Parametric Pedagogy: Integrating parametric CAD in Irish post-primary schools

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Abstract

Technology education in Irish post-primary schools is undergoing significant change. In recent years the syllabi of all technology-related subjects have been revised. A new subject, Design and Communication Graphics, has replaced the traditional Technical Drawing subject. This new subject aims to develop students' spatial awareness and graphical communication skills in the context of design. Parametric CAD forms a significant element of the subject. This research paper reports on a study into the use of parametric CAD by teachers in Irish post-primary schools. The research found that teachers were enthusiastic and welcomed the inclusion of the software as part of their teaching. However, the novel teaching environment was challenging which had a significant affect on their pedagogical approaches. The findings highlight the need for affective teacher professional development that explores the declarative as well as the procedural knowledge required for mastery of the CAD software.

Key words

applications in subject areas, improving classroom teaching, pedagogical issues, secondary education, teaching/learning strategies

1. Introduction

Owen-Jackson (2000) notes that many state education systems since their development have had a practical or craft element. Traditionally these subjects have had a strong vocational dimension aimed at introducing students to particular industries and developing skills and knowledge to be used in the workplace. The development of technical education in Ireland is no exception; subjects such as woodwork, metalwork and mechanical drawing were developed as vocational subjects in the early 1930s. With the development of a comprehensive curriculum in the 1960s these subjects found their way into the mainstream second level curriculum (McGarr, 2010). Although part of the mainstream curriculum, they remain strongly vocational in focus. Speaking about the focus of these early technology subjects Owen-Jackson (2000) claims these subjects were "concerned only with the passing on to pupils traditional knowledge and skills. Pupils were required only to learn the knowledge, not to understand it, and to copy and practise the making skills" (p. 5). Internationally technology education at post-primary level is now recognised as an opportunity for students to develop technological capability through project-based learning (Todd, 1999; Doppelt, 2003; Frank, Lavy & Elata, 2003; Mettas & Constantinou, 2008). The use of problem-based learning strategies and an increased emphasis in design has seen these subjects change from primarily a place of drill and practice activities to one which encourages student creativity, inquiry, research, evaluation and collaboration.

Recent curricular changes to the suite of technology subjects at post-primary level in Ireland reflect these changes. The new Design and Communication Graphics syllabus, which replaces the Technical Drawing Syllabus, has changed considerably in its focus. While traditionally a subject that focused on the development of draughting skills, the new syllabus claims that technology education is an "essential component of the curriculum" (Department of Education and Science, 2006, p. iii) providing learning outcomes which contribute significantly to the provision of a broad and balanced curriculum. These, according to the syllabus, include graphic communication, creative problem solving, spatial abilities, design capabilities and computer graphics and CAD modelling skills. Among the key aims of the programme it aims to develop the creative thinking and problem solving abilities of students.

A significant element of the new syllabus (40%) focuses on the use of parametric CAD software both to expose students to the most up to date practices in the industry but also as a tool to enhance the students design capabilities. Two-dimensional CAD has been an element of *Technical Graphics* at Junior level (12-15 years) but the emphasis at this level is on learning how to use the software and its basic commands rather that using the software as a design and communication tool. With the onset of the new syllabus, and given its radically different focus, the key challenge lies not only in up-skilling teachers on the use of new software but also in adapting to the new educational philosophy of the programme. Reconceptualising the subject in this way requires substantially different teaching strategies. Pedagogical approaches used in introducing the software can have implications for how it is perceived by students and the affordances it can provide.

The research reported in this paper was part of a larger funded study into the use of parametric CAD in Irish post-primary schools. The study was funded by the National Council for Curriculum and Assessment (NCCA) and the

National Centre for Technology in Education (NCTE). This paper reports:

- The process of integrating the software within the participating schools.
- The pedagogical approaches adopted by the participating teachers in teaching parametric CAD.

2. Teaching CAD and the problems of ICT integration

Garcia, Quiros, Santos & Penin (2007) argue that CAD is not easy to learn as it requires computer skills, mental capacity, spatial vision and physical coordination. The need for this combination of skills can pose significant problems for the learner being introduced to the software and as a consequence the demands on the teacher are also very high. Moreover, the challenge for the teacher is exacerbated in secondary schools by the novelty of the learning environment and the associated classroom management problems that can arise in such contexts. Early work into the integration of ICT by Mevarech (1997) found that the development of teacher expertise in relation to the use of the computer in the classroom is not a linear process but a U curve which involves "a negative slide of decline in performance and attitudes followed by a positive side of overcoming the difficulty or restructuring teacher pedagogical content knowledge" (p. 46). Her research evidence from observations and interviews with teachers who were teaching in two types of cooperative computer learning environments points to four successive stages. The first stage is characterised by a very narrow mechanical use of the innovation with excessive strictness and concerns with discipline and management problems. The next stage, exploration and bridging, is characterised by a move towards smoother integration with less management problems. The adaptation stage is characterised by reflective use of the technology in innovative learning environments where teachers are beginning to apply their own pedagogical knowledge. The final stage, conceptual change and invention, is characterised by dynamic use of the technology and a strong constructivist orientation in teachers' talk. Other work at that time by Sandholtz, Ringstaff & O'Dwyer (1997) identified a similar pattern of adoption in the Apple Classrooms of Tomorrow (ACOT) study. They described the process as moving from entry (where student misbehaviour and attitudes, the physical environment, technical problems and software management and the dynamics of the classroom environment are of central concern) to adoption where teachers develop strategies to cope with the new environment to adaptation. Gibbs (2000) also identifies a computer using continuum of changing practices in relation to their implementation and use of IT. This use ranges from personal use and experimentation to regular integration of IT within the curriculum.

The staged process of ICT integration, as highlighted from the examples above, are now widely used to categorise ICT usage. These frameworks are largely influenced by models of adoptions of innovations (examples include the Concerns Based Adoption Model (CBAM), the Stages of Concern by Hall, George, & Rutherford (1986) and Levels of Use by Hall, Loucks, Rutherford, & Newlove (1975)) and are commonly used to categorise teachers' use of technology along this continuum.
For example, Donovan, Hartley & Strudler (2007) used the CBAM as a model to assess teachers' concerns during a one-to-one laptop initiative in urban middle schools in the south-western United States. They found that the concerns of the teachers tended to focus on the impact that the laptop initiative had on them in terms of their time, planning and pedagogical practices; a smaller percentage were concerned with how best to use the technology to enhance learning. Research into the use of ICT by Australian teachers using a similar incremental framework

Stage of concern		Level of use	
0	Awareness	0	Nonuse
1	Informational	I	Orientation
2	Personal	II	Preparation
3	Management	III	Mechanical use
4	Consequence	IVA	Routine
5	Collaboration	IVB	Refinement
6	Refocusing	V	Integration
		VI	Renewal

Table 1. The concerns-based adoption model stages of concern (Hall, George, & Rutherford, 1986) and levels of use (Hall, Loucks, Rutherford, & Newlove, 1975)

found that the majority had achieved routine use of the technology but that greater time was required for teachers to use the technology to 'develop and challenge existing curriculum structures and school practices (Schibeci et al., 2008, p. 320). More recent research into the use of e-learning in Jordanian schools by AL-Rawajfth, Soon Fook, and Idros (2010) found that the vast majority of teachers were at the 'personal' stage of concern and few had progressed beyond that stage.

The use of these computer use frameworks highlight the complexity of the change process and how prevailing pedagogies rather than the potential of the technology influence the nature of its use. Koelher Mishra, & Yahya (2007) argue that technology integration requires an understanding of the dynamic, transactional relationship between technological, content and pedagogical knowledge. They further argue that, "good teaching with technology for a given content matter is complex and multi-dimensional" (p. 743).

The influence of teachers' existing pedagogical practices and beliefs has long been explored. As far back as 1995 Miller & Olson (1995) noted that teachers' prior practices are more influential in determining how technology will be used than the technology itself. For example, Hayes (2007), commenting on teachers use of ICT in Australian classrooms, notes;

> Our observations appeared to confirm that teachers were largely incorporating the computers available into their existing practices. They tended to integrate ICT in ways that supplemented existing learning designs, often by utilising ICT to replicate comparable tasks completed without ICT.
>
> (Hayes, 2007, p. 389)

More recent research into the use of technology by Taiwanese teachers by Liu (2010) found that while most teachers held learner-centred beliefs they did not integrate constructivist teaching when using technology.

This understanding of technology use by teachers, and more importantly the nature of its use, is helpful in understanding the pedagogical approaches commonly associated with the teaching of CAD in schools and how existing pedagogical practices influence practice. Garcia et al., (2007) assert that in most European engineering schools CAD is taught in quite a traditional manner where following a teacher explanation of the specific functions of the CAD programme, the students complete a series of exercises. This approach is mirrored in post-primary level, particularly in Irish schools where the focus of previous use of CAD has been on learning how to use the software rather than using it within a broader graphical context. Hamade, Artail & Jaber (2007) argue that from a learning point of view CAD involves a sequence of operations leading to a completed solid object. This involves both procedural and declarative knowledge. Procedural knowledge involves the mental manipulation of the object to be modelled into its basic shapes or geons (Biederman, 1987). Declarative knowledge involves the completion of the various necessary commands to produce the completed modelled object. Hamade et al., (2007) argue that most CAD training programmes tend to focus on the declarative knowledge, i.e. the basic commands of the particular software in question with less attention given to the analysis of the form and shape of the modelled object and the implications for its realisation. Johnson & Parsad Diwakaran (2011) highlight that the focus on model creation and low-level declarative thinking must be replaced with comprehending the importance of understanding design intent and how CAD tools are organised and function and this makes a significant contribution by emphasising the relationship between model attributes and the functionality and complexity of CAD models. When considering CAD education Chester (2007) highlights that; the didactic approach to teaching CAD is the dominant pedagogy, experienced CAD users often use sub-optimal modelling methods derived from knowledge of the commands combined with individual heuristics, and that expertise in CAD must go beyond procedural and command knowledge and focus on the application of strategic knowledge.

Therefore, as this brief review of the literature has highlighted, using computer technology in classrooms can be challenging, particularly for teachers with no previous experience. Given the demands of the environment use can often be limited to the initial levels of the computer use frameworks previously outlined. Cognisant of the mediating influence of existing pedagogy, this study set out to explore how teachers, new to the computer environment, teach CAD.

3. Research methodology

As previously mentioned the research reported in this paper aimed to explore the process of integrating the parametric CAD software within the participating schools and the pedagogical approaches adopted by the participating teachers in teaching parametric CAD. The research employed a case study methodology since it would most effectively capture the complexity of the issues raised during the course of the research. Case study is particularly suited to studies when the researcher has little control over events. The case study could generally be described as an evaluative case study since it was an enquiry into an educational project to determine its worthwhileness (Bassey, 1999). Due to the nature of the research it was deemed essential to include both teachers' perspectives and pupils' experiences and insights. Various research tools, including questionnaires, interviews, focus group interviews, collection of completed student work, student test scores and classroom observations, were used as part of the data collection.

The research was conducted in 15 schools in the southwest region of Ireland. The geographical region selected was serviced by two regional ICT officers who provided support and advice to the schools over the course of the project. Schools with suitable ICT resources were firstly identified and the 15 schools were selected to provide a range of different sizes and types which was a representative sample of the schools in the region.

3.1 Research participants

3.1.1 Pupils

243 pupils, comprising of 70% male and 30% female, across the 15 schools participated in the research. The students ranged in age from 15 to 17 (Mean age of 15.43 years and a standard deviation of 0.53). All pupils were studying the Transition year programme. This is a one-year optional programme between the Junior Certificate programme and the Leaving Certificate programme which aims to promote maturity and personal development through the development of general, technical and academic skills.

3.1.2 Teachers

Fifteen teachers, ranging in age from 25 to 52 years, participated in the study (14 male, 1 female). As teachers of technology subjects, all had previous experience of two-dimensional CAD from their pre-service qualifications or in-service professional courses delivered by the Department of Education and Science. While knowledge of CAD varied, all possessed a good working knowledge of basic CAD commands and terminology. They also reported high levels of ICT skills with only three teachers reporting a 'medium' level of ICT skills.

3.1.3 Course content

All schools followed a prescribed scheme of work consisting of a series of 15 modelling exercises. The tasks encompassed all the main functions of the software and progressed from simple extruded objects to more advanced multiple part assemblies. Student work was collated throughout the project and assessed on completion of the project as part of the data collection in order to determine the level of student engagement and knowledge.

3.2 Structure of the research project

The research was conducted in three phases. The first phase involved the training of the participating teachers in the use of the software. All teachers were trained in the use of the software over a series of three weekends. Training was organised by software type. Teachers were trained in small groups of five participants with each software type being trained by a professional trainer from the software provider. The content of the in-service training programmes were based around the scheme of work designed for students. The 15 core exercises to be used with the students formed the basis of the training programme over the three weekends. The tasks progressed from simple extruded and revolved models to more complex multi-part assemblies.

The CAD training commenced with a two-day introductory course (15hrs). This session firstly introduced the research project to all participants. Following this introduction teachers were then allocated to their software group and were trained by professional trainers from the software companies. The initial training weekend provided an overview of parametric modelling and introduced the sketching, extrusion and revolve feature of the programmes. The second part of the training programme took place two months later with a one day (8hrs) training programme. This session continued the training initiated in the earlier session and also gave teachers the opportunity to raise issues experienced by them when using the software independently. Aspects covered in this session included more advanced sketching, arrays, patterns, mirrors, and basic assembly. The third element of the training, conducted after the summer recess, completed the training programme. This session took place over two days (15hrs) and completed the training programme covering advanced assemblies. This final training session also included input from a teacher on his experiences of using the parametric CAD software with pupils. From the onset of the project, the timing of the second and third training sessions were arranged to act as milestones in the development of the teachers' knowledge of the software. By placing them at these times they aimed to compliment the teachers' independent study of the software and enable them to explore the potential of the software (Haydn & Barton, 2007).

Throughout the training courses teachers were observed. Observations focused on the teachers' level of IT competence, their initial reaction to the software, their level of interest, the level of difficulties experienced and their progress over the course of the software training programme. The views of teachers were obtained through questionnaires on completion of each of the three training weekends. Teachers were also invited to record the level of independent study they completed during the course of the training phase of the research.

The second phase of the research project involved the implementation of the software in the schools. Each participating teacher followed the prescribed scheme of work. During the implementation phase lessons were observed, student work collated and views of teachers and students sought on an ongoing basis.

The third phase of the research was conducted after the school-based implementation period. At this time the views of both teachers and students were sought using a wide range of research tools including surveys, semi-structured interviews and focus group discussions. This broad set of research tools was used to explore the multiple perspectives of all participants in the research study, the collation of which provided a rich and descriptive case study of the entire research project. The data presented in this paper focuses on the teachers' and students' reaction to the software and the pedagogical approaches adopted by the teachers when using it in their schools.

4. Research findings

4.1 Phase 1 – Software Training

The project commenced in Spring 2004. Phase 1, the software training and familiarisation period, was seven months in duration. During this time, participating teachers were provided with the necessary materials and training to become comfortable in the use of the software. From the onset of the project all 15 participating teachers were impressed by the software. A selection of questionnaire responses, from the initial teacher survey after the first training weekend, highlights this level of interest:

- Very impressed, user friendly.
- Very exciting and eager to get going.
- Excellent. Mind blowing.
- Glad to get the opportunity to be involved.
- Excellent, I'm looking forward to using it.
- Looking forward to its full implementation. Keep it going at full steam.

While all teachers felt the training courses were beneficial, there was unanimous agreement that personal experimentation was required to become familiar with the different aspects of the software package. As one teacher reflected at the end of the research during an interview; *"I think messing around experimenting at home was a big help"*. Another, commenting during the end of project focus groups, stated, *"you have to put in the hours … there's no short way around it. You have to make the mistakes"*. However, although teachers expressed the need to experiment and use the software in their own time, in order to become familiar with it, their levels of independent study varied significantly. Four of the 15 teachers admitted to relying solely on the training sessions and some preparatory work before each lesson. While the majority of teachers spent 10 to 15 hours of additional independent study familiarising themselves with the software, three teachers reported much higher levels of independent work (over 30hrs) and one teacher reported spending over 40 hours on independent study.

Concerns were expressed by three teachers, prior to the commencement of the project, that their knowledge of the software would not be sufficiently deep enough to effectively teach it in a classroom setting, " [the] biggest issue for me will be attaining a level of competence [in the] software to be able to use in a classroom". Their fears may also have been due to the new teaching environment as one teacher commented at the end of the project in a focus group discussion, *"you can fly by the seat of you pants with chalk or a marker but when you go into a [computer] room with 24, 13 to 14 year olds it is absolutely critical"*. From the focus group discussions after the school-based element of the study there was a general acceptance from the teachers that the level of in-depth knowledge of the software required could only be developed in a classroom setting:

> *The only way that you'll know from my point of view...is when you teach it. The kids will ask you the questions that you have been glossing over yourself in your head and when they ask you the questions you have to know it.*

Four of the participating teachers were not experienced in teaching 2D CAD in the past, for them teaching in a computer room was uncommon. As one teacher pointed out, *"I never used a data projector before the using of that I was sceptical of that the first day"*. While the teachers' perceived level of knowledge of the software varied on commencement of the school-based element of the research all reported feeling reasonably prepared to implement the software in the final teacher survey after the third training session.

4.2 Phase 2 – Software implementation

The school-based phase of the research study commenced in Autumn 2004, two weeks after the final training session. The original scheme of work was designed to run over a five week period. Installation problems and school-based activities, which resulted in a number of lesson cancellations, caused four schools to extend the time period in which the scheme was completed. While the project aimed to select schools that had similar levels of equipment, there were differences in the standard of hardware which resulted in differing performances of the software. The equipment in two schools, having the minimum specifications for the software programmes, caused ongoing technical difficulties.

Classroom observations began on the third week with visits to all schools. With one exception, the participating teachers followed the prescribed scheme. However it emerged that while teachers closely adhered to the scheme this in turn resulted in a guided approach being adopted in the lessons. Teachers tended to focus on the completion of the core exercises rather than using these as an opportunity to explore new aspects of modelling. For example, when rotations were introduced it was observed by the researchers that no teacher explored the concept before showing how revolved features are made in the modelling environment. The role and position of the axis of rotation and its effect on the completed object was not explored in any lesson observed, despite the fact that the position of the axis of rotation in relation to a sketched object will significantly affect the shape and form of the revolved object.

All lessons observed had a common format. The teacher would explain how to model the lesson's exercise, presented with the data projector, and following this explanation the students mirrored the commands to complete the drawing. In five of the fifteen schools this guided approach was very restrictive where the teacher would complete one step, allow the class to complete it and move to a second step. Where this approach was adopted it appeared to frustrate pupils as this comment from a student focus group shows: *"He [the teacher] won't let you go on. You could be waiting around forever"*. It was apparent in the lessons observed that teachers were 'competing' against the computer for the students' attention. Such was the students' level of interest in the software in many lessons observed they paid little attention to the teachers' explanations preferring instead to try it for themselves.

In such cases, while some students were successful in adopting this approach, others experienced difficulties later in the task, as the following teacher's comment highlights:

> *When they call you over generally they haven't done what you've told them they should do and then you've to try and track down where they went wrong.*

While the new environment brought different levels of challenge for the cooperating teachers, students across all the schools were motivated by its introduction. Speaking in one of the student focus groups one student noted that it was, *"more modern...more up to date than using pen or paper"*. High levels of student motivation were particularly evident when they had completed an exercise. Throughout all the schools many were observed rotating their completed models. They spent considerable time rendering them; this was particularly observed among the female students. Students with knowledge of drawing and design enjoyed the experience and also recognised its advantages over traditional drawing techniques:

> *It's so accurate. It's so tidy, there's no messing about. You're finished in way less time. There's no lining out a page or it getting dirty and torn.*
>
> *Realistically if you do have a job in engineering you're not going to be using a board and T-square.*

This level of student interest caused problems for the participating teachers. The following teachers' comments highlight the problems experienced:

> *When you do one thing they are inclined to head off instead of waiting.*
>
> *The only problem with the class was trying to hold them back...the boys want to press ahead.*
>
> *Well the problem I had was that they were too eager to go at it, they wouldn't watch what I was doing. They'll either lock the computer or they'd be gone too far that they couldn't get back. I wouldn't be able to get them back.*

In addition to the eagerness of the students, almost half of the teachers (seven in total) commented on the difficulty of managing the students within the computer room. The following comments from the participating teachers highlight this level of difficulty:

> *With over 20 of them in a classroom it's very difficult to get around to them all.*
>
> *With the wide range of abilities you could get bogged down with one student or two students.*
>
> *Getting stuck in an area and there's only one of you and 20 of them.*

Students' greater familiarity with the technology and their openness to explore was another problem experienced by the teachers in the research. As one teacher commented, *"the one thing with kids is that they latch onto things very quickly"*.

4.3 Phase 3 – Project evaluation

The prescribed scheme of work used by all schools was not complete in the time provided. Thirteen of the fifteen participating schools completed 10 of the 15 allocated tasks. Only two schools, consisting of 27 participating students, did not make a similar level of progress due to technical problems. All other schools had completed the single part extrusion and revolve tasks and completed the first assembly task.

On completion of the school-based element of the research all teachers were individually interviewed, following these interviews teachers participated in three focus group discussions. These interviews and focus group discussions provided an opportunity to explore the teachers' perceptions of the project. Reflecting on the project during the three teacher focus group discussions there was a general feeling among the teachers that the scheme of work designed was ambitious. Suggestions were made during two of the three focus groups that the prescribed scheme of work should have allocated more time to familiarising students with the software. The following teachers' comments from the focus group interviews highlight this:

> *Start with solid modelling as in your revolve, protrusion, polar alignments and all that, cool shapes. Bring solid models in front of them and [show them] what they can do...I wouldn't even worry about dimensions first then obviously they get into it...[get] each kid bring in an item from home and we'd model that.*
>
> *I think I didn't give them enough time to experiment. There wasn't enough time to experiment on their own...I think it would be very interesting to see what they would come up with on their own.*
>
> *The main problem, I thought, was that they didn't get familiar with the screen, it's [the] small things, zooming in, zooming out...being able to rotate...two weeks [are] needed to be given to learning how to get around the screen...the tasks came too quickly. I used a whole week explaining how to draw a box and just getting them to put fillets on it, put chamfers on it, getting them to figure out the toolbars aren't switched on...even at that I felt I was still only skipping over it...the kids weren't really comfortable with the software, I knew they weren't, they were going through the drawings in the exact same way as I drew them on the board or as I showed them how to draw...if they were given a design task I don't think they would be as comfortable with it...they needed more on the basics that's what I thought*

On completion of the research there remained a high level of interest among the participating teachers. During the final focus group discussions with the teachers several comments made reflected this interest. One teacher claimed, *"it's just amazing, absolutely unbelievable"*, while another claimed *"I'd hate to see it stop just as a pilot scheme"*. The teachers' level of interest in the software spread far beyond the scope of the research project. Many had begun to use the software with other class groups in their schools and, as teachers of Design and Communication Graphics, all recognised its benefits in developing students' visualisation capabilities in Junior and Leaving Certificate subjects:

> *I'd be looking at it for teaching drawing the fact that you can manipulate and turn it and explain it very easy. I can remember using AutoCAD and trying to get 3D on it. You'd be struggling for months to get anything like this.*

It can put across ideas that you have been struggling to explain using the blackboard.

5. Implications for future practice

Being an exploratory project, the research aimed to explore some of the issues that arise when implementing this software within Irish schools. Having examined the collated data there are many issues that may assist future developments in this area.

Training and software familiarisation

The approach adopted in the training sessions, being provided by professional trainers with significant experience in industrial training, tended to focus on acquiring the skills and knowledge of how to use the functions of the software effectively. This approach, while effective for this purpose, did not prepare the participating teachers for the demands of using the software in a teaching environment where pedagogical knowledge is critical in maintaining an effective learning environment. One of the greatest challenges for many of the teachers was the novelty of teaching in a computer room. Dealing with ongoing technical problems, gaining attention of the class and addressing student difficulties were regular problems experienced by the teachers. While the training provided included input from an experienced teacher, future training provision requires a greater emphasis on pedagogical strategies rather than on acquiring the software skills and assuming that the teachers can successfully implement the technology without pedagogical guidance.

In addition, during classroom observations it was noted that teachers tended to focus on completing the exercise

RESEARCH

with the students rather than challenging the students to analyse the shape and form of the object to be modelled and consider the best approach to its realisation. Insufficient attention was given to exploring the model's properties and on occasion a discussion on how the component should be modelled was merited before attempting the task. Future training should also attempt to simulate the type of learning environment that one would expect to see within classrooms. Therefore, greater emphasis on understanding the form and shape of the object to be modelled is needed. As the literature review has highlighted both declarative and procedural knowledge (Hamade et al., 2007) are needed in the use of parametric CAD. Within parametric modelling it could be argued that procedural knowledge, i.e. the mental manipulation of the object into its basic parts, is the most important of the two as the designer must have a broad understanding of the objects shape and form before it can be modelled. This also provides a higher cognitive element to the study of the software and avoids reducing the pupils' experience to one of completing a series of functions in order to model a desired component. In essence the lesson should be seen as primarily a lesson on design realisation supported through the use of technology rather than one focused on acquiring the skills to use the software.

The study has also found that students require time to become familiar with the software environment. Greater time should be allocated to independent exploration and experimentation with the features of the software before embarking on specific tasks. One cannot assume that students have previous experience of using such types of software, particularly those with comprehensive user interfaces. Time should be allocated within the students' scheme of work for this type of informal learning where students can acquire the skills at their own pace and in a collaborative supportive environment among their peers. It is only when students become familiar with the software and feel comfortable navigating through the various commands can they fully explore the potential of the software.

What explains the pedagogical approach adopted by the teachers?

As the research has highlighted, many of the participating teachers adopted a guided approach to the delivery of their lessons only enabling students to complete the tasks in a step-by-step manner as they progressed with their explanations during the lesson. Levin & Wadmany (2005) categorise this level of ICT use as partial or no change. The characteristics of this level of change include; 'significant emphasis on centralised, rigid management of each lesson; the teacher inflexibly follows a pre-planned route and goals; emphasis on specific contents rather than skills or mental processes; uses low-level questions to elicit a specific response; the computer is seen as a technical tool' (p. 294). In many respects the use observed mirrors the management/mechanical use outlined in the adoption models referred to earlier. What might be the reasons for this partial or no change in practice? There are a number of issues that have contributed to it.

Firstly the training provided tended to be software focused and the approach adopted by the teachers tended to mirror this approach. Given the challenges of integrating this technology it is understandable perhaps that teachers would apply the pedagogical techniques they themselves experienced as learners. A second reason for the approach adopted maybe due to the challenging nature of the new classroom environment brought about by the introduction of the technology. Speaking about the distraction caused by technology in classrooms Fried (2008) notes that access to the equipment and the information they can provide can cause attentional shifts and distraction. The introduction of the new software was a significant distraction for many pupils resulting in management problems and a perceived lack of control over the environment by the teacher.

Thirdly, while the teachers felt confident in using the software and were aware of the various commands their lack of experience of using it in a classroom environment left them unprepared to deal with the common mistakes and errors that new learners make when first introduced to the software. When instances such as these occurred the teachers often lacked the very in-depth knowledge of the software that is required to identify the origins of the learner's problem in order to rectify it. This may also explain the cautious step-by-step approach.

Fourthly, another contributing factor may have been the existing pedagogical approaches of the participating teachers. A culture of 'show and copy' has dominated vocational subjects since their inclusion in mainstream education (de Vries, 2002; McGarr, 2010). Rakes, Fields & Cox (2006) note that teachers often struggle to overcome the 'inertia of instructional practices in the traditional classroom' (p. 409). They further add that given the constraints of traditional pedagogical approaches, pupils are not afforded the opportunities to engage in dynamic learning experiences and instead their experiences are quite limited.

The range of factors that contribute to how the teachers teach the software highlights the complexity of the process of change and in particular the complexity of integrating new technologies in teaching and learning. Yet in highlighting these issues the study has drawn attention to important aspects that need to be considered in the future as the technology is implemented on a national scale.

6. Conclusion

The changes to the new Design and Communication Graphics syllabus have the potential to reconceptualise the role of the traditional technical drawing subjects at post-primary level. Through the integration of greater levels of design and the integration of parametric CAD the students' experience of the subject will be greatly enhanced. However as this research has highlighted, there are a number of challenges ahead.

The introduction of this type of software in schools should not be seen exclusively as an innovation in ICT, since its introduction has several pedagogical implications for teachers. Coping with the novel teaching environment and facilitating students in using this software were the greatest challenges faced by many of the teachers in this study Viewed in this context the professional development needed by teachers goes far beyond software training. While traditional strategies primarily equipped teachers with the technical knowledge and skills this model must not be repeated if effective use is to be realised.

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