

# Science Teachers' Engagement with ICT in Singapore: Different Perspectives

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**Abstract:** In this paper, we present narratives of three in-service biology teachers in their journey with the use of Information and Communication Technology (ICT) in their practices. These narratives provide useful insights into the in-service science teachers' ideas, dilemmas and actual usage of ICT. The use of narratives to present perspectives of biology teachers' engagement with ICT is a deliberate one — different teachers have different experiences with their students and across different schools. As such, the stories generated are different but personal and real to each participant. The in-service teachers are purposively sampled: all of them having taught science in secondary school for at least three years and had shown a keen interest in technology during their pre-service teacher program. A series of questions was used to help the participants reflect on their experiences and craft their narratives. These narratives were then analysed using content analysis of recurring themes. From the narratives, we found that generic ICT tools could be used for evaluation of students' learning while specific ICT tools such as sensors were used for the teaching of specific scientific concepts and to support scientific inquiry. Further, in deciding which ICT tool to adopt for their lessons, teachers took into consideration external factors such as availability of wireless networks, school infrastructure, ease of setting, and students' motivation. In terms of professional development on the use of ICT, we found that sharing sessions on what works, time and space for experimenting with new ideas, and in-depth implementation of fewer ideas rather than many ideas worked for the teachers.

**Keywords:** In-service science teachers, Narratives, ICT use, Professional development

## 1. Introduction

The use of Information and Communication Technology (ICT) in education has been ubiquitous for more than two decades. Information and Communication Technology has changed classrooms and the way people learn faster than any other educational reforms or initiatives. For example, in science teaching and learning, the call for teaching science as a form of inquiry started in the 1900s, and until today, the adoption of science as a form of inquiry remains fuzzy and sometimes even elusive. The penetration of ICT into science classrooms, however, appears to be more successful as evident from the pervasive use of laptops, sensors, videos, mobile computing devices and apps for science learning.

The popularity of ICT in science learning points to the need for science teachers to be proficient and confident in their use of ICT to enhance the teaching of science as a form of inquiry. As Singer and Maher (2007) pointed out, despite the prominence of learning technology in schools, significant changes in teaching strategies have not kept pace. They attributed this to the poor quality of professional development and inadequate teacher preparation. They argued that since the presence of ICT tools is characteristic of the 21<sup>st</sup>-century classroom, teachers need to know how to use computers, software and apps. In science classrooms, ICT can help students conceptualize invisible and abstract science processes, visualize particles that are either too small for the naked eyes or too large for normal sight, and to assemble scientific model and propose explanations (George & Ogunniyi, 2016).

A positive attitude of teachers towards ICT integration and their willingness to try various tools are important for effective use of these tools in the classroom. (Cracium & Bunoiu, 2015). Cracium and Bunoiu further argued for the need to relate the digital skills possessed by in-service and pre-service teachers be made sense of in the light of "their attitudes towards ICT in their everyday life for personal

and professional usage...” (p.82). The call for more attention to the needs and attitudes of teachers is heeded in this paper as we focus on science teachers’ personal ideas and experiences with ICT guided by the research question: “What are the ICT experiences of science teachers in teaching and learning of science?”

## **2. Background Literature**

In this review, we raised some questions at the nexus of science teacher professional development and the use of ICT. From the literature that we have read, we attempt to show that there is a need for us to better examine teacher professional development in ICT from a more teacher-centric angle. Science education journals published few articles pertaining to the use of ICT and teacher professional development. The articles that are published with respect to ICT are generally focused on how students respond to the use of ICT to learn specific science concepts. The only exception is the *Journal of Science Teacher Education* that revealed more articles related to how ICT is used to improve professional development and pre-service teacher education. Technology-related journals published articles related to science and use of ICT as well with a distinct difference from the articles published in science education journals. The articles published in technology-related journal tend to foreground the technology with little mentioned about the specific science content. After a scan of the literature from science education journals and technology-related journals, two key questions were raised.

The first question that arouses our curiosity pertains to what research has already informed us about effective professional development for science teachers in the integration of ICT to enhance science learning. Research findings of various studies generally point to a co-design modality as an effective way of equipping teachers with technology skills (Kafyulilo, Fisser, & Voogt, 2015; Leary, Severance, Penuel, Quigley, Sumner, & Devaul, 2016; Matuk, Gerard, Lim-Breitbart, & Linn 2016). Teachers working together with technological experts and researchers to co-design lessons not only enables teachers to increase their understanding of the relationship between the science content, the technology, and the lesson design but also empowers them to make critical decisions about what is best for their students’ learning. This is powerful in encouraging meaningful and sustainable change in classrooms.

The second question that we asked relates to the methods that are currently used to understand teachers’ needs and ideas about ICT and science learning. George and Ogunniyi (2016) used a survey (Technology Acceptance Model) and interview with 45 teachers in South Africa to determine the usefulness and intention of teachers to use ICT in their practices. Craciun and Bunoiiu (2015) used a self-report evaluation on a group of pre-service teachers to assess change in confidence level after being engaged in using social media and Web 2.0 technology for digital story-telling and digital comics in science. Qablan, Abuloum, and Al-Ruz (2009) used a series of interviews and classroom observations together with Activity Theory to assess the utilization of ICT in science teaching in Jordanian schools. Chittleborough (2014) studied chemistry pre-service teachers’ produced artefacts, their reflections and survey to determine if integrating technology into pre-service teachers programs will help to increase skill levels of use of technology for teaching and learning. The literature revealed few studies that used a research method that enables one to delve deeply into the experiences of teachers as they engage with ICT. The lack of teachers’ voices in the use of ICT is one area that we aim to address in this paper.

## **3. Methods**

This is a qualitative study that adopts a narrative approach to studying the lives of science teachers as they engaged in their business of teaching and learning. Purposive sampling of the three participants was carried out. The participants are all male in-service teachers who have been teaching science and biology for at least three years in a secondary school. These teachers are chosen as they have been shown to be confident users of technology while they were pre-service teachers. The teachers were invited to write a personal narrative of their experiences with ICT in their teaching. Prompts in the form of questions (such as what factors do you take into account when you plan to use ICT) were given to guide their reflection. We read through the narrative and surfaced questions that arose and send these to

the participant teachers to answer. We argue that working with the participant teachers on their experiences with ICT usage enables both the participants and us (as researchers) to become more sensitive and curious about our experiences. The research process in itself is a powerful learning experience that cannot be derived from books or formal training (Teo & Tan, 2011). Through this process, we refine their thoughts and our interpretation of the ideas.

The use of narratives as a means for us to present the different experiences that science teachers have with using ICT in their practices is a deliberate one. Narratives are stories that people tell based on their personal experiences with the world around them. From these stories told, it revealed how individuals make sense of and interpret the world around them. As such, using stories, we can understand the existence of different interpretations of social life (Clandinin & Connelly, 2000) – in this case, how the policies of ICT and its local implementation are experienced by teachers. Personal narratives are able to reveal more personal perspectives of the world than interviews or questionnaires can. As Nicole Grimes (2013) wrote in her personal narrative of her identity as a Caribbean female teaching science, she justified her choice of using narratives by arguing that “the stories we craft describe our perceptions and our experiences, and in themselves are highly significant, as when examined closely, they provide us with information about our human culture” (p. 334). In this study, we present narratives from three secondary science teachers in an attempt to understand the role that ICT play in the teaching and learning of science.

Coding was also carried out on the three narratives. Although the sample of three is small, the coding was meant to under the frequencies with which external factors and internal factors affecting their experiences with the use of ICT in their practices were mentioned. Coding was carried out in NVivo and the coding categories were emergent from the narratives.

## 4. Results

In this section, we present the three narratives written by three science teachers, Glen, Edmund and Hugo (pseudonyms). The narratives themselves are stories that ought to be read, reflected and interrupted by the readers, sometimes in the context of the readers’ personal experiences. As such, the narratives, in themselves, form a rich corpus of information from which we can learn from. In the second part of this section, we presented the frequencies with which the various external and internal factors were mentioned in the three narratives to highlight the emphasis that the teachers places of each of the factors.

### 4.1 Glen: “How technology can allow AfL to happen in the classroom.”

I am a biology teacher who has been teaching for 10 years. I had previously taught at junior college students and now is teaching secondary school students. From the many years of teaching biology, integrating ICT into my practice means that I use ICT (e.g. PowerPoint software, Edmodo, Socrative and Nearpod apps) to support my teaching and students' learning. I have recently changed my style of teaching in the science classroom. In the past, I used to teach using PowerPoint slides and ask questions verbally in class to check on students' understanding. When I finish teaching the entire topic, I will give students worksheets to complete and then I will go through the answer with them in class. Nowadays, I have used Nearpod for my lessons. I upload my slides into the app and integrate the questions from my worksheet into the app. Once I finished a concept in a topic, which can be about 2-3 slides, I will show questions related to the concept and get students to respond immediately on their mobile devices. I will be able to use the data collected to give on-the-spot feedback to close any learning gaps the students may have, before proceeding to teach the next concept. ICT has also allowed me to do flipped learning as I would upload some video links, etc. on Edmodo and students will learn about those concepts first before attending lessons. So the shift in my use of ICT in these 10 years is from simple PowerPoint slides (presentation, frontal) to Socrative (elicit responses) to Nearpod (presentation with eliciting responses).

The availability of ICT tools has influenced how I planned my lesson. Nowadays, I need to prepare all the questions before I teach a topic so that I can integrate the questions with my slides as I go through Nearpod. In the past, I would prepare and give the questions after I have finished teaching a

topic. I need to be mindful about which ICT tool I use in my lessons, especially if I collect responses from students for the purpose of formative assessment. Every ICT tool has its strength and limitations, and a good awareness of this is important in my selection. For example, Kahoot is easy to set up but only allows multiple choice items; Nearpod allows students to provide open-ended responses, but it takes more time to prepare.

With respect to the role that ICT play in science teaching, I don't really distinguish between using ICT in science teaching or the teaching of other subjects. The choice of ICT tool should be fit-for-purpose. The only benefit of using ICT for the teaching of biology is that simulations can be shown to help students better visualise processes, e.g. transcription and translation, at the cellular/molecular level.

Beyond science learning, I think ICT enhances students' learning in general because I use it a lot for assessment for learning (AfL). Technology has now allowed me to collect data on students' learning on-the-spot and I can adjust my pace of teaching and tailor my delivery to better suit the profile of learners. I use the information collected with the help of ICT tools to inform my next pedagogical move in the classroom.

The decision to select the most suitable ICT tools for my lessons rely on different factors such as the (1) infrastructure (whether the school's internet wifi is able to support), (2) time to set up the equipment (I settled with Nearpod because it is relatively quick to set up), and (3) student motivation (I have not used it for my NT class because they tend to be distracted by mobile devices). I am trying to explore other ICT tools (e.g., Plickers) for this group of students such that I can gather quick responses without having them to have any computers/mobile devices.

In my school, the school leaders have dedicated staff training days for staff to learn ICT tools. For example, in the training session last year, I learnt about Edmodo. This year, the EdTech team taught us Nearpod, Kahoot, and Padlet. I have chosen to explore further into Nearpod and am intending to embark on my own research about the use of such apps to support teaching and learning. I think more research needs to be shared with teachers about how an ICT lesson could be structured and how technology can allow AfL to happen in the classroom.

#### *4.2 Edmund: "Grounds up construction of knowledge with much convenience."*

I have been teaching in a school for 3.5 years. For me, the integration of ICT ranges from the basic use of a projector to the more advance use of motion analysis app such as Tracker (<http://physlets.org/tracker/>). For example, in the teaching of how objects fall (see attached for lesson plan), a video can be made of a tennis ball that was dropped from a certain height. This can then be analysed using Tracker to plot various graphs such as the velocity-time graph, and calculations can be done to determine the acceleration as the tennis ball falls. Results from such analysis can then be used to reinforce concepts taught in Kinematics.

When I plan for my science lessons, my primary concern still lies in how the content can be delivered to the students in a manner that ensures the accurate learning of that particular concept. I will only use ICT if it aids in the teaching and learning of the subject matter. That being said, the basic use of ICT tools such as PowerPoint slides, animations, and videos are now indispensable in my day to day lessons as they allow for more clarity of thought in the ideas that are being communicated to the students. Generally, the factors that I will consider include whether the ICT tool is supported by the school's infrastructure, the cost of the ICT tool, the 'user friendliness' of the ICT tool (since a class of 40 students with diverse backgrounds may need to handle the ICT tool), how does the ICT tool brings about learning, the time spent teaching on the use the ICT tool vs. the actual time spent learning the concepts by students.

Beyond running simulations for a richer and easier way of teaching scientific concepts, ICT can bring about the much-needed authenticity into the teaching of science. The affordance of cheap sensors such as those in Arduino allows for experimental data to be gathered readily from the environment and analysed to verify scientific laws. This removes the abstractness of ideas in the teaching of science and helps students to reconcile their day to day experiences with the concepts that are being taught.

From my experiences of experimenting with the various ICT tools such as Tracker, Arduino, and others, the use of ICT tools definitely helps to enhance science learning as it allows for a grounds-up construction of knowledge with much convenience. Previously, such construction of knowledge requires students to carry out of experiments in science labs, which are not only time and

resource intensive, they are also more prone to mistakes by students. However, with videos, animations, and simulations, the scientific inquiry process can be made more efficient and meaningful with more focus on the discussions of ideas by the students. Sensors can also be readily deployed to not only gather large amounts of experimental data to minimise any random errors, but also to directly verify scientific laws (for example, acceleration is directly measured using accelerometers rather than derived from the double differentiation of a displacement-time graph which is gathered from the use of a ruler and a stopwatch).

When I first started out, there was a lot of usage of videos and simulations (<https://phet.colorado.edu/>), but now, what interests me are the apps and sensors that can allow me to directly verify scientific concepts to bring authenticity into the classroom. To help me use ICT tools more effectively, I think the sharing of lesson ideas for the integration of ICT would be great since most teachers are more interested in how ICT tools can help elucidate scientific concepts rather than the ICT tools themselves.

#### *4.3 Hugo: "We have tried too many things."*

I am a teacher who has been teaching Biology in a secondary school for the past three years. My students are keen to learn, and they are generally well behaved. My school is supportive of innovative practices in teaching and learning. For me, integration of information and communication technology (ICT) suggests a pervasive use of ICT in teaching and learning that can be sustained regardless of context. It could be as simple as using a routine method of assessment for learning. For example, I frequently use the powerpoint app "polleverywhere" as a method of understanding my students' knowledge before the start of lessons. Students use their mobile phones to answer questions in real-time. Other than having a real-time understanding of the data, I can collate the data back-end to compare if they have improved over the course of the lessons.

The use of ICT does influence how I plan my lessons. For me, the use of ICT makes teaching and learning more efficient. I constantly think about how best to make my understanding of my students' learning efficient. This includes the use of ICT to gather data to capture students learning.

Personally, I do not think there is a specific role of ICT in science teaching, but in teaching as a practice. There might be ideas that seem more "applicable" to the context of teaching science, such as the use of visualisations or animations (on the PhET websites). Beyond that, I would like to zoom out of the science context and look at the bigger picture and ask myself "why ICT in my teaching?" In science, ICT helps to make the learning of abstract concepts more efficient. Through visualisations and animations, it is possible to visualise concepts that are otherwise not feasible to demonstrate or to manifest in a classroom context. However, it is only with clever and thoughtful planning supplemented with instructions/worksheets before learning can be done. So the question is — are we able to have a really immersive ICT lesson with interaction with only an ICT tool with real-time data collection, without the need for pen and paper? Would that then allow me to enhance the learning of science?

In considering if I should use ICT, I think efficiency and scalability are two very important factors. There is little point in using ICT if it means more work with little impact. In my opinion, ICT should make the job easier, and not tougher. I am beginning to use more ICT in my science teaching but have a preference for ICT that builds into routines that engage students. Importantly, I would also use ICT that allows me to have a measurable impact in order to understand how students have learnt or are weak at.

With regard to professional development needs for myself related to ICT, I think we have tried way too many things. I think we should be using a few things more often in class than to keep trying new things. But if there is one that I would like to try it will be a long-term collaborative tool. Till now, I do not think any Learning management system is able to engage students for a long time in order to learn.

#### *4.4 Factors Shaping Science Teachers' Experiences with ICT*

The factors that shape the participant teachers' experiences with ICT can largely be understood as internal factors (teachers' beliefs, teachers' competencies) and external factors (cost, ease of usage, infrastructure, hardware, software, perception of students, availability of time). Table 1 reports the

frequencies in percentage of the mention of the various factors in the three narratives. We hypothesize that the prevalence of mention of any factors is indicative of the concerns or importance that the teachers placed on the factors. In their narratives, the teachers make reference to what they belief to be important functions and purposes of incorporating ICT in their practices. All the three held the belief that ICT ought to make learning more effective and authentic. They however, deferred in the kinds of ICT tools that they would use to achieve their purposes. The high frequency of mention of different types of softwares and Apps is indicative of their different experiences and forms of interaction with ICT tools.

**Table 1: Frequencies of factors shaping teachers experiences with ICT**

	Percentage (Frequency)
<b>External Factors</b>	
Time	6
Cost	6
Perception of students	2
Availability of hardware	6
Ease of usage	8
Infrastructure	4
Exposure to software	20
<b>Internal Factors</b>	
Teachers' beliefs	38
Teachers' competencies	0
Strategies for teaching	10

\*Total number of codes is 50

## 5. Discussion

The narratives of the three participant teachers on their ICT experiences in science classrooms revealed that the same ICT policy has yielded similar yet different experiences for the teachers. Each of the teachers has slightly different reasons for using ICT tools in their teaching. For Glen, his key reason for using ICT tools is to obtain feedback on his students' progress of learning. This is one of the technological pedagogical knowledge (TPK) – use digital technologies to help in assessing students learning (Graham, Burgoyne, Cantrell, Smith, St. Clair, & Harris, 2009). For this purpose, he does not focus entirely on tools pertaining to science learning. Rather, the ICT tools that he used are generic tools that enable him to ask questions and obtain answers from the students. Hugo shared similar application of ICT tools in his practice. He also used ICT tools to capture students' learning. The use of ICT tools for evaluation of students' learning is one that is important for both Glen and Hugo, and this resulted in Hugo wondering if there is a need to distinguish between usage of ICT in science teaching as compared with teaching in general. He is of the opinion that there is no one “specific role of ICT in science

teaching, but in teaching as a practice.” The use of ICT within specific domains was also an area of interest among researchers that lead to the development of the constructs of Technological Pedagogical Content Knowledge (TPACK or TPACK) (Graham, et. al, 2009).

Edmund, reflecting on his experiences with ICT in science teaching, focusses on tools that are directly related to science, that is, his focus is on using technological content knowledge (TCK). TCK emphasizes the use of digital technologies in the data collection, recording and analysis in science. He describes in great detail about using sensors to collect data as part of the science inquiry process and also about the use of tracker app to enable students to visualize motion. The emphasis on these ICT tools to collect data is a result of his goal in his teaching – to ensure that his students learn the content of science. It is evident that Edmund’s focus of ICT is the process of teaching and learning rather than evaluation. Edmund used the affordances of various ICT tools to ensure that the learning of science concepts is made more efficient and authentic. The authenticity comes from the opportunities presented to students to work with data and process them to be used as evidence in their explanations.

We have seen how the three teachers can potentially use ICT for either evaluation or teaching and learning, that is, teachers apply the whole range of knowledge from Technological Pedagogical Content Knowledge (TPACK) to Technological Pedagogical Knowledge (TPK) to Technological Content Knowledge (TCK). Beyond these curriculum matters, when teachers are deciding on whether to use ICT in their science lessons, they also take into account external factors such as the availability of wireless connections, the school infrastructure, the amount of time required for setting up and the students’ abilities. Glen and Edmund expressed the need to consider these external factors explicitly while Hugo discussed these factors in the light of increasing efficiency of teaching. These concerns about the factors that will promote the use of ICT is similar to what George and Oyunniyi (2016) found from their study using the Technology Acceptance Model. They found that factors such as the ease of usage and the usefulness of the ICT tools are important considerations for teachers. Similar findings with regard to frustrations of insufficient and unreliable ICT infrastructure, when needed, were also reported by Qablan, Abuloum, and Al-Ruz (2009).

From the narratives, it is clear that the three participant teachers have different views with regard to professional development to improve their use of ICT tools in science teaching and learning. For example, Hugo believes that he has been introduced to too many ideas to try in his classroom. He would prefer to test fewer new ideas and have more in-depth experimentation with the ideas. Edmund thinks sharing of ideas of what works in ICT is a useful and practical way to learn new tools. For Glen, he prefers to learn about new ICT tools from formal structured sharing and subsequently be given to exploring its implementation in his practices. He also thinks that more research based evidence of ICT tools ought to be shared with teachers.

## **6. Conclusions: Implications for Science Teacher Professional Development**

In this paper, we set out to examine the experiences of science teachers as they engage with ICT tools in their practices. The three narratives presented shows how three different teachers perceived their ICT experiences in teaching science with the same national ICT policy but interpreted by their personal preferences and opinions. Two key areas emerged from the narratives on how ICT tools are used in science teaching – used of generic ICT tools to obtain feedback on students’ learning and use of more science-specific tools to collect data and engage students in the authentic inquiry of science. As these are areas that are probably of interest to science teachers, professional development on the use of ICT tools for science teachers can draw explicit examples to how the various tools such as used of sensors, digital storytelling, videos, trackers and others can be used to support scientific inquiry and also to create avenues for collecting feedback on students learning. It is of value to draw reference of how the various tools can be used to support the learning of specific scientific concepts. Hence, we argue for the need for explicit instruction of concepts and principles of TPACK, TCK and TPK in teacher professional development and pre-service teacher education.. Matuk, Gerard, Lim-Breitbart, and Linn (2016) presented evidence to support this idea that technology can help to enhance teachers’ understanding of patterns of students’ thinking, manage class progress at individual or group levels and acquire information to aid teachers in making modifications for their next pedagogical move (AfL).

Secondly, the narratives revealed that science teachers also take into account the ease of usage and implementation in considering the choice of ICT tools. We argue that this implies that the

successful use of ICT is not merely the business of the teachers or isolated in the classroom alone. Rather, there has to be an ecosystem to support the teachers and their implementation of ICT to enhance their teaching and learning. Administrators can ensure that school infrastructure is well developed to support ICT use. Staff involved in technical support of ICT should also be well trained to help with trouble shooting and to solve technical issues related to implementation. This will ensure that teachers have time to devote to the teaching and learning aspect of technology. The intention to use technology can be influenced by various variable such as perceived ease of use, perceived usefulness, attitude toward technology and motivation (George & Ogunniyi, 2016).

Lastly, the modalities of professional development for science teachers related to ICT should be varied to meet the different demands and needs of teachers. From just three narratives, we saw three different opinions of what professional development ought to be (ranging from sharing of ideas on what works to giving time for exploration after workshops, to creating space to try new and fewer ideas instead of many ideas). The narratives indicated that professional development also need to be varied to tackle different forms of knowledge related technology (TPACK, TPK, and TCK) use in schools. As such, professional development providers need to offer a more sincere listening ear to understand different groups of teachers and the stages of their journey with ICT before offering ICT solutions for their classrooms. Different modalities of professional development can also be adopted. For example, Matuk, Gerard, Lim-Breitbart, and Linn (2016) showed that by getting teachers to work on various technological tools together with researchers helps to empower them to design better and more meaningful lesson. Moreover, the teacher will be able to develop a better understanding of the relationship between technology, teaching, and design. Similarly, Leary, Severance, Penuel, Quigley, Sumner, and Devaul (2016) also adopted a co-design mode to help teachers appreciate how to better resolve the tensions between the Next Generation Science Standards (NGSS) and their existing classroom practices. Kafyulilo, Fisser, and Voogt (2015) also provided positive evidence in support of a co-design mode of teacher professional development for the use of ICT.

Professional developers could also possibility move beyond the technology and foreground the scientific content to help science teachers better appreciate the usefulness of the technology in fulfilling science as a form of inquiry. Earle (2002, p. 8) aptly argues that “integrating technology is not about technology — it is primarily about content and effective instructional practices. Technology involves the tools with which we deliver content and implement practices in better ways. Its focus must be on curriculum and learning. Integrations is defined not by the amount or type of technology used, but by how and why it is used.” We support this argument and hence perhaps the construct of Technological Pedagogical Content Knowledge (TPACK) could be better utilized to fulfil this. On the other hand, we could also question if there is a venue for the professional development of science teachers into the epistemology of technology, that is, understanding ICT as the content itself and as a way of knowing (van Eijck & Claxton, 2009).

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