A Framework for Teachers' Integration of ICT Into Their Classroom Practice

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1. Introduction

The lack of uptake of science in Post-Primary Schools (High-Schools) has been a strong cause for concern both in Ireland (Regan & Childs, 2003) and internationally (Bennett & Hogarth, 2009; Barmby, Kind & Jones, 2008; Hassan, 2008). In publication of the Strategy for Science, Technology and Innovation (2006) Report, the Irish government highlights the need to significantly change the nature of instruction of the Physical Sciences in Post-Primary Schools, in recognition of the continuing decline in numbers taking science subjects through to Senior cycle (16-18 year olds) and beyond to University. The report emphasises the need to focus on investigative approaches, problem solving, the assessment of practical work and the effective use of ICT. The National Council for Curriculum and Assessment (NCCA) are the government body responsible for implementing these challenging changes and are currently reviewing the Senior Cycle Science Syllabi with a focus on more inquiry based approaches.

This research is looking at the potential of a Virtual Chemistry Laboratory (VCL) to address the issues raised. The use of simulation-based software is becoming more main-stream within science education (Su, 2008; Dalgarno, Bishop, Adlong & Bedgood, 2009 and Jara, Candelas, Torres, Dormido, Esquembre & Reinoso, 2009). Virtual experimentation offers many potential learning gains that can facilitate inquiry approaches: it gives space and time independency, it is low cost and easy to access and overall it shifts the centre of learning from the teachers to the students (Georgiou, Dimitropoulos & Manitsaris, 2007). Despite these advantages the integration of an ICT based resource is a complex change process that needs careful consideration of the people it affects most: teachers.

Educational change is dependent on "what teachers do and think – it's as simple and as complex as that" (Fullan, 2007:129). This is not to dismiss other educational stakeholders but to highlight that changes in the student learning experience ultimately reside with teachers. When faced with educational change teachers are less likely to engage with policy documents as "the size and prettiness of the planning document are inversely related to the amount and quality of action" (Fullan, 2007: 41). Instead, the most effective source of help for teachers tends to be other teachers (Fullan, 2007:133). As re-enforced by Tyack and Cuban (1995:10) teachers look towards resources, practical designs for change and collegial support in bringing about change. Ultimately, successful change processes require a "bias for action" (Fullan, 2007: 41) i.e. conditions under which people become motivated to change.

Structural and cultural changes to schools make little improvement unless the importance of teachers is taken into account from their construction of "the reality of educational practice on a day-to-day basis in their schools and in their classrooms" (Helsby, 1999: 30). This is not surprising as any form of change leads to intensification of teachers' work by adding burdens to a job that is already excessively demanding (Hargreaves & Evans, 1997: 4). However, many teachers are interested in adopting change in their classrooms and "will do so under the right conditions"

(Fullan, 2007: 60). What is needed for effective educational change is "reculturing" (Fullan, 2007: 25) and this can only come about through the development of shared meaning in the change process which "is at the heart of the matter" (Fullan, 2007: 42).

Moving from internal factors influencing school culture to external factors outside schools adds another dimension to the issues that must be considered. In curriculum reform efforts towards assessment, Trant (1998) highlights various underlying tensions in the Irish education system between teachers, curriculum developers, the Department of Education and Science (DES, now known as the Department of Education and Skills) and teacher unions. He notes the "hostility from the guardians of the system" (p.2). For example, teachers can feel a lack of ownership in curriculum development and therefore do not readily engage with it (Trant, 1998). This lack of ownership relates to the fatalism in a lot of teacher practice (Portelli, 2010). Fullan (2001: 87) re-enforces this notion in that "local school systems and external authority agencies have not learned how to establish a processual relationship with each other". Ultimately, in educational change, a basis of co-operation is needed through partnership that recognises the rights and responsibilities of all involved (Trant, 1998). However, throwing ICT integration into the educational change mix brings about further issues for consideration.

Many barriers must be overcome to bring about successful integration of ICT within Post-Primary School classrooms. Ertmer (1999) described a simple model of two types of barriers, first- and second-order, that are commonly cited as issues in ICT integration. First-order barriers refer to missing or inadequately provided resources such as equipment, training and support. These are barriers that are easily removed once money is provided and hence are usually the barriers concentrated on first in reform efforts. For example, in a multiple case study carried out by Baher (1998) in three universities using a software called CyclePad for thermodynamics education issues were cited such as a lack of computer facilities, constraints of the courses and student scheduling as reasons for difficulties in using the software. Second-order barriers are ones that impact on fundamental change and are typically rooted in teachers' core beliefs and are therefore the most significant and resistant to change. These beliefs revolve around issues relating to teacher-student roles, teaching methods, organizational and management styles and assessment types. Teachers' knowledge of practice, underpinned by beliefs, are difficult to articulate as they are oftentimes tacit and implicit within the practice of teachers (Berry, Loughran, Smith & Lindsay, 2009).

Zhao, Pugh, Sheldon and Byers (2002) presented an expanded model of barriers to technology integration. They identified 11 salient factors that influence the success of technological innovations in classrooms. These factors were placed within three interactive domains of the teacher, the innovation and the context. The factors within the first domain, the teacher domain, will be discussed in detail in a later paragraph. The factors in the second domain, the innovation domain, revolved around two areas: distance and dependence. The first area, distance, referred to the deviation of the innovation from the status quo. This encompassed three sub-areas within distance: distance from the existing school culture, distance from existing practice and distance from available technological resources. The second area, dependence, referred to how much an innovation relied on other people or resources, in particular people or resources that are beyond the innovator's immediate control.

The third domain, the context, had three aspects that were of key importance to the impact of an innovation. These were the human infrastructure, the technological infrastructure and the social support. The first aspect, human infrastructure, refers to organizational preparation to support technology integration in the classroom. The second aspect, the technological infrastructure, refers to how much resources are currently available in a school to meet the needs of the innovation. The third aspect, the social support, refers to the extent to which peers support or discourage the innovators.

Various studies on the implementation of ICT innovations in schools highlight factors of success or failure that can be related to Zhao et al. (2002)'s three interactive domains (Chen, Looi & Chen, 2009; Tondeur, Devos, Van Houtte, Van Braak & Valcke, 2009; Lowther, Inan, Strahl & Ross, 2008; Brinkerhoff, 2006). In a study by Tondeur et al. (2009) of 527 primary school teachers in Belgium, they found that schools classified with greater structural and cultural characteristics (context domain) had a greater frequency of educational ICT use. Similarly, it was argued that the development and dissemination of new practice using ICT is not just impacted by the availability of reliable resources but also by a supportive organizational culture (social support factor) and a collegial work environment (Deaney & Hennessy, 2007).

In terms of the Irish context, a study on the historical development of ICT within Irish Post-Primary schools (McGarr, 2009) highlighted significant trends between ICT initiatives and the resulting ICT use in schools. It was found that despite ICT reform efforts little influence on teachers' practice had occurred. Teachers' ICT use had in most cases developed independently of these reform efforts, in particular within informatics subjects where teachers put a greater onus on learning about the particular ICT rather than learning with it. Issues for consideration from the study expressed the need for future initiatives to be presented as teaching and learning initiatives and not as ICT initiatives. Also, it was recommended that future ICT policy needs to be mindful of previous ICT initiatives in schools and how current teacher ICT use affects external ICT initiatives.

When looking at factors that affect technology use the teacher is 'naturally' the first person one can look to (Zhao et al., 2002). In the teacher domain, Zhao et al. (2002) explained three factors associated with the teacher that impacted technology integration in classrooms: technology proficiency, pedagogical compatibility and social awareness. The first factor refers to not just knowledge of the technology but also its enabling conditions. The second factor refers to the compatibility of the teacher's pedagogical beliefs and the technology being used. The third factor highlights the significance in the ability of a teacher to negotiate the social facets of the school culture. The discussion is now going to expand on the second factor mentioned; the compatibility of teacher's pedagogical beliefs and the technology being used. If teachers' use of technology is to change then their beliefs about the technology has to change (Russell, Bebell, O'Dwyer & O'Connor, 2003).

Within schools some teachers still hold the belief that they can keep out change by shutting the classroom door while other teachers concur that this is too much of a simplistic description of how their work as teachers relate with the wider society (Robertson, 1996: 28 in Goodson & Hargreaves, 1996). More recently, in a study of

English secondary-school teachers in core subjects such as English, Maths and Science the teachers did feel the inevitability and acceptance of the role of technology in education (Hennessy, Ruthven & Brindley, 2005: 185). These teachers however also expressed an air of caution to some forms of technology use portraying a reflective and critical standpoint on the use of ICT to support learning. It is clear that the adoption of any new technology depends on the values and beliefs of teachers about the importance of the ICT for learning (Webb & Cox, 2004, cited by Schibeci, MacCallum, Cumming-Potvin, Durrant, Kissane & Miller, 2008: 314).

In a study of science teachers' beliefs and practices (Monsour, 2009), it was highlighted that not all beliefs are reflected in practice. Teachers explained that there are many barriers that hinder them from putting their beliefs into action, for example the changing of teaching approaches under the pressures of preparing students for examinations. Hence, it was explained that an understanding of the role of external influences e.g. curriculum, principals etc. was important to make sense of teachers' mismatches between their beliefs and practice. Significantly, these influences militated against constructivist approaches. This mismatch has also been reported in other research (Ertmer, Gopalakrishnan & Ross, 2001; Fang, 1996). Ertmer (2005) highlighted the importance of sorting through the apparent contradictions of teacher beliefs and practices in order to understand their use of technologies. However, she notes these beliefs can be tacit and the difficulty with the contradictions is determining what belief caused what action.

Webb (2005) explains ICTs from the point of view of the affordances they provide to support learning and the need for teachers and curriculum developers to see how these affordances could be used to support other innovations such as cognitive development, formative assessment and new science curricula. La Velle, Wishart, McFarlane, Brown and John (2007) echo the importance of ICT as a tool that allows teachers to transform the learning in their classrooms as it aids them in the development of new Pedagogical Content Knowledge (PCK) domains (Shulman, 1987) i.e. new ways in how they make concepts understandable for students (Shulman, 1986). Mishra and Koehler (2006) present an expanded model to Shulman's PCK that encompasses technology-related knowledge and they refer to this as Technological Pedagogical [and] Content Knowledge (TPCK, more commonly referred to as TPACK). This model highlights the important role ICT plays in enhancing teachers' PCK and the distinct types of teacher knowledge underpinning teachers' ICT use e.g. the 3 main knowledge areas of content, pedagogy and technology derive four more interrelated types of knowledge i.e. PCK, Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and TPACK.

From a knowledge of how ICT affordances can support other innovations combined with pedagogical content knowledge i.e. TPACK and a knowledge of learners, teachers can work with students to develop ICT-rich learning environments that provide appropriate affordances to student learning (Webb, 2005). Therefore, in understanding teachers' use of any new technology it would be important to grasp the knowledge and beliefs that underpins this practice. This research project is focused on the beliefs and practice of science teachers on the integration of an ICT-based resource (the Virtual Chemistry Laboratory) to support scientific inquiry and how

various knowledge areas are highlighted through teachers' use of the ICT-based resource.

2. Methods

2.1 Context of the Study

In 2000, staff in the Chemistry Department of Carnegie-Mellon University set up the Chemcollective, an online repository of Chemistry resources. Within this repository is a Virtual Chemistry Laboratory (VCL). The features of the VCL will be discussed in the next section. This research is looking at applying this resource to the Irish context in order to address many of its contemporary science education issues. Research thus far on this resource has been limited to tertiary level studies (for examples see: Yaron, Leinhardt, Evans, Cuadros, Karabinos, McCue et al., 2006; Yaron, Cuadros, Karabinos, Leinhardt & Evans, 2005; Cuadros, Yaron & Leinhardt, 2007). This research has been concentrating on the potential of such a resource within the Post- Primary school (high-school) sector in Ireland. The initial part of the research involved interviews with teachers and other key educational stakeholders related to their views on the potential role of a VCL within the Irish system and a second stage of the research involved a follow-up case study to see how these views transpired into teacher practice with 5 practising Chemistry teachers. This paper draws on elements of the two studies and relevant literature in an attempt to develop a framework to describe various teachers' integration of an ICT resource.

2.2 Features of the Virtual Chemistry Laboratory (VCL)

The Virtual Chemistry Laboratory (VCL) is very distinct and different from other Virtual Laboratories in that it has a very open infrastructure in which all variables are left to the students' experimental design (*Figure 1*). Students can chose from a vast database of solutions (stockroom on the left-hand side of *Figure 1*), mix them in whatever way they see fit on the workbench (centre of *Figure 1*) and see detailed solution information for each addition they make (right-hand side of *Figure 1*). Also, with an extensive homework repository the VCL provides students many affordances to challenge themselves to solve varying problems. The topics in the homework repository include molarity and density, stoichiometry and limiting reagents, quantitative analysis, chemical equilibrium, solubility, thermochemistry and acid and base titrations. The VCL is a Java applet and is available free online and to download at www.chemcollective.org/vlab. There is also an authoring tool for the VCL that allows problems on the VCL to be modified.

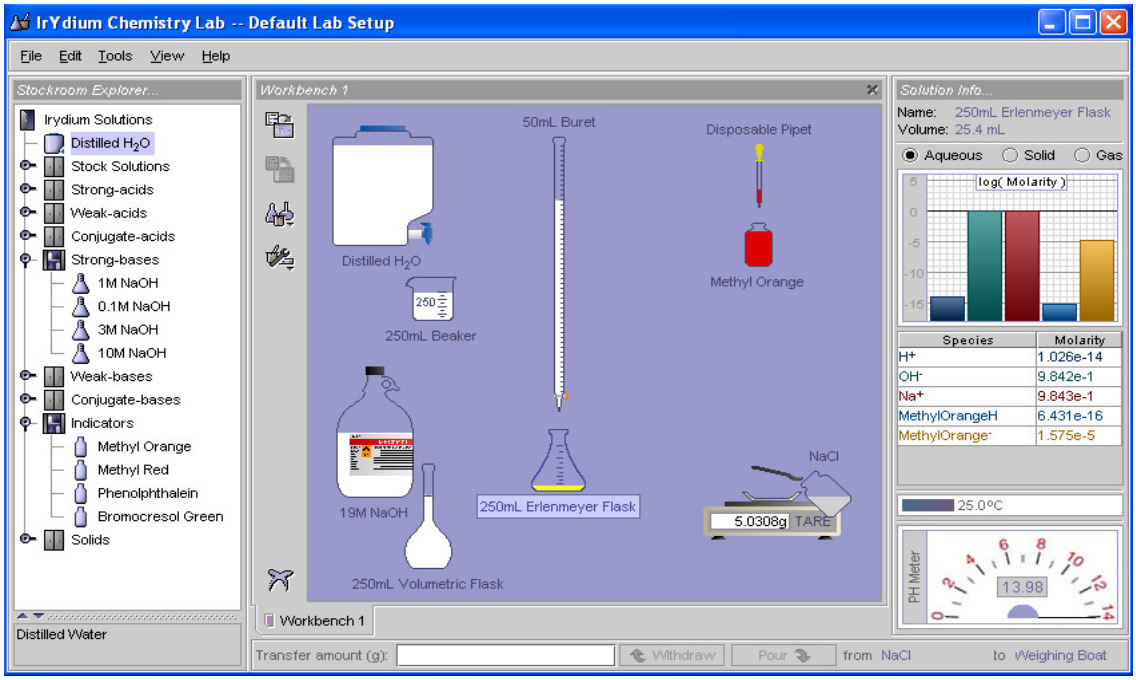

Figure 1 - Screenshot of the Virtual Chemistry Laboratory

2.3 Methodology

The initial study involved interviews with science teachers and educational stakeholders around issues relating to science education, ICT integration and the use of a VCL (see Appendix A for topic guide). The follow on study involved five practising Chemistry teachers using the VCL within their practice in order to highlight any factors emerging in how they integrated the VCL into their practice. The follow-on study was exploratory in that teachers were presented with the VCL and asked to use it as they saw fit. This highlighted how the teachers integrated the ICT resource into their practice. Before teachers' use of the VCL a Content Representation (CoRe) (Loughran, Berry & Mulhall, 2006) was done with teachers before the lesson. The teachers were then observed teaching a lesson with the VCL. Following the lesson a focus group was carried out with the students and a follow-up interview was also carried out with the teachers (see Appendix B for topic guide). The follow up interviews with teachers were used to develop Professional and Pedagogical Experience Repertoires (PaP-eRs) (Loughran et al., 2006).

2.4 Participants

The initial study involved interviews with seven Science teachers and six educational stakeholders from backgrounds such as the NCCA, the Inspectorate, the Second Level Support Service (SLSS), the State Exams Commission and science teacher educators. The SLSS (a support structure for Irish Post-Primary School teachers) recommended teachers who would be willing to be interviewed. From the teachers recommended, seven teachers were contacted from various schools across Ireland e.g. Cavan, Clare, Donegal, Dublin, Galway. The interviews took place at the schools of the teachers while the interviews with the educational stakeholders took place at locations agreed by the stakeholders and the primary author. The five participants of the follow-up study were some of the teachers who took part in the initial interviews but also

consisted of other teachers who had also been recommended by the SLSS. They came from Cork, Dublin, Galway, Kilkenny and Tipperary.

2.5 Data Collection and Analysis

The data for the initial study was collected between May 2009 and October 2009 while the follow-on study data was collected from September 2009 to May 2010. All data was collected by the primary author. All data was transcribed and analysed in Nvivo 8 software. Issues relating to perceived difficulties in ICT integration were coded in the initial interviews firstly through an exploratory approach but then were refined into more fixed categorisations. This refinement took into account a theoretical perspective of Ertmer (1999)'s first and second order barriers to ICT integration. These first and second order barriers were also used to identify issues cited in the follow-on study of teachers' practice relating to the VCL.

3. Results

The first part of the findings presented relate to the initial interview while the second part of the findings explain factors related to ICT integration in using the VCL.

3.1 Initial Interviews

Teachers and stakeholders were asked three questions in the initial interview directly related to ICT and a fourth question looking for the reasons they may use a VCL. The first three questions related to ICT's role in meeting the challenges of teaching science, how they viewed other teachers' use of ICT and how they viewed their own use of ICT. The main findings to these three questions and the question on the VCL will now be presented.

3.1.1 ICT's Role in Meeting the Challenges of Science Teaching

When asked what they viewed as ICT's role in meeting the challenges of teaching science, teachers' and stakeholders' responses to this question centred on first-order barriers in terms of resources and students. In terms of resources the role of ICT in meeting the challenges in teaching science highlighted were the sharing of resources, better organisation and time saving. Firstly, in terms of sharing of resources this refers to sharing between teachers and sharing between teachers and students. Teachers can save time preparing resources if other teachers already have the same resources. One teacher noted that their use of Moodle allowed them to make resources available to students not just inside the classroom but outside of the classroom as well. Another teacher viewed ICT as a means to get notes to the students in a more efficient way:

> *We'd say as regards notes and that, we'd say the way I normally work it is that I'd normally, I'd give them all their notes on a disk. You know, we'd say they all, most of them have computers now at that so you just, you know rather it saves a lot of paper work as well in that area like.*
>
> *Teacher B*

Also, teachers explained the value of ICT in how it let them organise their classroom activities much better and as a result it saved them time and thus let do other activities in their classes. One teacher explained the value of PowerPoint to their teaching:

> *The key stuff is up quickly, summarised easily and I can normally get all my theory stuff done in 15/20 minutes now so it gives me that extra 15/20 minutes maybe to be at something else. Maybe a bit more practical work or demonstration or getting the kids doing something. Now I usen't be able to do that when I'd chalk and talk and overheads and writing so it has, it definitely has speeded up.*
>
> *Teacher D*

In terms of students, the comments on the role of ICT in meeting the challenges in teaching science related to alternative transmission, better explanations, modernity, critical thought and ICT overload. Firstly, ICT has a huge role in how it allows information to be provided to students in different ways as one teacher argues:

> *There are huge possibilities for example using well-designed graphical PowerPoints as a form of active learning where what's on the screen demands a response from the student rather than just have the student sitting passively looking at it and the other area in Science is the use of data-logging which is very useful both as a demonstration and as a method of they're doing their practical, their own practical work.*
>
> *Teacher A*

Secondly, ICT allows for better explanations. This stakeholder explained about ICT:

> *It has a very, very useful place in science teaching because some of the concepts can be explained so easily with the right animation. It, just, you know, you could be talking about global warming and until you can show an animation of the rays coming in from the sun and bouncing off the earth coming back. Two minutes and they can see it and that's enough. You know, you could be talking about it and putting headings up on the board and trying to draw your diagrams and they're looking at you but you know, five minutes.*
>
> *Stakeholder C*

Thirdly, an important feature of ICT in terms of students is that it is viewed as modern and hence, more relevant to students. One teacher explained that teachers are responsible for providing an education but that students like to be entertained also and there is no reason ICT cannot play a role in that. One stakeholder points to the danger of not using ICT:

> *I think the very first thing to do is, to say, is that we must embrace it. It must be, it just has to be included as a day-to-day part of students' lives as they go through school. It's an artificial, we create an artificial environment if we do not include ICT tools.*
>
> *Stakeholder A*

Fourthly, an issue highlighted by two stakeholders and none of the teachers in terms of ICT's role is that it can be used to develop critical thought within students in that it can provide opportunities for more open-ended investigations. As one stakeholder explained about the use of data-logging:

> *What we're trying to get out of this is to use appropriate equipment, appropriate tools to teach the appropriate material and if you have, you know, if you want to the experiment that's in the textbook, well, fine but that's not, that's just a recipe directing whereas if you want to make it open-ended and bring in say your data-loggers, bring in other tools that are available.*
>
> *Stakeholder F*

Finally, one teacher made the point that even though ICT has a role in classrooms it is important that teachers do no overload students with ICT related activities. For example, students going from History to Geography to Science lessons and all these lessons could have been taught through PowerPoint.

3.1.2 Other teachers' use of ICT

When asked how they would describe other teachers' practice there was discussion that related to both first-order barriers and to second-order barriers. In terms of first-order barriers teachers again discussed issues around resources and these related to greater resources and more training. Two teacher comments highlighted these:

> *The Science department, as I said earlier, is totally ICT dedicated, as you would expect I think. Other departments are now taking it on quite, quite strongly but the, the biggest thing of course is the expense.*
>
> *Teacher E*

> *Skill level of most teachers is fairly low at ICT. They're not ICT suave. Okay they can do their email and book a flight with Ryanair and they can type Word and maybe do an Excel but they're not good at computers. They're not, they're not computer people. They haven't grown up with it and then they don't have many resources and they've had very little or no training on how you could do stuff, do a class plan and do, teach a course with IT. They have no idea how you could, you could take a topic and use IT to teach it. They've never seen it done. They've no model. None of their teachers in their time ever had this so they've never seen any of them do it.*
>
> *Teacher D*

In terms of second-order barriers issues that emerged related to assessment and teachers' willingness to engage in the critical use of ICT. Firstly, in terms of assessment this teacher highlighted the effect of assessment in guiding teacher attitudes towards ICT usage:

> *They, they have limited IT skills and they feel they haven't got the resources and they have everything they need at the moment to get the kids the results. They've all the notes and the handouts, paper, chalk and talk that's successful in getting the kids points in exams so again it's the exam, it's the exam that's killing it. They know they don't have to, why change your teaching methodology when at the end of the day you can turn out the results? And they're measured in September by the results. The parents come in, how many points, did the kids get the points? That's all they're measured on, not the methodology so unless the exam changes I can't see too many teachers in this school changing their methodology.*
>
> *Teacher D*

Secondly, in terms of teachers' willingness to engage in the critical use of ICT many teacher comments related to teachers not engaging with the ICT resources in the school and even when the teachers did the ICT may not be used very critically. Two teacher comments highlighted how they felt other teachers were using and view ICT:

> *I would also feel that a lot of the stuff that is being done is not really very, well I don't think it's very well thought out in as much as a number of people would see a PowerPoint some place and they like it and they'd take it but they don't make it their own. They don't adapt it to their circumstances.*
>
> *Teacher A*

I think it would be quite representative of the, of schools throughout the country. You have some people who use it very, very well, very, very effectively. Other people who don't use it at all. Other people who don't use it and don't even want to know about it. And I think that in any school, in any system we're going to have to reflect and we're going to have to respect that, that you know we cannot force people to use ICT in the same way as you cannot force them to use any other classroom resource but I think it beholds us to encourage those who do want to, you know to make it as easy as possible and to provide as much support and resources as possible for those people.

Teacher G

3.1.3 Teachers' Personal Use of ICT

When teachers were asked about their own personal use of ICT their comments certainly linked directly to second-order barriers in terms of the beliefs they held on the use of ICT to their practice. All teachers were mostly positive in describing the amount of ICT they used in their practice but the ways in which they described their uses of the ICT tended to reflect certain teaching methodologies. Two teacher quotes highlighted this:

An alternative to write-ups I'd say they could take photographs of all the stages of their experiment and put it into sort of a PowerPoint presentation so they enjoy that. That was great but again it's time consuming and you'd never be able to do it for every class so.

Teacher F

I've spent a lot of time now putting a lot of notes etc. all on PowerPoint. We'd say finding applets. That's from my own we'd say presentation of work. As I said already I give out notes, cut a disk of notes you know we'd say it saves a lot of paperwork. Possibly it could be more student interactive. You know we'd say I tried it out a bit with transition year. They like do a project and say they'd have to use ICT as well like to research the project and also to present the project but you know we'd say having access and again trying to get the kids interested in the whole thing, that's the biggest challenge really like you know…but again it's like everything else. If you see it being done it makes it easier to learn it.

Teacher B

3.1.4 Reasons to Use a VCL

When asked for reasons why they would use a VCL the teachers focused on responses relating to first order barriers in terms of resources and to second-order barrier in terms of the students. Firstly, in terms of first order barriers, interviewees mentioned items such as time, equipment and cost. Firstly, in relation to time it was mentioned that students get bogged down on the physicality of an experiment and lose sight of the key theory of the experiment and experimental design as they waste time setting up equipment and try to add chemicals together safely. It was felt that these manipulative skills are important but actually become a hindrance time wise once they are mastered. The VCL saves time in allowing students to move past this physicality and thus allow them to get to the finer details of the experimental design more quickly.

Also, in terms of equipment and cost the VCL stands out on its own. Something that stood out in particular though is that a teacher suggested that with equipment aspect of the VCL he would use a more inquiry based approach with his students:

If I'd get access to computers, then let them work away themselves at it…just to give them the hands on and let them mess around with various different options and what'd happen if you change do you know we'd say change concentration or change…various different options, you know, carry out various different experiments, you know, without having go through the whole process of getting down glassware etc. you know.

Teacher B

Secondly, in terms of second-order barriers the teachers highlighted some of their beliefs through how they viewed the utility of the VCL to aid students. Items mentioned by interviewees relating to students in the use of a VCL revolved around strengthening didactic methods, allowing more inquiry-based approaches or comparisons of a VCL with a physical laboratory. Firstly, in terms of strengthening didactic methods some interviewees discussed how they would use the VCL for demonstration purposes or to re-enforce key points about the physical practical. As one teacher explained:

It allows me as I said earlier to repeat the experiment and repeat the experiment and repeat the experiment as opposed to doing a demonstration once [physically].

Teacher C

Secondly, some interviewees explained why they would use the VCL through inquiry based reasons such as student control, problem-solving and critical thought. Students would be able to work away on a computer themselves and the infrastructure of the VCL provides problem based questions that demands a critical thought process from students in what they are doing. The comment below expresses some of these views:

Yes. Quicker. Kids can do it in their own time. They can do at home. They can do it at weekends. They can spend more time at it. They can park it halfway through maybe.

Teacher D

Finally, many reasons given for why a VCL would be used in terms of students related to factors associated with physical laboratories. Some interviewees said they would like a mixture of both and also if teachers lacked resources for physical experiments the VCL would be better than the students doing no practical at all. Certain interviewees also expressed the fear that the VCL might be viewed as a replacement for practical work. An example of a comment was:

I found in my experience the kids get tied up in the mechanics of the thing rather than the theory that you're trying to get across and in some ways because of that practical work can be counter-productive which it shouldn't be but it is because they get, they concentrate on the wrong things. This seems to have, to me (referring to the Virtual Chemistry Laboratory) to have the potential that kids can use it afterwards to go back over the thing and try it again and try it again and try it again and it seems to pick out the important points.

Teacher E

3.2 Study on Teachers' Practice

The initial interviews shed light on important aspects of how teachers feel they integrate ICT into their practice, how they feel other teachers are integrating ICT into their practice and where they feel a VCL may be useful in education. The follow-on study sought to see how some of these views transpired into practice. Many of the views expressed in the initial interviews came to light in observations of classroom practice and again through follow-up interviews. Before discussing the follow-on

study it is important to note that some of the teachers in the initial interviews declined to use the VCL in classroom practice. The reasons cited were the organisational difficulties of getting to use the computer room, busy schedules and that the VCL had not enough problems catered to the Irish curriculum. These comments link strongly to first-order barriers but the latter comment on the curriculum hints at a salient point that links to second-order barriers and the role curriculum plays in teachers' practice.

The follow-on study involved five teachers who were asked to use the VCL in whatever way they saw fit. This led to many interesting findings even within this small sample of teachers. The study centred on teachers' PCK (Shulman, 1986) by using instruments designed to illustrate facets of teachers' PCK i.e. Content Representation (CoRe) and Professional and Pedagogical Experience Repertoires (PaP-eRs) (Loughran et al., 2006). The findings in terms of PCK will not be explicitly discussed in this paper but what will be discussed are (i) the observations of the teachers' practice integrating and using the VCL and (ii) the teachers' comments relating to the use of the VCL in the post-lesson interviews.

3.2.1 Observation of the Teachers' Practice

Teachers ultimately used the VCL in a way that re-enforced their current practice, whether that was more student-centred or teacher centred, towards ownership in the use of the VCL or illustrating a lack of ownership. Two of the teachers (Teacher D and Teacher G) used the VCL in a student-centred manner and demonstrated ownership in their use of the VCL in that they had a clear idea of what students they wanted to use the VCL with and in what way. They chose to use the VCL with fifth year students (15-17 year olds) who have a 'high-stakes' Chemistry examination at the end of their sixth year of school that determines their entire grade. Two other teachers (Teacher I and Teacher J) that used the VCL demonstrated a lack of ownership in that they had difficulty in deciding how to use the VCL and with what students. They sought considerable advice from the primary author. Teacher I used the VCL with second year students while Teacher J used it with a fourth year class (Fourth year is known as Transition Year, an optional year in which students have the opportunity to engage in extra-curricular activities without an examination focus). The fifth teacher (Teacher H) illustrated ownership in that they decided to use the VCL as an assessment activity for their fifth year students. This use of the VCL did not reflect much in the way of the Teacher H's classroom practice.

From the observations of Teacher D and Teacher G, they adapted the VCL quite easily and illustrated a degree of comfort in aiding students throughout the lesson, whether it was an issue in using the VCL or an issue with the content on the VCL. They had let their students play around with the VCL themselves in a previous lesson so that they would be clear of its functionality. Teacher I and Teacher J did not provide their students with the opportunity to find out the features of the VCL for themselves but instead spent a lesson showing the students the features of the VCL in a didactic and teacher-centred manner. They also gave a significant amount of information in how the problem on the VCL was to be solved. In essence, they reduced the problem on the VCL to a cookbook approach. This approach was in stark contrast to the approach taken by Teacher D and Teacher G. Teacher H had in effect distanced themselves from being observed as the students had to spend the lesson solving the problems on their own.

Within the lesson of using the VCL, Teacher D and Teacher G moved around the classroom often in a relaxed manner, observing students' activity on the VCL and noting the results the students were getting. They asked and answered questions where deemed necessary, while not devoting their attention too much to any one student in particular. Teacher I moved around the classroom quite comfortably but spent a lot of time with individual students while other students sat waiting for the teacher to answer their question. It was clear that many students in the lesson were not willing to think things through and sought advice regularly from the teacher. Teacher J had similar issues in that the students seemed to give up on solving the problem quite easily and then sat waiting until the teacher came to answer their question. Teacher H spent a lot of time sitting down at their desk during the assessment using the VCL but began to move around and observe students more as it became clear some students were having difficulty in solving the problem on the VCL.

3.2.2 Interviews VCL Lesson – Teacher Opinions

A follow up semi-structured interview was carried out with each teacher after they had used the VCL (Appendix B) and some of the questions centred on their use of the VCL. The teachers' responses to the questions specific to their use of the VCL will be discussed and considered in relation to first- and second-order barriers where relevant.

Firstly, teachers' were asked about how they viewed the VCL as a learning tool. Teacher D and Teacher G expressed many positive comments in relation to using the VCL as a learning tool. They commented on the affordances offered by the VCL to give more varied and enhanced learning in certain aspects of practical work but they also noted that the VCL had limitations in terms of students' learning in other certain aspects of practical work. The following comment is Teacher D's response to being asked about the VCL as a learning tool:

> *Very happy with it and I'd love more time to be able to bring more classes down to it. The kids have enjoyed it. It's, the kids have enjoyed it. They can work very quickly with it. It's very safe. The only thing I'll say about it is that they can be, they're are techniques they can't learn with it. You just draw the pipette over the conical flask and it empties. There's a lot of practical things there from putting on the filler and using the filler and then letting it empty by gravity and the rinsing out of the pipette. There's a lot of things, they could leave gaps in their knowledge so I wouldn't like to use it as the tool to teach the topic fully because they'd be asked questions in Leaving Cert. that they wouldn't be able to answer.*

The above comment from Teacher D illustrated their satisfaction with the VCL in certain regards but also highlighted the teacher's awareness of the students' learning that was relevant to their final 'high-stakes' assessment. This comment highlights the guiding influence of assessment in a teacher's judgement of any new technology i.e. a second-order barrier. Teacher D also commented:

> *I think with a virtual lab they could spend a lot more time thinking about it, solving a problem and then you haven't to be bogged down with how do I put that filler on the pipette. The one we did with the vinegar, the different vinegar from different chip shops. They hadn't to worry about, about breaking glassware or spilling glassware. How do I empty the pipette? They were engaged in how do I solve the problem and*

you just draw out, take out a pipette and it did the job for you so I think it was at a much higher cognitive level when they were using the virtual lab because it eliminated all those practical things that you do need to know if you are actually doing it but you don't need to know if you're problem solving so I like it from that point of view.

This comment reflects the difficulty in getting students to think while carrying out physical practical work. This could also reflect first-order barriers but ones related to practical work, not ICT integration. Teacher D commented several times about the utility of the VCL to allow students to move beyond the physicality of practical work to greater problem-solving and as Teacher D felt, students were thinking more. This highlights part of this teachers' thinking around a second-order barrier i.e. student-teacher roles. Teacher G commented on the VCL as a 'superb learning tool' but felt it was limited in its current state compared to what it could potentially do. Teacher G commented:

It [VCL] gives students an opportunity to learn or to study or to play around with concepts any time in any place. That the learning is not being limited to the classroom. Learning is not being limited to the school and not only that it allows them to replicate what they would be doing in a real world. So it is not just reading about how a titration can be carried out. It allows them to carry out the titration so therefore they're in a position to make mistakes.

When asked about the VCL as a learning tool, Teacher I commented that the VCL 'takes a bit of getting use to' but not for smarter students, that the presentation of the VCL could be 'jazzed up a small bit' and that a help function in the VCL would be useful to guide students more. He noted the utility of the VCL to support trial and error by the students but felt that a hint system would make it more user-friendly. When questioned further about the use of the VCL to support learning Teacher I commented:

I felt now that problem, they were jumping in at the deep end whereas maybe if they was a grading progression, start off with something simple and work your way up to the next step you know. Turn it more, we'll say, into an online lesson.

These comments suggest the open nature of VCL in its current state did not suit this teacher's pedagogy and could be linked to a second-order barrier of preferred teaching styles. Teacher J commented that that the VCL was an excellent learning tool and particularly for varying levels of student ability as students could use it in their own time. Teacher J also felt the VCL took a bit of time 'getting use to it'. This comment could relate to the teachers' efficacy in the use of ICT as Teacher D and Teacher G noted the VCL interface was quite intuitive. Teacher J also noted that she had difficulties getting into the physical laboratory sometimes due to clashes in her timetable with other teachers so she noted the VCL would be a very useful aid when the physical laboratory was unavailable. This comment links to the organisational factors of first order-barriers.

Teacher H commented that he liked the VCL as a teaching and learning tool and that 'it was very useful to let the students go and practice the titration problems'. However, he expressed frustration in not being able to add his own problems to the VCL as 'in terms of the Irish curriculum it's not developed in that direction'. This comment highlights the view of the necessity of a VCL developed specifically to the Irish context but also points to the underlying second-order barrier of assessment.

Secondly, teachers were asked about what they perceived their role to be when students were using the VCL. This question links strongly to the second-order barrier of student-teacher roles. Teacher comments generally revolved around firstly ensuring all the students were up and running on the VCL and then secondly, walking around the classroom ensuring students were progressing through the problem. Teacher G commented succinctly when asked this question:

> *Facilatator. Essentially you hover around and you, if people have specific questions or specific problems you try and facilatate them. Otherwise then you butt out and let them get on with their learning.*

Teacher I also commented on the importance of guiding the students along where necessary:

> *I suppose really I'm there kind of looking over their shoulder making sure that they're doing the right thing or if they're in trouble I'm there to answer a question on it you know, not to give them the answer but to guide them along you know. I'd say that's simply my role there really you know, just to guide them along. Make sure they're going to head towards the right answer at the end of the day you know.*

Teacher J commented however that she felt 'stretched' to get around to all her students and felt that if students were to be examined using the VCL then she would get more motivation out of them to do the problem on the VCL. This comment strongly points to a second-order barrier in which the students perceive their role as not having to work at something unless it is on an examination and it is clear that this also influences the teacher's perception of their role in the classroom.

Finally, teachers were asked a question if they would use the VCL next year in their practice. This was an important question in potentially highlighting some important factors teachers considered in integrating an ICT resource into their practice (first- and second-order barriers). Both Teacher D and Teacher G responded 'definitely' when asked this question and they both noted that they would like if they could use the VCL with all their students and Teacher D expressed his desire for more activities to be added to the VCL for a broader range of age groups. When Teacher D was asked why he would use the VCL next year he commented:

> *Safety. Kids enjoy it. Quick to do. You can spend more time thinking, thinking than hands-on. All the reasons we've talked about already. You're spending less time with physical doing of stuff that you're doing, if you want kids thinking you have to remove the physical things. The getting stuff, going around collecting or organising it, pouring, there's a whole lot of...the kids don't need to be able to do it. If you want them solving problems you want to have to remove that kind of stuff. Now they love doing all this physical stuff as well because it fills up the class, great craic but they're not doing much thinking so I think the virtual lab spends more time, more time thinking.*

Teacher I commented that he would consider using the VCL the following year but he also hinted that this would be based on if the VCL was be altered to include recommendations he had made:

> *If it were to be improved you know through the various ways I mentioned I would definitely use it you know*

As noted previously, this relates strongly to a second- order barrier of preferring teaching style. Teacher J noted that she would also use the VCL next year and

suggested the utility of the VCL to be used by students at home. Teacher H also commented that he would use the VCL the following year:

> *I will use it again next year because it does, it does re-inforce learning. It does help them to get their head around the concept of the whole acid and base and the titrations in a different way than chalk and talk or the PowerPoint.*

The teacher comments presented and discussed here illustrate many important factors in teachers' use of the VCL and what the teachers consider important in the use of VCL, some of which reflect strongly on first- and second-order barriers. These findings lend themselves to significant considerations for how teachers integrate an ICT tool into their practice and aid in constructing a model for teacher ICT integration.

4. Discussion

This section presents a model of teacher ICT integration (*Figure 2*) based on the findings highlighted and also takes from relevant literature. The findings and the literature lend themselves to many interpretations but predominant issues that surface are the influence of curriculum/assessment on teachers' practice and difficulties associated with teachers' perceived efficacy in technology use. A model was desired that acknowledged different teacher stances on technology integration but that also highlighted significant and important boundaries between these stances.

In a study of physics teachers' beliefs and perceptions relating to laboratory and ICT supported instruction Sorienta and Jimoyiannis (2008) identify three types of teacher stances: traditional teachers, non-traditional teachers and undecided teachers. They also make note of the role assessment plays in classroom activities chosen (Eisner, 2000, cited by Sorienta & Jimoyiannis, 2008) and the potential of ICT initiatives to enhance teacher confidence (p.189). Their categorisation of teachers has similar characteristics to the model proposed in this paper. However, the model in this paper identifies four types of teachers in relation to ICT integration into their practice. These four types are (i) a Contented Traditionalist, (ii) a Selective Adopter, (iii) an Inadvertent User and (iv) a Creative Adapter. These four types of teachers have also been further positioned in terms of two main teacher conflict areas emerging from the research that affect teachers integration of an ICT integration i.e. empowerment versus fatalism and a learning focus versus an assessment focus.

Firstly, in relation to empowerment and fatalism, the findings highlight how some teachers see ICT as an opportunity for them to do something new and interesting with their students in terms of how the students learn while other teachers feel it is beyond their control to do anything about the types of ICT resources they have within their classroom. This teacher conflict links to Ertmer (1999)'s first-order barriers. Teachers who have a sense of ownership will push to have a greater variety of resources in their classroom and this includes ICT. Secondly, in terms of learning and assessment the findings clearly illustrate teacher difficulty in attempting effective ICT integration in light of assessment that favours content regurgitation. This is re-enforced by Ertmer (1999) who cites assessment types as an issue in terms of second-order barriers. She also notes student-teacher roles, teaching methods and management and organisational styles in terms of second-order barriers and these can

also be linked to the influential factor of assessment and how it interacts with learning objectives and thus teacher- versus student-centred classroom activities.

In the Teacher ICT Integration Model (*Figure 2*) the two conflict areas are represented as two continuums intersecting. For the purpose of this model and based on many contemporary assessment types (content regurgitation), assessment focused teachers are viewed as being aligned with teacher-centred approaches while learning focused teachers are aligned with student-centred approaches. This is to say that if assessment changes to align with more varied learning approaches the model would expect more teachers to incorporate greater student-centred approaches. The next section proceeds to explain the four teacher categorisations in terms of the teachers' focus, their level of ownership and their PCK.

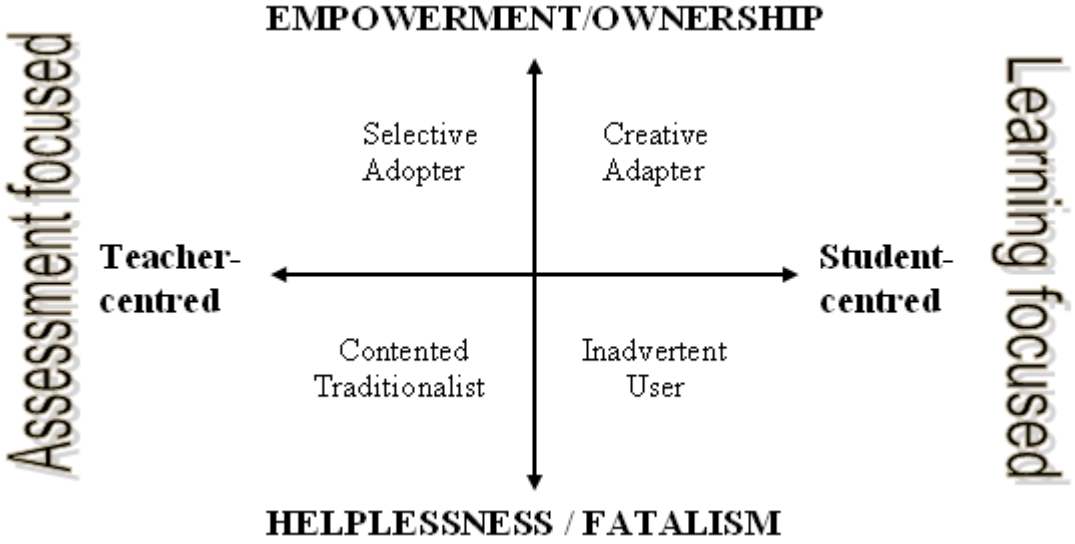

Figure 2: Teacher ICT Integration Model

4.1 Contented Traditionalist (CT) Focus, Ownership and PCK

CTs' focus is on assessment with limited methodology use. The underlying reasons for their focus are extrinsic factors such as the curriculum, the principal, school management etc. They lack intrinsic motivation and this relates to their fatalist views on the education system within which they work. They know what they will be most merited on (student exam results) and feel no pressure to move beyond chalk and talk unless extrinsic factors change. As noted by Ward and Parr (2010: 120) some teachers see no real need to use computers when "traditional practices continue to work" and hence see "no clearly recognised need to change".

CTs would lack a sense of ownership and empowerment in terms of what their classroom activities can be and hence they would allow their actions to be strongly swayed by the prevailing culture within the school. They would not question the syllabus and would essentially view being a teacher as being a technician. They would generally tend to adhere to the textbook quite strongly and would not look to deviate beyond material outside of the curriculum. Once the curriculum has been covered by these teachers they would engage in examination drill exercises with their

students, which are also based around an authoritative source e.g. doing past exam papers or using revision based books. These teachers

> "feel the most pressure to show traditional academic success for all students, that is achievement in national qualifications. These are the subject areas where the canon of knowledge, what students are expected to learn, is the most clearly determined and where the match between traditional methodologies and desired outcomes (generally success in national examinations) is likely to be the strongest, lessening the need to either change practice or to use computers."
>
> *(Ward & Parr, 2010: 120)*

CTs would be considered to have a low PCK. They may only start to use an ICT tool if it becomes the norm in the culture of the school but even then, they will try to resist it citing they do not need it for their practice. Even when use of the ICT occurs, CTs would be unquestioning of the particular effect the ICT is having on students' learning. They would use ICT only towards an attempt to improve students' grades and would not think critically as to what elements of the ICT tool lend to a greater understanding for the students. In terms of their teaching methodology they would be very much of the persuasion that if something is not broke, then why fix it. They would not question the system within which they work and this would lead to a limited scope in opportunities for how the students get to learn.

It is difficult from this research to say what teachers exactly would fall into this group as CTs would be difficult to engage in ICT-based research. However, from the comments of the various teachers in the initial interviews it is acknowledged that CT teachers do exist within schools and hence their inclusion in the framework.

4.2 Selective Adopter (SA) Focus, Ownership and PCK

SAs' focus would be on assessment with varied methodology use. The underlying reasons for their focus would be both due to extrinsic factors and importantly, intrinsic factors. SAs would have a strong desire for their students to do well and will work hard within the system which they are placed in order to maximise their students' success. Unfortunately, the assessment system within which they work would not reward varied types of student learning and to improve the quality of teaching. SAs would only adopt and continue to use an ICT resource if it helps their students do better in their final assessment. Niederhauser and Stoddart (2001: 27) note that teachers will select particular curricula and instructional methods that fall in line with their already existing pedagogical perspectives and it is these perspectives that have a strong influence on how computers are integrated into the teacher's practice. In the model proposed the SAs' pedagogical perspective would be on the final assessment.

SAs would have a strong sense of ownership and empowerment in that they strive to be very successful within the system they are placed within. Their students would be likely to get very good results in final examinations as this is the ultimate motivating factor for the teacher. When faced with integrating any new ICT into their practice they would be happy to take it on if they feel it will fall in line with their existing perspectives that have rewarded them in the current system. If an SA feels their ownership lessened in any way by adopting a particular ICT they would most likely stop using it.

SAs' PCK would be considered high but only in a narrow sense. Whether they think like scientists would be a completely different issue. They would know how to help students learn but would sacrifice students' understanding. They would get the students as good as grades using chalk and talk methods (including incorporating ICT) as a Creative Adapter using many varied teaching methods and that would be all that matters as far as SAs are concerned.

Based on the follow-on case study it would be felt that Teacher I would be considered an SA. Teacher I demonstrated teacher-centred approaches within the observations and in the follow-on interview he noted the VCL for what is was in terms of trial and error but then suggested changes to the VCL to make it more into a lesson and guide students more. It is felt if these changes were made to the VCL it would simply become an exercise in which students plugged in figures until they were told they got the right answers and this would not truly represent scientific processes. Hence, this serves as another reason as to why Teacher I would be an SA in that they will only properly integrate a technology if it falls in line with their current practice. Teacher H would also be viewed as an SA. The observation of his use of the VCL did not highlight this but in the follow-up interview he noted that he integrates ICT only to reinforce the didactic method of 'chalk and talk' and also expressed his desire to put problems on the VCL that related specifically to the Irish curriculum.

4.3 Inadvertent User (IU) Focus, Ownership and PCK

An Inadvertent User (IU) would not have a particular focus per se in that they are more of an accidental user of a particular ICT in their classroom. They would not feel particularly competent in using new ICT. The prevailing culture in their school may be encouraging the use of a particular ICT-related resource and they would take up the use of the resource from a sense of external pressure and/or a certain mixture of curiousness but with hesitation. Using the resource however would actually move the teacher towards a more learning focused and student centred approach but the teacher would be unaware of the implications of what is occurring in their classroom. Their motivation to use the resource would not be grounded in concrete terms. Hennessy et al. (2005: 185) highlight "the dangers of uncritical use" in that ICT should only be used where it enhances learning over other methods. This is not to say that IUs would be completely uncritical but that they would be missing a clear focus. Voogt (2010) notes the importance of science teachers having enough time to construct routines into their ICT integration in their practice. This point would link strongly to an IU.

It is not surprising that IUs would lack ownership in their use of a new resource in their classroom. The most explanatory reason for this is that the resource would have either been pushed on them by another teacher or the principal or they would have decided to participate in research, in which case the resource is still pushed on the teacher. Either way, the teacher would not have sought out the innovation. The innovation would have come to them. They would seek a lot of advice from whoever recommended the ICT tool to them. The following quote by Hennessy et al. (2005: 186) highlights important considerations for researchers attempting to bring about ICT integration in schools and relates well to how and why IUs would struggle for ownership:

> "A degree of caution by teachers is inevitable. The widespread use of ICT is a relatively recent phenomenon within education and the top-down approach, which

> imposes use of ICT in subject teaching and learning, may lead to critical questioning of the value of using ICT instead of a sense of ownership. Work on organizational change shows that, for an innovation to have a significant impact, shared ownership of plans is required—starting by experimenting in small ways and then expanding upon success—while individuals must work out their own meanings (over a realistic time-frame)."
>
> *(Hennessy et al., 2005: 186)*

IUs would have a rather low PCK. They would not critically question and reflect on their own knowledge and would have certain trepidation towards new teaching ideas. When using a new ICT in their practice it may help them teach better "because of the built-in pedagogy steeped into the design of the tool" (Ferdig, 2006: 756). In most cases they would rely on feedback from other sources on what they are doing in their classroom. These teachers would have low confidence in their ability. Lee and Luft (2008: 1361) highlight the importance of teachers needing a knowledge of resources for teaching science to aid their PCK as it is resources that can provide teachers with instructional experiences outside of the curriculum.

From the case study Teacher J would be considered as an IU. She would not be an IU in the complete sense as some of her practice was quite teacher-centred but from her use of the VCL she was beginning to see how it was aiding her in giving the students more ownership of the material as opposed to Teacher I who wanted the VCL changed to incorporate other features. However, as noted in the findings, it was clear that not all her students desired this sense of ownership. This highlights the difficulty in changing perceived teacher-student roles in integrating ICT effectively.

4.4 Creative Adapter (CA) Focus, Ownership and PCK

Creative Adapters would have a strong focus on student centred approaches that facilitate meaningful learning. They would have no qualms about trying new techniques in their teaching if they think it may lead to greater learning for their students. As noted by Becker (1994: 289) exemplary computer-using teachers were not teachers who simply liked computers but had "significantly more well-rounded educational experiences than the other teachers had had". These well-rounded educational experiences would underlie CAs' strong focus on meaningful student learning. This is not to say they would ignore assessment but that they would be keen on keeping the focus on learning.

CAs would have a strong sense of empowerment in their teaching. They would be very wary of the intended and unintended restraints that curriculum or assessment place on student learning and would very much continuously question what is included on the syllabus. CAs would not see themselves as shackled by the system but would try to overcome these issues as effectively as they can. A quote from Ward and Parr (2010: 120) sums up the confidence CAs would have:

> "This idea of level of confidence could also explain, at least to some extent, the importance of student-centred activities. Where such activities are being undertaken in the classroom already, not only are teachers more likely to see advantages to using computers and have a greater perceived need to do so, they are also less likely to be concerned about their ability to facilitate student learning in an environment over which they have less perceived control."

CAs would have a wide-scoping and rich variety of PCK which they utilize in all their classroom practice. They would be very reflective on their practice and would carefully consider the effect a new resource has on student learning. They would be very critical in terms of the possible teaching approaches they use to aid students in their understanding of content. A comment by Ferdig (2006: 756) suggests the ease at which a CAs' PCK could aid them in adapting a new technology:

> "There are other times when a knowledgeable person can take a technology and make it pedagogically sound 'on the fly'."

In relation to the case study Teacher D and Teacher G would be considered CAs. They kept a focus on the examinations but their ultimate focus was to aid meaningful learning for each student. They adapted the VCL quite readily and noted the particular advantages and limitations it had in terms of enhancing their students learning experience. Their degree of comfort with the VCL and insight into how it would enhance student learning pointed to a strong PCK.

5. Implications for ICT Integration in Schools

This model for teacher ICT integration raises important questions in terms of how ICT-based resources are integrated into schools and how teachers are supported through this process. From the model it would become clear that a 'one-size fits all' approach would maybe work for some teachers in a school but would be unsuccessful in adequately supporting other teachers who are grappling with different issues. Two important questions derived from the model that will now be considered in terms of their implications for ICT integration are 1. Are teacher positions fixed or can they move between groups? and 2. What type of ICT integration support structures are needed for the individual teacher groups in this model?

1. Are teacher positions fixed or can they move between groups?
It would be felt and certainly hoped that the teacher positions are not fixed. However, based on the model, if teachers were to move to another group it would be assumed that teachers would only be able to move vertically or horizontally and not diagonally. The reasons for this assumption are that the expertise gap would be viewed as too different for a teacher to make this transition e.g. a Contented Traditionalist would not easily develop the expertise to become a Creative Adapter and a Selective Adopter would already have enough expertise not to become an Inadvertent User. Therefore, based on this argument, if a Contented Traditionalist were to eventually become a Creative Adapter, they would first have to either become a Selective Adopter (*Figure 3*) or an Inadvertent User (*Figure 4*) before eventually moving towards a Creative Adapter. It is important to note that the argument assumes that the overall intention would be to aid teachers in a movement towards becoming Creative Adapters. The two teacher transitions to becoming a Creative Adapter will now be considered.

5.1 Contented Traditionalist → Selective Adopter → Creative Adapter

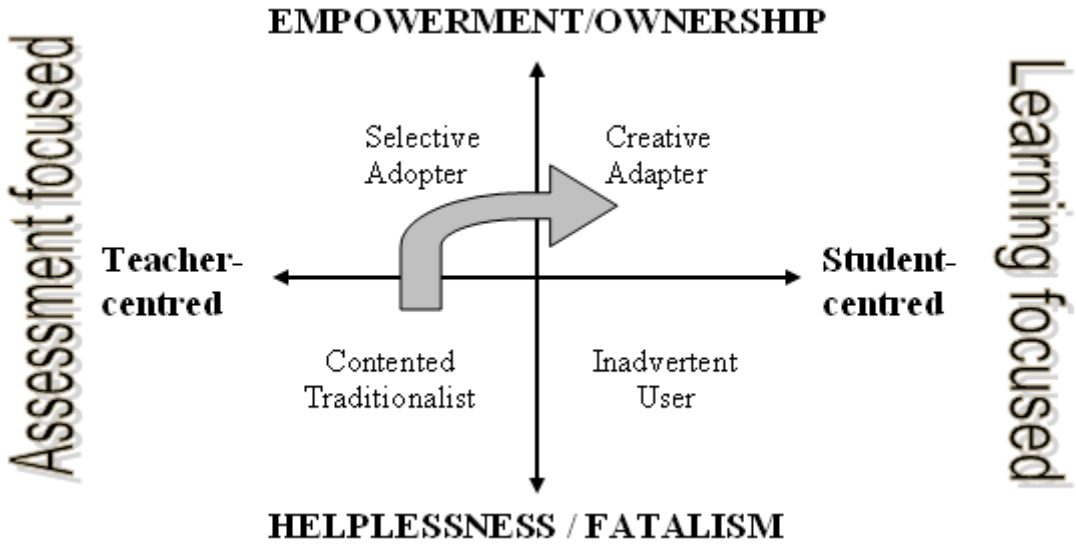

Figure 3 – Transition from CT to SA to CA

CTs would have a strong focus on assessment and teacher centred approaches. However, they would have low confidence in their own PCK. This would have resulted in them following the prevailing culture of the school so as not to be noticed and have their methodologies questioned. When new resources appear they would try to avoid them. However, when asked to incorporate them by other teachers or the principals they would do so in a way that is selective in terms of how it improves examination results. An important question to consider is if this use would eventually move CTs towards becoming SAs? The factors that would cause this change need careful consideration. Based on the model outlined, the main difference between CTs and SAs is their sense of ownership and PCK. Therefore, a pertinent question would be what strategies aimed at developing CTs' sense of ownership and PCK would move them to becoming SAs?

Once a teacher has become an SA the next stage of the transition would be become a CA. SAs' confidence would be considered high and they would have clear PCK in terms of how students effectively learn for the examinations. It is important to note that SAs have a strong PCK but that this PCK knowledge is confined to the boundaries of the current assessment structure in place. The student learning that is valued by SAs is learning for assessment. However, a CA values student learning beyond the scope of assessments and for example would see no issue in covering material outside of the curriculum if they felt it enhanced the students' learning. As illustrated from the model, SAs differ from CAs based mostly on their views towards assessment. Importantly, it is these views that shape their classroom activities in different ways between teacher- and student- centred approaches. The views on assessment by an SA would be borne out of the prevailing school culture. An appropriate question to therefore ask then is if the culture of the school changes would a SA become a CA? Following on from this question it would then be important to consider what would bring about a change in the school culture? The model outlined would suggest a change in assessment that aligns with meaningful learning may help.

5.2 Contented Traditionalist → Inadvertent User → Creative Adapter

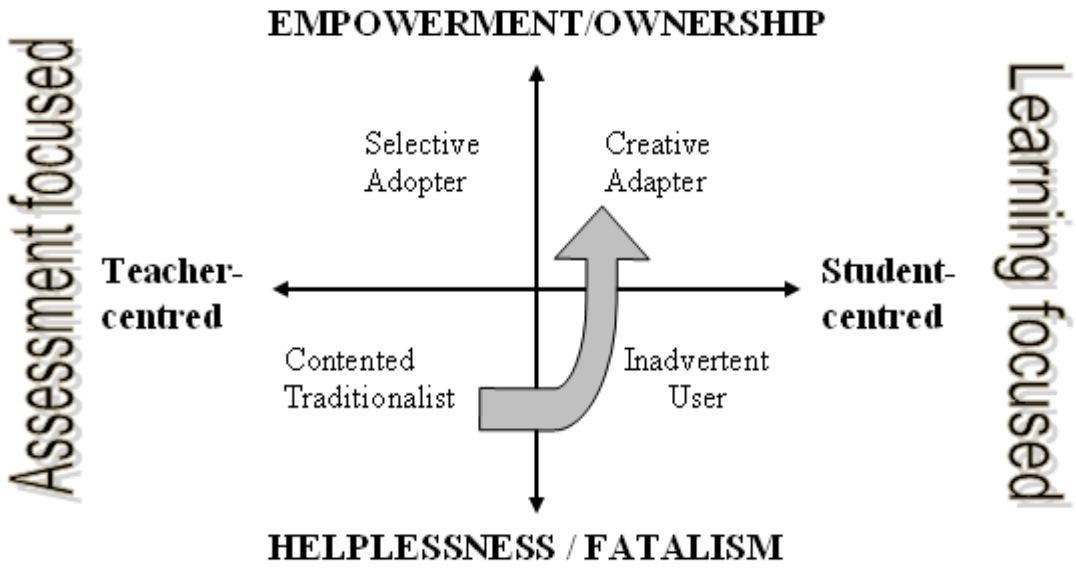

Figure 4 – Transition from CT to IU to CA

In a different type of transition a CT may become an IU before becoming a CA. Oftentimes CTs would find themselves in a situation where the principal of the school has pushed something on them to do in a student-centred way. An apt question for consideration would be if the mandatory use of a particular ICT-based resource in a particular pedagogical manner would result in CTs becoming IUs? In a relation to the model CTs have a strong focus on assessment so moving them towards an IU with a learning focus would require consideration of their beliefs. This then asks the question of how teachers' beliefs can be attended to? This is a really important question as attempts at implementing instructional change that ignores teachers' beliefs lead to disappointing results (Clark & Peterson, 1986 and Richardson et al., 1991 cited by Niederhauser & Stoddart, 2001: 28)

Once teachers become IUs the questions lead to how a transition from being an IU to a CA can occur. For this to happen, the model highlights that IU's sense of ownership and PCK need to change. These issues are the same as the issues for a transition from CT to SA. This raises an important question in terms of the strategies used. Should the strategies used to aid IUs to becoming CAs be the same as the strategies used to aid CTs in becoming SAs? If they are not the same, then on what grounds should they differ? If successful strategies were used for IUs their confidence would increase and they would feel empowered paving the way for them into becoming CAs. Of course the teacher may not manage to move past the IU stage and may even go back to the CT stage. Strategies used to aid IUs would need to cognizant of this occurring and thus these teachers may need another approach.

2. What type of ICT integration support structures are needed for the individual teacher groups in this model?

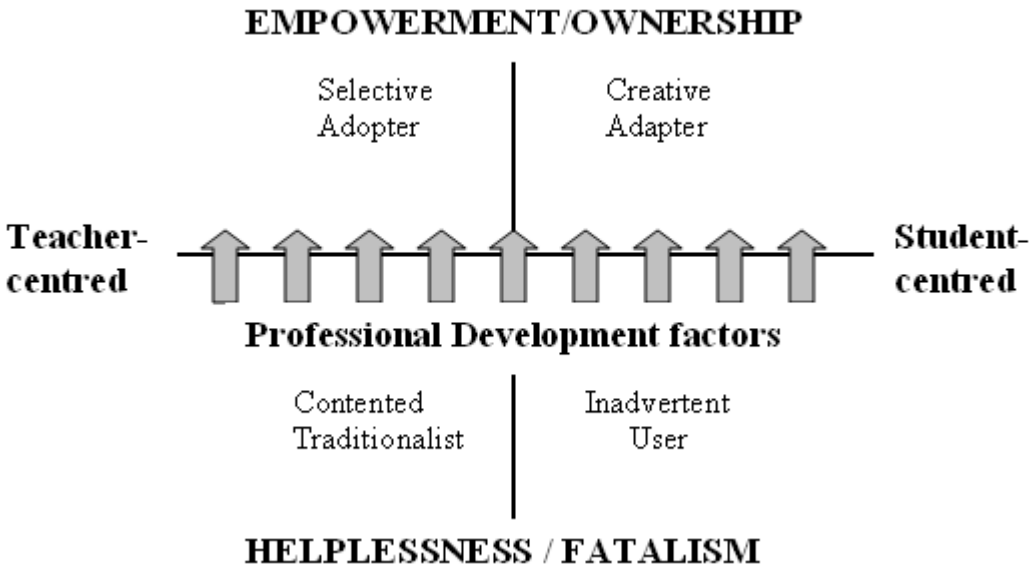

Figure 5 – Professional Development Factors

From *Figure 3* and *Figure 4*, it is clear that there are two ways of a CT eventually becoming a CA but that there are four transitions altogether. Each of these four transitions raise different questions in terms of the support structures needed for teachers to make a change. Firstly, the transitions moving to the upper quadrants, from CT to SA and IU to CA require a focus on teacher ownership and their PCK and this would be aided through Professional Development (*Figure 5*). Pedagogical professional development would aid these teachers in their use of ICT and through these experiences "teachers are likely to be more willing to learn, to try new things and to move away from more traditional classroom practices" (Ward & Parr, 2010: 121). It would again be important to be mindful of the differences between the two transitions occurring and the relevant strategies required for each. Ultimately, any attempt at professional development must help increase teacher confidence in their ability to use computers in ameliorating student learning (Ward & Parr, 2010, 113).

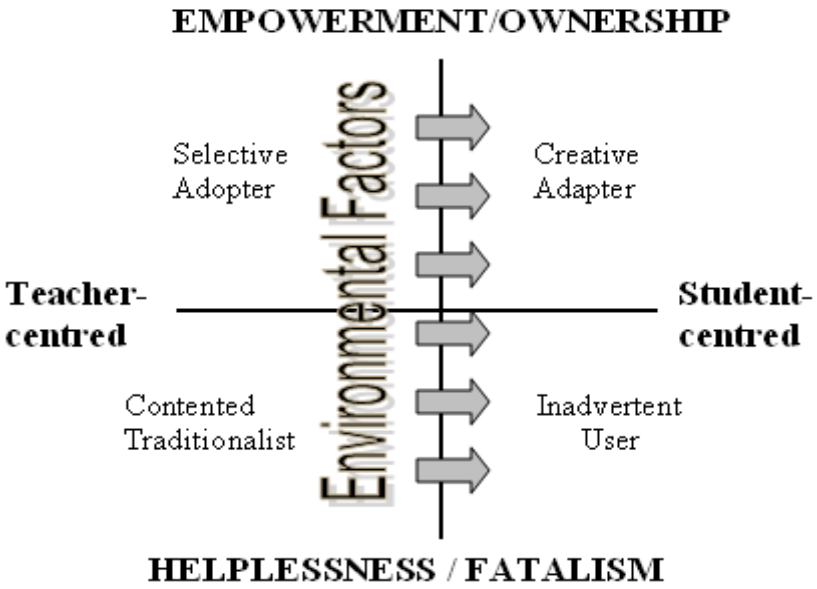

Figure 6 – Environmental Factors

Secondly, the transitions from left-hand side quadrants to right-hand side quadrants, from CT to IU and SA to CA would need a change in environmental factors such as assessment or other mandated changes (*Figure 6*). Hennessy et al (2005: 186) notes the difficulty in significantly changing subject cultures due the restraints of "nationally prescribed curriculum and assessment frameworks". In relation to mandated changes Dexter, Anderson and Becker (1999:1) noted catalysts that brought about more progressive teaching practices in teachers such as the classes taken, the context or culture of the school and reflection upon experience but noted that the ICT based resource only aided the change and was not the actual catalyst for change. This is an important consideration in how teachers would be supported with mandated changes.

6. Conclusions

This model may serve as a useful starting point to many educational stakeholders who are planning on integrating an ICT-based resource into schools. The model provides useful descriptors of the different types of teachers and how they relate to the introduction of new ICT into their schools. With a clear interpretation of what stage each teacher is at, educational stakeholders would then have a good starting point in considering the relevant strategies they should adopt for effective uses of the ICT-based resource by teachers. The model may also serve as an interesting reflective tool for teachers in considering where they fit into the model and the reasons underlying this. Future research could be carried out in relation to the interaction of the different types of teachers within the school culture. A knowledge of these interactions would greatly lend to more specific ICT-related professional development activities for teachers .

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Appendix A

Topic Guide for Initial Semi-Structured Interviews

Note: Before beginning the interview participants will be explained the general purpose of the interview (what the findings will be used for) and informed of any relevant procedures/layout relating to the interview.

- What do you feel are the challenges in teaching science in Irish schools today? What challenges affect you most?

- What is ICT's role (if any) in meeting these challenges?

- What are your views on how ICT has been used by teachers in this school to date? Reasons for this. How would you describe your use of ICT?

- How do you think a Virtual Chemistry Laboratory might change the quality of science education in schools?

- What reasons would cause you to use a Virtual Chemistry Laboratory in your teaching?

- Do you think a Virtual Chemistry Laboratory would be useful in the assessment of practical work? Why?

- To conclude what are your views on ICTs future direction in schools? (What is its place in secondary schools?)

Appendix B

Post-lesson Semi-Structured Interview

Note: Before beginning the interview participants will be explained the general purpose of the interview (what the findings will be used for) and informed of any relevant procedures/layout relating to the interview.

- What are your overall comments on the lessons you taught under the topic of (topic taught)? Were they what you expected or not?

- What have you learned from teaching this topic to these students?

- Are there any other thoughts you have after having taught the students about (topic)?

- How did you make the topic of (topic) understandable to students? What were the methods you used?

- Why did you use these methods? As opposed to other methods? Particular reasons?

- What ways did you determine that you made the topic understandable to students?

- What were typical responses/actions from students that demonstrated their understanding of the topic to you?

- What were the typical questions asked by the students?

- Was there particular attributes/characteristics of the students you had in mind when teaching the topic?

- What is your thinking on the use of the Virtual Chemistry Laboratory as a learning tool? How effectively do you think it could facilitate inquiry methods of teaching?

- What do you see as your role in the classroom when the students are using the Virtual Chemistry Laboratory? Why?

- What is your thinking around the use of the Virtual Chemistry Laboratory as an assessment tool?

- Do you see yourself using the Virtual Chemistry Laboratory next year? Why or why not? If yes, in what way?