worked for centuries. Why change?

One of the main reasons for change is that Science and Technology are innovative, exciting, ever changing environments where new discoveries, inventions and development happen daily. It engulfs the exploring spirit of us humans like no other environment, ranging nowadays from cancer research on a nano scale to launching a spacecraft and exploring the outer limits of our solar system. These changes have to be reflected in our classrooms where young minds are eager to be engaged.

To start this change in teaching and learning learners need to be exposed to a series of <u>relevant</u> and <u>exciting</u> learning topics to make the classroom experience count. Choosing relevant content material immediately integrates the latest available technology and thus challenges the art and science of teaching in the classroom. Educators can’t teach any more from an 'ivory tower' attitude and expect better results. The TPACK model provides a framework for training, research, dynamic changes, support, future improvements, influencing the way we incorporate current and future technology to teach and learn.

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