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A Case Study in CAD Design Automation

Andrew G. Lowe and Nathan W. Hartman

Abstract

Computer-aided design (CAD) software and other product life-cycle management (PLM) tools have become ubiquitous in industry during the past 20 years. Over this time they have continuously evolved, becoming programs with enormous capabilities, but the companies that use them have not evolved their design practices at the same rate. Due to the constant pressure of bringing new products to market, commercial businesses are not able to dedicate the resources necessary to tap into the more advanced capabilities of their design tools that have the potential to significantly reduce both time-to-market and quality of their products. Taking advantage of these advanced capabilities would require little time and out-of-pocket expense, since the companies already own the licenses to the software. This article details the work of a small research team working in conjunction with a major turbine engine manufacturer endeavoring to make better use of the underutilized capabilities of their design software. By using the scripting language built into their CAD package for design automation, knowledge-based engineering applications, and efficient movement of data between design packages, the company was able to significantly reduce design time for turbine design, increase the number of feasible design iterations, increase benefits from relational modeling techniques, and increase the overall quality of their design processes.

The design of turbine engines involves creating, modeling, and documenting the development of airfoil geometry for turbine, impeller, and compressor blades. This process is highly iterative due to the circular revisions made between design and analysis groups chasing the optimal airfoil shape and performance. Airfoil blades are a crucial component within a turbine engine, and their design covers many engineering disciplines such as thermodynamics and statics. For both analysis and manufacturing, these airfoils are modeled in a CAD system. However, the complex shapes of airfoils make this difficult. They are typically modeled using b-splines or NURBS, and the development of methods to do this has been ongoing for decades (Corral, Roque, Pastor, & Guillermo, 2004; Korakianitis & Pantazopoulos, 1993)). After revisions are made, geometric data are often re-engineered and recreated within the CAD system. This process ranges from hours to days because the current methods of creating the airfoil models in the CAD system are not parametric, (i.e., the geometry is not associated with the engineering definition of the airfoil after the model is created). A turbine engine can contain as many as of 20 different airfoils, so any improvement in the time for one design iteration will have a beneficial effect on the total design process. In addition, additional benefits can be realized depending on whether a turbine, compressor, or fan blade is being designed, as the geometric complexity of each part varies from relatively simple to highly complex.

According to O'Brien et al. (2006), the knowledge-based engineering (KBE) techniques can make a substantial impact in the design of engineering products. It is gaining prominence as a major tool to speed up product development by capturing knowledge from engineers and designers and embedding that into software configuration (Bermell & Fan, 2002; Prasad, 2005; Rosenfeld, 1995). This knowledge is then used to assist designers while they create products within the CAD system (Hunter, Rios, Perez, & Vizan, 2005). KBE systems are used to automatically create objects (Clark, 2001; Sekiya, Tsumaya, & Tomiyama, 1998), assist designers while they create objects (Carleton, 2005), and compare the cost versus efficiency of created objects (Susca, Mandorli, & Rizzi, 2000).

The industrial research partner in this project does its CAD design in Siemens PLM NX and ports their models into assorted versions of ANSYS and various other in-house applications for analysis. At the beginning of the project the design process was almost totally manual – aerodynamics engineers would pass point cloud data representing turbine airfoils to modelers who would spend one or more full workdays constructing a CAD model from the data. This time encompasses only the airfoil itself and not any of the turbine wheel attachment points or internal cooling geometry. There were no standards in place, so each modeler created their airfoils in their own way which complicated and unnecessarily extended the time required for design changes and additional design iterations. Altering a turbine model would either require adding the task to the queue of the original modeler, each of whom works on several projects concurrently, or enlisting an available modeler to decipher the original modelers techniques and make the necessary adjustments. Even in ideal circumstances, the time to make a design change would be roughly equal to the time required to make the original model.

The company was interested in the capabilities of Knowledge Fusion (KF), a scripting language built into the NX CAD package to automate, standardize, and streamline this process. It had several objectives in mind for the prospective KF application. The first was to reduce the overall design process time by automating the repeated tasks involved in creating the initial airfoil CAD model from the aero engineer's point cloud data. The second was to reduce the time required for design changes and design iterations. By building on objectives one and two, it hoped to standardize the process, both to reduce the likelihood of costly errors in the existing fully manual process and to have consistent models suited to more efficient or automated importation and meshing in analysis software.

Initial requirements were for a KF application capable of reading the raw point cloud data provided by the aero engineers and automatically generating a solid model to which a modeler could add the necessary geometry for attachment points and internal cooling. Ideally the application would be user friendly enough that the aero engineers, who have no CAD training, would be able to generate the initial airfoil model themselves and verify that the solid model conforms to their design intent before passing the model off for final modeling, analysis, and production, a capability they did not currently have. If the application proved robust in generating the initial airfoil solid, additional capability would be added to the application allowing for automation of additional features, including framework for internal cooling geometry, representations of thermal coatings, and NX-specific settings to conform to company design policy and to make the final modeler's job easier.

Project Background

Knowledge Fusion (KF) is a procedural, object-oriented scripting language built into the NX CAD package. Generic Windows-style menus and dialog boxes can be created and tied into KF applications with UI Styler, a user interface design tool also built into NX. KF applications run from simple text files, so they do not need to be compiled on each computer they are to be used with. This makes distribution of the applications throughout a corporation a simpler matter, and it also gives a company the ability to store the application files on a server to which employees can point their copy of NX and run the application without having to download the files.

KF offers most of the basic capabilities one would expect from a programming language – conditional logic, looping, file input/output, basic math, text parsing and string manipulation. The language's vast function library allows the user to call virtually every action available in NX's traditional graphical user interface. With basic programming architecture and the large library of geometry-related functions, a KF application can create automatically almost any model a trained human could design by hand (Golkar, 2006).

Program Capabilities

The automated turbine design application was developed in stages by a series of small research teams and individuals, each building upon the work of the previous researchers and adding features as each stage was determined to be robust enough for production. The initial application would only read in the point cloud data and create the solid model, but through succeeding iterations all desired capability was added and determined to be stable.

Solid Model Generation

The company for which the application was designed uses a handful of proprietary file formats for their turbine point cloud data depending upon the application used to design the turbine and the location at which it was designed. Each format is roughly similar regarding the way the points are organized. The airfoil points are divided into sections, each laterally ringing the airfoil. Some formats use a fixed number of sections, others support a dynamic number. Three separate parsing functions were developed to read in the data and store them in a consistent manner to avoid costly and inefficient repetitions of modeling functions within the body of the program.

The user interface requires the user to select the appropriate file format before the data is fed to the program. At that point the parser ignores any existing header data, then reads and stores the points in a three-dimensional array (referred to as lists in KF), the top-level array holding an array of points for each section. The application then loops through the list, drawing a spline through each array of section points. Each spline is stored as an element in a new array, which is, in turn, looped through by one of NX's multi-section solid operations using each spline as a guide to create the airfoil solid. Due to the complex curvature of turbine airfoils and the necessity of absolute smoothness and precision in the model, several multi-section solid functions had to be evaluated by the research team and the company's modelers before an appropriately precise and robust operation was found (Farin, 1997).

Layering and Coloring

The partner corporation has strict modeling guidelines regarding the development of models. Each type of reference and final geometry has to be placed on a different layer in NX both to avoid graphical cluttering of the final model and to make modifications and design changes easier as the part file circulates through different modelers during its design. For the airfoil generation application to be useful in a production context, the models it creates must conform to these standards. When every point, line, surface or solid is created, the application puts it on the appropriate layer. There is a set of default layers built into the program, but these can be changed before model generation through the user interface.

Due to the sheer volume of geometric data that the application creates, it was deemed necessary to alleviate potential visual clutter by making each piece of geometry noticeably different from the rest. The same command that allows for specific layer placement of newly generated geometry also allows the color to be controlled. Similar to the layering capability, default colors are stored for each piece of geometry, but these can be changed through the user interface. The layered geometry also reduces visual clutter, since the user can quickly hide construction or other geometry without being familiar with the feature tree generated by the application.

Face Tagging and Finite Element Analysis (FEA) Integration

The partner company is developing an automated CAD/FEA integration, discussed in detail in the BENEFITS section, that relies on named or "tagged" faces for automated meshing. When the initial solid model is generated, the operation is repeated with the added specification that the generated geometry be a surface instead of a solid, effectively wrapping the solid airfoil in a geometrically identical blanket. The hub and tip surfaces are then cut away from the initial surface wrap using the uppermost and lowermost section splines. Each point cloud file type has the potential to describe each section with a differing number of points, so the points in each section that represent the border between the four vertical faces must be identified based on the type of file in which they are contained. Once identified, the border points are saved in arrays where the program loops through them to create cutting splines running from the hub to tip of the airfoil. The surface wrapping the airfoil vertically is split into four individual faces using these splines as references. Each face is named using a convention recognized by the automated meshing program.

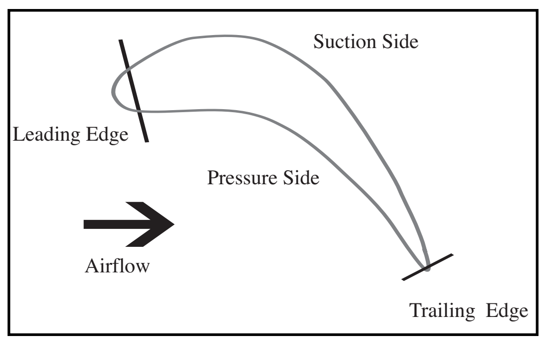

Figure 1: The key vertical faces of a turbine airfoil.

Internal and Coating Geometry

The turbine portion of an engine operates at very high temperatures, often exceeding the melting point of the metal of the airfoils, so some turbine airfoil designs include hollow internal geometry for cooling or a spray-on coating of a thermal-resistant compound (Newman, 2002). The coating can add weight and thickness that affects results of mechanical and aerodynamic analysis, and the internal cooling geometry is often complex, requiring significant time to model. Both could benefit from automation.

After the initial airfoil solid is created, the application's user interface can be reopened and the user can select whether the blade will be solid, hollow, coated, uncoated, or any combination thereof. If a solid or coated blade type is selected, the user is prompted to load a text file, referred to as a wall file, which contains thickness data for the selected operation. As shown in Figure 1, every wall file has offset information for both the coating and cooling geometry grouped by section and face (leading edge, suction side, trailing edge, pressure side). Each section is grouped by face, and each group of face data contains several pairs of numbers; one for the distance the coating or cooling geometry is offset from the original sections, and one that defines where on the face the offset will be located, expressed as a percentage of the face's total length.

To create the coating geometry, the program loops through each section spline of the original solid, and then through each face of each section. For each face, the program loops through the coating data in the wall file and offsets points outward from the original spline based on the thickness data provided; it then stores the offset points in an array. Once all the points are stored, they are looped through, section-by-section, and a new spline is drawn through them. The splines then are used to create a solid that represents the coating.

Creation of the cooling geometry operates on very similar principles, but with some added complexity. The coating offset thickness is by nature uniform, but the offsets for internal geometry are variable to allow for tailoring of the cooling properties as well as the physical strength of the resultant hollow blade. During initial design, a solid would be created from the cooling offset splines to hollow out the airfoil solid, but it was found in testing that modelers could finalize the complex internal geometry faster without the solid or a hollow blade, just using the cooling offset splines as references. The coating splines are visible in green outside the airfoil solid. The blue splines represent the hollow core as shown in Figure 2.

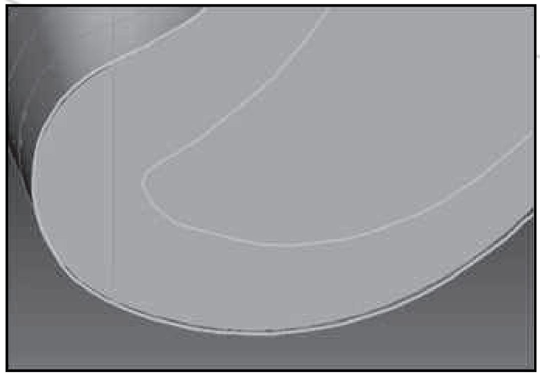

Figure 2: The leading edge of a hollow coated airfoil model done by the KF application. Curves digitally enhanced to aid visibility.

Gas Path Representation

All geometry in a turbine engine will at some level reference the path air takes through the compressors, into the combustion chamber, and out through the turbines. This is referred to as the gas path, and the splines that represent it would essentially be the highest level skeleton model for a completely relationally modeled turbine engine. A tool for generating the gas path inside the turbine model was built into the airfoil generation application. The users may select whether they wish to display the hub annulus, tip annulus, or both through the user interface, and they are then prompted to load a text file. The text file contains a series of simple x,y,z points (typically 100-150) that the program loops through to create a spline.

Benefits

Time Savings

The first and most obvious benefit of automating a process is reduced time for executing that process. Surveys indicated that the typical modeler would take from 5 to 8 hours to create a solid model from Computational Fluid Dynamics (CFD) point cloud data. Using the automated airfoil generation tool, modelers were able to create the same airfoil in a uniform and consistent manner in 4 to 6 minutes. Members of the research team with more familiarity with the application would routinely generate airfoils in two minutes or less. The company estimates use of the KF tool will save approximately three quarters of a million dollars in direct costs alone on a single engine project.

The time savings created by the tool extend farther through the design process than the creation of the initial turbine model. Before the automated airfoil generation tool was put into production use, any change to an airfoil design would encounter a bottleneck in the modeling department. Each modeler works on multiple projects, and multiple parts per project, so a design change would have to be queued into the original modeler's current tasks, which would create a period of up to two weeks between a change in design from engineering and analysis where nothing could be done with the design. The dead time could be reduced by finding a modeler with available time to make a design change, but that modeler would have to waste considerable time deciphering the original modeler's techniques to make the appropriate changes. Even if the original modeler were immediately free to execute design changes, if the change was in the original CFD definition, the airfoil the model would have to be rebuilt virtually from the ground up. Not only would the modeler have to reinvest the 5 to 8 hours required to make the initial airfoil solid, but the additional time necessary to re-model attached geometry dependant on the airfoil, such as internal cooling slots or external features for mounting the blade to a turbine wheel.

By automating the process and making airfoil models the same way every time, any modeler can update the model just as efficiently as the modeler that originally created it. The tool requires no knowledge of CAD to operate, so a modeler would not be required to update the model provided robust relational modeling techniques were used to create cooling and turbine wheel attachment geometry. Using the application, an engineer could run analyses on several different design iterations in a single day without having to utilize a modeler for each design change.

Increased Iterations

Another benefit for reducing process execution time is the ability to run more design iterations in equal or less time for equal or less cost. As stated previously, the airfoil generation application was designed so the KF code would stay embedded with the part file after the application was run, allowing the user to re-run the program at any time, even after more geometry had been added, either by re-selecting the application though the NX menus, or by double-clicking on any of the geometry it creates. When the application is reopened, the user may replace any of the text files that define the automatically created geometry and the application will update all relevant geometry using the new text files. Because the geometry is updated and not deleted and recreated, any geometry added to the model that relationally references the application's geometry will also update.

There is much more than just an airfoil in a final turbine blade model. The initial airfoil model is purposely made longer on both the hub and tip ends to ensure that the part of the airfoil that will be used has contiguous curvature, so both ends must be trimmed. Complex internal cooling geometry is added when necessary, and geometry defining the blade's attachment point to the turbine wheel (often referred to as a "fir tree" because of its uncanny resemblance to a profile view of a Christmas tree) must be added, as well. Since it is not feasible to manually redefine the many thousands of points that define the CFD definition of the airfoil, a modeler would have to start from scratch, creating a new initial airfoil and rebuilding all the aforementioned geometry with each new design iteration created. With the airfoil generation KF application, that time investment is still required for the initial iteration, but subsequent iterations require only that the appropriate text files be changed, reducing the time required for additional iterations from days or weeks to a matter of minutes.

Robust relational solid modeling techniques are key for this process to work in a production context. Any piece of geometry not relationally referencing either the KF application geometry or another piece of geometry that relationally references it will not update with the rest of the model and could take longer to fix that it would have to create it from scratch. Because of geometrically complex nature of turbine blades, the type of relational referencing must be tested for robustness on updating. Several of the company's modelers were tasked with developing a standardized, documented, and robust method of modeling the additional geometry. At their request, a handful of axial and radial splines were added to the application to make fully relational modeling easier. Using the modeling techniques the partner company developed, final, fully modeled turbine blades can be completely controlled by the KF application's text files.

Increased Process Control and Quality

Turbine blades have a high degree of geometrical complexity and require skilled modelers to model them effectively. In the past, once aero engineers finalized the design of their airfoil in a CFD program, they were forced to pass their point cloud file to a modeler to create the CAD file, who would in turn pass the model on to analysts for FEA and so on until production. It was assumed that the CAD model would conform to the aero engineer's design intent, but there was no process in place to establish this empirically. Since the multi-section solid operation that creates the airfoil model uses the point cloud section as a reference, the model would be valid at those points, but the validity of the surfaces between the sections was in question.

The airfoil generation KF application removes virtually all the modeling skill required to create the initial solid. By distributing the application with a simple two-page user guide to aero engineers, the engineers were able to create the initial airfoils themselves. A separate KF application referred to as the Point-Body Comparison tool (PBC) was distributed as well. The PBC accepts a point cloud text file in the same format that the airfoil generation tool uses, then prompts the user to identify the pressure side, suction side, leading edge and trailing edge faces on the airfoil solid. When the application runs, it creates each point, measures the distance between it and the appropriate face, then colors the point based on its distance – ranging from blue, representing little or no difference, to red, representing larger differences. The result is an easy-to-interpret graphical representation of the solid model's conformity to original CFD design intent. By using the airfoil generation tool to create the initial airfoil, then exporting a new point cloud file representing the same airfoil but with sections in different places, now an aero engineer can verify that an airfoil model conforms to the original design intent before it ever leaves their control.

Quality issues surrounding that transfer of data between departments and employees also arose when the company was using an all-manual modeling process. Due to a lack of process documentation and the variety of dissimilar modeling techniques, it was not uncommon for necessary operations such as movements in the coordinate system or flipping of models to be done by one employee, then passed to another employee who would perform the operation again, sometimes resulting in costly errors. The airfoil generation application and the development of the relational modeling techniques that accompanied it not only standardized the modeling process, but also made it much easier for the company to rigidly define the roles of each employee in the design process, always performing each modeling operation at the proper time, always performing each translation and flip at the proper time.

Efficient Analysis Integration

Analysis is just as important to an effective product as the initial model itself, and like modeling, creating a robust mesh for FEA can be just as manually labor-intensive as creating CAD geometry. Just as each CAD modeler tends to employ a unique technique for creating a model, analysts tend to create meshes in their own way, which can lead to small differences in the final output. To both remedy this potential problem and to speed the design cycle, the partner company is interested in developing a method for automated meshing. Its method relies on indentifying four key vertical surfaces and two key horizontal surfaces on the airfoil to be used as references in the meshing operation. The vertical surfaces are the pressure side, suction side, leading edge, and trailing edge. The horizontal surfaces are the hub and tip.

The combination of the airfoil generation application's face tagging plus fast, text-file based design iterations and the company's development of an automated meshing tool makes for an incredibly fast analysis and optimization process. An analyst can sit down with a variety of CFD point clouds or wall file data or both, make a model for each desired combination, mesh and analyze them in batch and interpret the resultant data. The only factor significantly limiting the number of designs they can analyze in a day is the speed of the computer running the FEA program. The company estimates that the combination of the KF application and FEA integration will save approximately $3.7 million in direct costs on a single engine project.

Conclusion

Through thorough testing and evaluation, automated CAD design via built-in scripting tools has proven to be an effective way of reducing design time, increasing the number of feasible design iterations, increasing the quality of processes and the company's control over them, and enhancing integration with other automated processes outside of CAD. The turbine engine manufacturer has deemed the KF application robust and reliable and has recently put it into production on a current engine project.

Such automation also opens the door for further enhancements to the design process. Development of similar applications is possible for most engine components, and could automate most modeling required in an engine project. By using text files to control important engineered data in tandem with robust relational modeling techniques, it would be possible to achieve the company's goal of total gas path design and engine reuse. By total use of relational modeling with the gas path as the highest level reference, an existing engine model could be reused on a new project. The gas path could be changed to alter the overall sizes and airflow, and text files controlling airfoils and combustor geometry could be changed to meet new thrust and efficiency requirements. This, combined with quick iterations and automated analysis time-to-market, has the potential to drastically reduce overall time-to-market.

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Student Reflective Perceptions of High School Educational Cell Phone Technology Usage

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Abstract

High school students are prohibited from using cell phones during the school day within most public schools in the United States; the majority of students, however, maintain possession of a personal cell phone within the high school setting. Most administrators and teachers regard cell phone possession and usage as a negative distraction and deterrent to learning rather than as an educational learning tool. This study investigates college freshman students' reflective perceptions of potential high school utilization of cell phones by students and teachers as educational learning tools. Positive response from surveys suggests there is interest in and potential for educational implementation and use of cell phones as learning tools in schools. Perceptional gender differences were uncovered suggesting further study is necessary before successful implementation can occur.

School policy regarding cell phones, within the majority of public schools in the United States, is generally quite prohibitive and requires students to leave their cell phones at home or turn them off and leave them in their lockers during the school day (Obringer & Coffey, 2007). Other schools report changing policy from banning cell phone use to allowing students to use them before or after school (St. Gerard, 2006). As a result of the rapidly occurring technological advances within the cell phone industry, schools have been hard pressed to make and keep current educational policy regarding the use of cell phones (Obringer & Coffey, 2007).

Students' personal and social cell phone use has been well established, but how do high school students reflect on the usage of such phones in an educational setting? Determining student perception toward using the educational technological capabilities of cell phones within a learning environment is a first step. Knowledge of students' attitudes could possibly lead to, aid in, and influence future decision making regarding the implementation of cell phone use for academic purposes within high school classrooms.

Literature Review

Administrators and teachers often regard the use of cell phones by students at school as a deterrent to student learning (Johnson & Kritsonis, 2007). Administrators often are concerned about inappropriate use of cell phones in schools and this is the major cause of restricting their use (Obringer & Coffey, 2007; St. Gerard, 2006). Cell phones ringing during a class time present unwanted distractions and, for some students, sending or receiving text messages can lead to cheating (Gilroy, 2003). The existing possibility of posting improper photos on the Internet is also a cause for concern (Obringer & Coffey, 2007). For these reasons, students are not allowed to visibly possess cell phones within most high school classrooms. The challenge faced by many administrators is to effectively balance the needs of the school with the demands of the students and the parents.

Parents characteristically agree with school policy and want their children to abide by the rules (Obringer & Coffey, 2007). In contrast, regarding school emergencies or schedule changes, parents have often demanded immediate communication, which cell phones can provide (Johnson & Kritsonis, 2007; Obringer & Coffey, 2007). Parents report safety as the primary reason for supplying their children with cell phones, whereas children place a greater value on the technological capabilities of the cell phone and its potential to facilitate socialization (Johnson & Kritsonis, 2007; Obringer & Coffey, 2007).

According to Prensky (2001a), students of today are referred to as "Digital Natives." They have grown up with technology and multitasking, and they are in the habit of processing information quickly (Prensky, 2001a). Digital Natives want to be involved in active learning as opposed to sitting passively in class (Prensky, 2001a). They thrive on interactive technology, for example, tools like the cell phone (Prensky, 2001b; Prensky, 2005). Instructors may miss an educational opportunity if they do not incorporate cell phone use into their learning process (Prensky, 2005).

Many teachers in a number of foreign countries already use cell phones as a learning tool (Librero, Ramos, Ranga, Trinona, & Lambert, 2007; Prensky, 2005). Often in remote areas connections to the Internet via cell phone are easier to access than connections via computer (Shinn, 2009). In these instances, cell phones are also less expensive to use (Shinn, 2009).

Some teachers in remote areas have been forced to abandon the practice of supplying one laptop per child as a result of increasing costs (Norris & Soloway, 2009). In the United States, administrators and teachers are finding the costs to continually purchase, repair, and upgrade computer technology to be overwhelming; thus, cell phones have become more appealing (Norris & Solway, 2009). As the number of services provided by telecommunication companies increases and cell phone technologies advance, the more likely it becomes that students will have fingertip access to learning opportunities, anywhere, anytime, and at a reasonable price (Houser, Thornton, & Kluge, 2002). Cell phone portability, online access, and device applications could allow and encourage students to enhance learning opportunities and group collaboration (Chen, Chang, & Wang, 2008)

Gender differences in computer technology applications have been studied and documented. According to Willoughby (2008), boys and girls who had access to a variety of computer technologies tended to use them for differing purposes and in differing amounts of time. High school males were reported to spend more time on the Internet and engaged in computer games than time spent by high school females (Willoughby, 2008). The overall amount of time engaged in technology by males could influence their perception and possibly increase their comfort level with technology applications within the school setting. What needs to be determined is whether there is a difference in male and female students' perception of cell phone use in education and if student interest to use cell phones as educational learning tools within the classroom exists. Determining answers to these questions may uncover underlying factors that may need to be considered and addressed before implementing cell phones as learning tools within the high school classroom. Differences in gender perception may necessitate varied forms of pretraining before implementation can take place.

Despite the cell phone's enormous potential, how students view their high school's current cell phone policies, their use of cell phones within the school setting, or their use as an educational learning tool is unknown. Before a school system adopts cell phones as learning tools, student perceptions should be investigated.

Purpose of Study

The purpose of this study was to investigate college freshmen's reflection of high school cell phone usage policies, the perception of cell phones as possible educational learning tools, and the potential perceptual differences by gender. College freshmen's reflective perceptions of cell phones used as learning tools initiated by high school teachers and usage as learning tools initiated by high school students were studied.

Method

Participants

Participants were 166 college students currently enrolled in one of nine sections of a semester-long, face-to-face, introductory university student success course in an upper-Midwestern university. One hundred and sixty-one participants (83 males and 78 females) completed the survey. Five surveys were excluded due to incomplete information. Current academic standing of the 161 respondents was as follows: freshmen (142), sophomores (11), juniors (5), and seniors (3). Because this study investigates the reflective perception of high school cell phone use, only the 142 freshmen (72 males and 70 females) respondents were used for the analysis.

Demographic Information of Freshman Sample

	Freshman $\underline{n}$ = 142 Count	%
Gender		
Male	72	50.7
Female	70	49.3
Age		
20 and under	133	93.7
Over 20	9	6.3
Academic Standing		
Freshman	142	100.0
Cell Phone Possession		
Did have	137	96.5
Did not have	5	3.5

Table 1. Demographic Information of Freshman Sample

Instrument

A twelve-item Institutional Review Board-approved survey containing three constructs was developed. Four survey questions comprised each of the following constructs: perception of fairness of school cell phone policy, perception of teacher initiated educational cell phone applications, and perception of student initiated cell phone educational applications. Responses were based on a six-point Likert-type scale with the neutral response omitted. Respondents selected one of the following responses for each question: strongly disagree: 1; disagree: 2; slightly disagree: 3; slightly agree: 4; agree: 5; strongly agree: 6. Construct one contained four questions regarding recollection of high school cell phone usage policies and the respondent's perception of policy fairness. Construct two contained four questions regarding student perception of teacher-initiated cell phone usage applications as

Table 2. Average Scores for Survey Questions (1=Strongly Disagree, 6=Strongly Agree)

Satisfaction School Policy				
q1.	While attending high school, I was aware of my high school's cell phone policy.	142	5.7	0.9
q2.	I felt my high school's cell phone usage policy was fair.	142	3.7	1.6
q3.	In my high school, I felt I could use my cell phone at any time.	139	2.8	1.6
q4.	I felt the consequences for using my cell phone during high school hours were fair.	141	3.4	1.7
Perception as Teacher Initiated Learning Tool				
q5.	I think cell phones could be used in high school as an educational learning tool.	141	3.7	1.5
q6.	I think cell phones could be used in high school by students to participate in surveys.	142	4.1	1.5
q7.	In my opinion, cell phones could be used in high school by teachers to provide feedback to students.	141	3.7	1.6
q8.	In my opinion, cell phones could be used by students in high school to compete in an educational activity.	141	3.6	1.5
Perception as Student Initiated Learning Tool				
q9.	In my opinion, cell phones could be used in high school by students to obtain peer tutoring.	141	3.9	1.4
q10.	I think that cell phones could be used in high school by students to submit assignments to teachers.	141	3.2	1.6
q11.	In my opinion, cell phones could be used in high school by students to collaborate with other students on class projects.	142	4.6	1.3
q12.	In my opinion, cell phones could be used in high school by students to seek teacher assistance on assignments.	141	3.9	1.6

an educational tool. Construct three contained four questions regarding perception of educational cell phone usage initiated by students to disseminate information between students and teachers or among fellow students. Included on the survey were additional check-list-type items including: grade level, gender, age (20 and under or over 20 years of age), high school cell phone status (have or do not have), and types of high school cell phone application usage.

Cronbach's alpha was used to measure internal consistency of the constructs. The reliabilities of reflective student perceptions of policy, teacher use, and student use were measured at 0.539, 0.873, and 0.827, respectively. For further statistical analysis, a factor analysis was conducted to determine interrelationships among the items of each of the three constructs (perception of policy fairness, perception of teacher initiated use, and perception of student initiated use). The principal axis method was used to extract components, followed by a varimax (orthogonal) rotation. It was determined that question one in the first construct did not relate to fairness of policy and was removed, leaving questions two, three, and four within construct one. Cronbach's alpha of the newly configured construct using questions two, three, and four measured at 0.603.

Procedure

Surveys were administered to a random pool of students enrolled in one of nine sections of an introductory university student success course over a two-day period. Sampling was conducted on a voluntary basis by the course instructor at the end of each class period. Participants were instructed that the survey was voluntary and asked to answer as many of the questions honestly with the option of stopping at any time. Principal investigator contact information was provided for further questions or inquiries regarding the study. The pool comprised a mixture of 166 participants from each of the four classifications of undergraduate academic credits earned by freshman through seniors. An approximate equal number of male and female students were sampled. Data were analyzed using Predicative Analytics Software Statistics 18 (PASW®). An independent-samples t test was conducted. The significance level was set as .05.

Results

Survey completion rate was 97% of the 166 participants surveyed. Because the intent of this survey was to determine the perceptions from recent high school graduates, only participants who categorized themselves as freshman (85.5%), 142 of the 166 total respondents, were included in data analysis. As shown in Table 1, of the 142 freshman survey participants, 50.7%

were male and 49.3% were female. Most of the participants (93.7%) were 20 years of age or younger. 137 participants or 96.5% reported having possession of a cell phone during their high school years.

Individual questions listed within each of the three constructs including the number of respondents, mean, and standard deviations are shown in Table 2. The question with the highest percentage of some form of agreement and the question with the highest percentage of some form of disagreement fell within construct one. Question one, which read, "*I was aware of my high school's cell phone policy,*" reported the highest mean of 5.7. Eleven of twelve questions reported a higher average percentage of some form of agreement than some form of disagreement. The exception was question three, which reported a higher average of some form of disagreement. The mean for question three, "*I felt I could use my cell phone at any time,*" was 2.8.

In addition, the researcher investigated differences in perception between freshman male and freshman female respondents in regard to high school cell phone usage as an educational learning tool. The survey items categorized into each of the three constructs were averaged and further analyzed to compare differences of means between genders by utilizing an independent-samples *t* test.

Construct one, policy, was analyzed by averaging questions two, three, and four. An independent-samples *t* test was calculated comparing the mean score of respondents who reported themselves as male to the mean score of respondents who reported themselves as female. The mean for all participants was 3.31; in addition, the mean for males was 3.27 (sd = 1.406), and the mean for females was 3.35 (sd = 0.999). The mean difference between males and females was 0.08. No significant difference was found, t (140) = -.397, $p > .05$.

Construct two, teacher initiated use, was analyzed by averaging questions five, six, seven, and eight. An independent-samples *t* test was conducted comparing the mean scores of male respondents and female respondents. The mean for all respondents was 3.77; in addition, the mean for males was 4.07 (sd =1.295) and the mean for females was 3.46 (sd = 1.187). The mean difference was 0.30. This was found to be statistically significant, t (140) = 2.901, $p < .05$.

Construct three, student initiated use, was analyzed by averaging questions nine, ten, eleven, and twelve. An independent-samples *t* test was conducted to compare the mean scores of male respondents and female respondents. The mean for all respondents was 3.91; in addition, the mean for males was 4.22 (sd = 1.222) and the mean for females was 3.60 (sd = 1.116). The mean difference was 0.62 and found to be statistically significant, t (140) = 3.129, $p < .05$.

Discussion

This study was conducted to determine students' reflective perception of cell phone policies and possible use as an educational tool within the high school setting. Although the respondents reported a higher percentage of some form of agreement in regards to the majority of items within the policy construct, having been removed from the high school setting for approximately five months and having been exposed to the less restrictive college environment where cell phone usage was more prevalent may have unintentionally influenced their reflections. Current high school student perceptions may not have yielded such favorable results. High school students who were aware of their high school cell phone policies may or may not have viewed them as favorable.

Results uncovered in the investigation to determine gender effect or influence on the students' perception revealed an overall positive reflective perception regarding the usage of cell phone technology in secondary education. Males responded with a statistically higher degree of acceptance toward cell phone use initiated by teachers-to-students in education and by students to collaborate with other students. These findings could indicate that males were more receptive to communicating indirectly through technology rather than directly by face-to-face communication. Igarashi, Takai, & Yoshida (2005) reported that face-to-face communication was more highly valued by females than by males. By implementing the use of cell phones in the classroom, some students may feel a higher level of comfort responding through technology rather than in person. Another possible interpretation of higher acceptance by males relates to gender differences in technology use with males historically overrepresenting occupational fields that involve math, science, and technology (Mammes, 2004). Instructors should be mindful of these possible gendered influences regarding the use of technology in the classroom and recognize that some students may feel more comfortable than other students using cell phone applications and technology. Therefore, instructors may wish to consider the use of this type of technology in the classroom as an option rather than as a requirement.

Although this study has shown significant differences in perception by gender, some limitations do warrant further study. This study has not specifically included the perceptions of actual high school students, post high school students that did not go on to attend college, or individuals of different ethnicities, nor has it shown how culture affects perception of cell phone use as learning tools as studied in the Philippines and Mongolia (Librero, et. al., 2007). This study was limited to only one school, which represented the perceptions of first-year academic standing college freshman students who possessed their own cell phones and did not shed any light on the perceptions of foreign students in foreign countries, where use has been more prevalent and research on technology use in education has been more abundant (Campbell, 2007).

Although students today have grown up surrounded by technology, only during the past decade have schools begun to integrate the use of technology within the curriculum (Kim, Holmes, & Mims, 2005; Prensky, 2001a). The introduction of technology in education at lower grade levels translates to a considerable increase in the number of years a student will have been exposed to technology upon reaching high school. Therefore, it is imperative that research be continued in the area of educational technology and student perception.

Further studies should be conducted that explore the perception of students currently enrolled in high school courses and their perceptions of cell phone usage as teaching and learning tools within the classroom. Research is also needed to analyze school administrator, faculty, and community perception of cell phone use in an educational setting in order to determine whether or not their implementation would be feasible.

Policy regarding cell phone use by students in school will not change unless studies indicate that administrators and faculty also view them as valuable learning tools. With further research, it is possible that cell phone policy can be changed, allowing cell phones to be used within schools by students not only for socialization but also as a valuable learning and resource tool between students and teachers (Kharif, 2008). Cell phones are not going away. Cell phones can be used as a learning tool for knowledge construction if educators teach students how to use them appropriately (Kolb, 2006).

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Student Recollection of High School Cell Phone Usage Survey

Please take a moment to complete the survey below. Participation is voluntary and participants must be age 18 or older. The purpose of this survey is to assess student opinions of cell phone usage in **high school education**. I appreciate your time and willingness to participate.

1. In High School, I used my Cell Phone for:

Check all that apply.
___ Calling
___ Texting
___ Photos
___ Videos
___ Internet access
___ Calculating
___ Calendar
___ Clock
___ Alarm Clock
___ Planner
___ Games
___ Light
___ Other (please explain)

2. High School Cell Phone Status
___ I did have a cell phone
___ I did not have a cell phone

3. Current Academic Standing
___ Freshman
___ Sophomore
___ Junior
___ Senior

4. Gender
___ Male
___ Female

5. Current Age
___ 20 and under
___ Over 20

	Please rate each of the statements below by circling the appropriate option based on the following questions:	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
1.	While attending **high school,** I was aware of my high school's cell phone usage policy.	**1**	**2**	**3**	**4**	**5**	**6**
2.	I felt my **high school's** cell phone usage policy was fair**.**	**1**	**2**	**3**	**4**	**5**	**6**
3.	In my **high school,** I felt I could use my cell phone at any time.	**1**	**2**	**3**	**4**	**5**	**6**
4.	I felt the consequences for using my cell phone during **high school** hours were fair.	**1**	**2**	**3**	**4**	**5**	**6**
5.	I think cell phones could be used in **high school** as an educational learning tool.	**1**	**2**	**3**	**4**	**5**	**6**
6.	I think cell phones could be used in **high school** by students to participate in surveys.	**1**	**2**	**3**	**4**	**5**	**6**
7.	In my opinion, cell phones could be used in **high school** by teachers to provide feedback to students.	**1**	**2**	**3**	**4**	**5**	**6**
8.	In my opinion, cell phones could be used by students in **high school** to compete in an educational activity.	**1**	**2**	**3**	**4**	**5**	**6**
9.	In my opinion, cell phones could be used in **high school** by students to obtain peer tutoring.	**1**	**2**	**3**	**4**	**5**	**6**
10.	I think that cell phones could be used in **high school** by students to submit assignments to teachers.	**1**	**2**	**3**	**4**	**5**	**6**
11.	In my opinion, cell phones could be used in **high school** by students to collaborate with other students on class projects.	**1**	**2**	**3**	**4**	**5**	**6**
12.	In my opinion, cell phones could be used in **high school** by students to seek teacher assistance on assignments.	**1**	**2**	**3**	**4**	**5**	**6**

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The Relationship Between the Time Spent Studying Subject Knowledge and the Attitude of Trainee Teachers to the Subject(s) They Will Teach

Stephanie Atkinson

Abstract

The study emanated out of a mounting concern regarding the lack of subject knowledge of students training to become teachers of Design and Technology (D&T) in England and Wales. The article presents the research carried out to establish whether or not the length of time a student spent studying subject knowledge might have some bearing upon how positive their attitudes and beliefs were about the subject and teaching it. The data were collected from a cohort of 83 D&T Initial Teacher Training (ITT) students from a University in the North East of England using a self-completed attitude measurement scale comprising 22 statements concerning a student's attitude to teaching D&T, their beliefs about the subject, and their perception of their own D&T ability with particular reference to design activity.
The results of the survey were discussed in detail, and conclusions and implications were drawn.

Keywords: subject knowledge, designing, attitudes, trainee teachers

In this article the author considers the relationship between attitude and the time available to study subject knowledge for students who are training to become teachers of Design and Technology (D&T). Literature has indicated a strong link between positive attitudes, motivation and being successful in whatever task is undertaken (e.g. Atkinson, 2009; Sternberg, 2005; Weiner, 1992). This is particularly so in tasks where creativity is an integral part of that activity (Cropley, 2001; Hennessey, 2007; Sawyer, 2006). In D&T taught within schools in the United Kingdom and elsewhere around the world, designing which involves creativity forms a central aspect of the subject. The literature on creativity would suggest that pertinent knowledge is required for creativity to occur (Cropley, 2001; Sternberg, 2005; Urban, 2007) as well as it being crucial for a teacher to be successful (Barlex & Rutland 2003, 2004; Ball, Hill, & Bass 2005; Lewis 1996; Simmons 1993). The lack of substantive knowledge acquisition during the training of D&T teachers in England and Wales has become a concern of researchers and practitioners over the past decade (e.g. Banks & Barlex, 1999; Martin, 2008; Rutland, 1996, 2001; Tufnell, 1997; Zanker, 2005).

Although it is recognized that subject knowledge in the context of D&T can refer to a plethora of skills, knowledge, and understanding, in this study it is the knowledge, skills, and understanding that surround the central and fundamentally important activity of designing, which have been targeted.

Data collected from previous research (Atkinson, 2009) concerning the difficulties D&T students on Initial Teacher Training (ITT) programs had with the activity of designing hinted that the longer students studied D&T the better their attitude became toward D&T in general, the activity of designing, and teaching D&T.

This article presents the research carried out in 2009 to establish whether or not these indications were accurate and if so what the implications could be. In this instance data were collected from a cohort of 83 D&T ITT students from the same University in the North East of England where the previous research had been carried out.

Initial Teacher Training of D&T Teachers

There are eight routes available in the UK for those wishing to achieve Qualified Teacher Status (QTS) that will enable them to teach in state-maintained schools throughout England and Wales (see Table 1).

Referring to these eight routes the Training and Development Agency for Schools (TDA) (2010) for England and Wales explained that the "…training comes in all shapes and sizes, providing options to suit everyone – no matter what the qualifications, experience, preferences or personal circumstances are." There are six employment-based or training-based routes that enable trainees to qualify while working in a school and there are routes offered by a number of Universities that after rigorous and frequent inspection by the government are allowed to provide programs of ITT. These programs either combine training to become a teacher while completing an undergraduate (UG) degree of two or three years duration, or, for those who already possess a degree, there are postgraduate (PG) programs of ITT that last for one or two years. The research presented in this article concerned University based ITT and not employment-based ITT.

Table 1. The Eight Routes Available in the UK for Those Wishing to Achieve Qualified Teacher Status

Route		Explanation
University based	Postgraduate Certificate in Education (PGCE)	One-year Program for Graduates
	Undergraduate BA/BSc (Honors) with QTS or Bachelor of Education degree	Students study for a degree and complete ITT at the same time
School-based	School Centered Initial Teacher Training (SCITT)	Graduates train in a school environment
	The Graduate Teacher Program (GTP)	Graduates achieve QTS while teacher training and working in a paid teaching role
	Teach First	Graduates train to be effective teachers in challenging schools
	Registered Teacher program (RTP)	Employed by a school, earn a salary complete a degree and work towards QTS all at the same time
	Assessment-based training	Candidates with substantial school experience may be able to qualify with minimum teacher training
	Overseas Trained Teacher Training Program (OTTP)	Program for teachers qualified outside the European Economic Area

Reason for the Study

In the UK a recent report into teacher training for the Department for Children Schools and Families (CSFC, 2010) suggested that the government should withdraw its financial support for UG Secondary ITT programs. The reason given was that PG ITT programs provided a better quality of teacher. If this report were to be accepted then all UG D&T ITT programs would cease to exist, as such programs would become unviable without government financial support. This would mean that D&T teachers would be trained by either employment-based routes or within a University environment using the One-Year PG route only, which provides little time for students to develop any further subject knowledge upon which to base their Pedagogical Content Knowledge (PCK) (Shulman, 1986; 1987) and subject constructs (Banks et al., 2004) that are essential if they are to become successful D&T teachers. This possibility is therefore of great concern to all those who wish to provide the best possible D&T teachers to meet the educational needs of school pupils in the future.

It was therefore decided to carry out a small-scale study looking at the attitude and beliefs of 83 D&T students at the University in the North East of England where Three- and Two-Year UG and One- and Two-Year PG ITT programs were all being studied. It was believed that the data from this project could add to the picture gained from earlier research (Atkinson, 2009) by indicating which program provided the students with the most positive attitude and beliefs about the subject they were training to teach.

A Review of the Literature

Attitudes and Beliefs

As explained in the introduction attitudes and beliefs have a bearing upon being successful in achieving a goal. In this article that goal is for each student to become a successful teacher of D&T. Galletta & Lederer (1989) suggested that attitudes provide people with a framework within which to interpret the world and integrate experiences, whilst the aim of attitude measurement has been shown to derive indices of socially significant behavior (Lemon, 1973) or as Ajzen & Fishbein (1977) suggested, that by understanding an individual's attitude towards something, one could predict an individual's overall pattern of responses to a situation.

Fishbein & Ajzen's (1975) definition of attitude as a ". . . learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object" (p. 10) is an accepted definition although different researchers would tend to place different emphases, or have different understandings concerning each element of that definition. In 1993 Robson agreed suggesting that ". . . the term 'attitude' is somewhat slippery" (p. 256) leading to a lack of response consistency in attitude tests, partially because of the plethora of interpretations of the definition and partially because it is not easy to assess something like attitude by means of a single question or statement. To help rectify this problem the attitude scale devised for this study using a Likert-type scale included several items targeting the same attitude from different angles in an attempt to provide triangulation and allow a much fuller picture of the attitude under question to be built-up. The researcher was aware that problems could arise in statement selection in terms of demonstrating that the different items were related to the same attitude and determining that the method used to pull together the responses in terms of the numbers assigned to particular answers were justified, while being aware that combining statements relating to several dimensions on the one scale may well reflect the underlying structure of the attitude, but could make it difficult to interpret cumulative scores.

However, given all these pitfalls, Robson (1993) explained that a well-designed Likert-type scale could be quick, and easy for respondents to complete and that respondents were more likely to co-operate and provide considered replies than when using other forms of questionnaire that could be seen as boring.

The Importance of D&T Teachers Understanding the Process of Designing

Archer and Roberts suggested in 1992 that:The design act is one of discovering and elaborating and adapting requirements and provisions to match one another. The problem is obscurity about what the requirements might be, ignorance as to what sorts of provisions might be suitable and uncertainty as to how well the one might fit the other. (pp. 3-4)

In 2004, Miliband (then a junior Minister in the government's Department of Education and Skills) wrote that "designing is the combination of, and movement between, thought and action and an aspect of D&T that helps to make it distinctive in the curriculum" (p. 4). That statement continues to provide a sound educational reason for designing being part of every child's education, while within the D&T curriculum itself designing continues to play a vital role. Without it, the subject, as we know it in England and Wales today could not exist. Unfortunately, taught poorly it has been shown to taint the view that many pupils have of the subject (Atkinson, 2000) and regrettably there has been considerable evidence from the Office for Standards in Education (OFSTED) (1998, 2000) and others (e.g., Toft, 2007) who suggested that too often designing in schools has not been taught as well as it could be.

One of the aims of D&T teachers should be to develop a pupils' understanding of how to design effectively and efficiently so that they can make functionally appropriate, creative, and innovative products that are fit for purpose. Through various appropriate forms of design activity pupils can learn to appreciate the relevance of designing as a significant part of their D&T curriculum, not the unpalatable means to an end, which it is perceived to be by many pupils today (Atkinson, 2000). The "end" being referred to here is the activity of "making," which is understandably enjoyed by the majority of pupils. In terms of manufacturing a well-crafted product "measure twice and cut once," says it all. Sadly, the complexity of designing is such that it cannot be summarized in as simple a maxim. It is this complexity that has caused various educators over the past 50 years to produce simplified models of the activity for teachers and their pupils to follow.

Pupils should be able to enjoy designing as much as making, and some of them do, although quite often the reason for their enjoyment is nothing to do with the process of designing itself and more to do with an enjoyment of the individual skills that they use during that process (Atkinson, 1994). Pupils need to believe that although it can be a challenging learning experience, it can, if carried out successfully, lead them into making their design into a product that they will be proud to own. Although teachers need to be aware that badly designed products however well made, and whatever new skills have been learnt along the way, will be a disappointment. Such outcomes are frustrating to those pupils who were born with, or who have developed tacit design intelligence that enables them to understand what is or is not well designed. Unfortunately these very pupils are the ones who easily become bored by the simple step-by-step models that they are often expected to follow. Frequently, these are the pupils who become disenchanted with the entire subject. However, at the opposite end of the spectrum are many D&T pupils who need a structure to follow. They require considerable help in order to understand what they must do, how they must do it, and what they should be thinking about in order to achieve the level of "designerly" thinking that should be inherent in the activity.

Designing can be divided into two main sets of knowledge and understanding. It is essential that both sets are explained, thought about, and taught if teachers are to provide the necessary support and learning required by pupils when they are carrying out the activity. There is a set of easily taught physical skills and there is a set of difficult, intangible concepts that include intellectual thinking skills. The first set incorporates areas of learning such as drawing skills, presentation skills, CAD and CAM skills, researching skills, specification writing skills, 3D modeling skills, and tasks to encourage creativity. This set also embraces a plethora of practical skills concerning appropriate materials, components, and processes that need to be understood well enough to be used when turning ideas into reality. These are all straightforward to teach, but very time- consuming. It is the second set, the intangible designerly thinking aspects of the activity that are difficult for teachers to provide a simple and yet not constrictive set of explanatory guidelines for pupils to understand.

Acquiring new conceptual tools consists of putting a complex series of individual ideas, or unconnected pieces of knowledge together to make sense of them as an integrated whole (Antonio, 2009). The point at which the pieces come together as a whole is the point at which our minds have grasped hold of a new conceptual tool (Polanyi, 1958), and it is these conceptual tools which the author believes are the crux of the problem for pupils in schools and for some of their teachers. Especially as many teachers seem to be unaware that such skills have to be developed slowly over time rather than being taught just once, or worse still not at all, when it is believed that they are skills that everyone possesses and therefore do not need to be taught.

Designing has been considered problematic within D&T in the UK by educational researchers since its incorporation into the school curriculum in the early 1980s (Secondary Examinations Council [SEC], 1986). The process itself, the procedural knowledge required, the practical skills, the thinking skills, the creative skills and an understanding of the complex relationship among them, have provided the author and other researchers with aspects requiring in-depth study (e.g., Baynes, 2009; Kimbell & Stables, 2007; Nicholl, McLellan, & Kotob, 2009; Norman, 2008; Toft, 2007; Spendlove & Rutland, 2007; Welsh, 2007). As early as 1986 the SEC indicated concern about the rigid design process model that was being used in school design activity, while in the early 1990s Archer and Roberts (1992) and many others (e.g., Atkinson, 1993; 1994; Kimbell, Stables, Wheeler, Wonsiak, & Kelly1991) referred to the use of rule-based models that failed to help pupils solve design tasks with briefs that appeared simple but were in fact often ill-defined and complex. Part of the problem has been that all the models produced over the years have been of necessity a simplification of the real process. A simplification that is useful as a set of reminders of what might be involved (SEC, 1986) but unhelpful in explaining the complex, interactive nature of the activity. Hennessey and McCormack (2002) provided a pertinent insight into what they called "a veneer of accomplishment" (p. 119) in which pupils appear to use a process (and hence have apparently learned it) but in fact may not have understood it. By comparison, teachers and pupils have tended to find the knowledge and physical skills required to support design activity straightforward to teach and/or learn, although the sheer volume of knowledge and skills required and whether this should be learned before or on a need-to-know basis has attracted much attention and debate.

For the past ten years OFSTED reports (1998; 2000) have identified that designing skills lag behind making skills. The author's own research (Atkinson, 1997) and that of Barlex and Rutland in 2003 and 2004 have all suggested that this has consistently been the case since the introduction of D&T into England's National Curriculum. This would appear to be due to a combination of factors. First, there are difficulties in teaching pupils the necessary conceptual tools, and yet there is the need to do so as many pupils without tacit design intelligence are unable to develop an understanding of these tools. Second, designing was not part of a craft teachers' training at the time designing was introduced into the curriculum. This has had a "knock-on" effect over the past 20 years because of the cyclical movement of knowledge from teacher to pupils who then become teachers and lecturers training the next generation of teachers to design. This has inevitably resulted in many teachers in schools today still not displaying a deep understanding of the activity within their teaching. While many would suggest this is caused by a lack of teachers with the necessary required physical skills, others would lay the blame at the door of GCSE and A level [1] examination boards, citing imposed assessment regimes as the cause of the problem. However, the author would suggest that although this may be the case for some teachers, for many others the problems arise more from the lack of a secure understanding of designing and the feeling of security that the examination board models of assessment provide for them. For one can find examples from schools of excellent practice where examination work has not been strait-jacketed by the process undertaken, and where design activity has achieved top grades plus the "wow" factor that well-designed outcomes deserve.

Unfortunately, in recent years this is far from the norm. Evidence from visits to schools, from work as an external examiner at a number of different universities, and from applicants who wish to study at the author's own university having completed their school examinations in D&T, would suggest that many pupils are still not encouraged, even at A level to understand the complexities inherent in the activity or how they can design creatively within an examination structure. Unfortunately, the model of the activity that is used is all too often just a repeat of the simple model used earlier in their education – re-enforced by their Grade A at GCSE level leading them and their teachers to believe that pupils must have been taught to design correctly to achieve such a good grade, so a repeat of the same is all that is required at A level. Sadly their beliefs are often supported by "good" A level grades too. Once at University these students expect that the "successful" design process used in school will continue to serve its purpose; however, many of them find that they have to spend valuable time struggling to come to terms with their misconceptions and poor design practice. The more mature UG students who come to train as teachers of D&T do not necessarily have A Level D&T qualifications but have experience and qualifications appropriate to an industrial setting. These students also tend to have either limited or no design skills having been in the school system at a time when they either used the tightly structured simple design model already described or attended school before design activity was carried out at all. Many of them have then spent time in an industrial setting building up practical expertise pertinent to a narrow aspect of D&T with little attention given to developing their understanding of designing as that has often not been a requirement of their occupation.

There are of course students studying to become D&T teachers whose designing activity is excellent and whose skills are such that they will be able to transfer that knowledge into an appropriate form for use in the classroom when they become teachers. However the author does not believe that the D&T community can be complacent about the group of students that do not fit into this category, either for the sake of the pupils they will teach in the future or the prospect for our subject in the years to come.

Six small-scale research projects carried out by the author (Atkinson, 2003, 2005, 2007, 2008, 2009) over the past 10 years have identified that there is a growing number of students training to become teachers for whom the activity of designing is problematic. The analysis of the data collected has indicated factors that could be causing these problems. For instance, students on D&T programs at the university under question are now drawn from all four material specialisms that form the D&T curriculum found in state-maintained schools in England; that being Materials Technology (MT) (wood, metals, and plastics), Electronic Communications Technology (ECT), Textile Technology (TT), and Food Technology (FT). This breadth of applicants' subject knowledge means there is significant variation in their understanding of designing. In addition students who come to the university straight after completing A level examinations, are arriving with weaker D&T knowledge than they had in the past.

Time Spent Studying Subject Knowledge

Out of these earlier studies a third factor has emerged. Students are now studying subject knowledge during their degree programs for less time. Until the early 2000s D&T teachers were mainly trained on a Four-Year UG program. On such programs they studied subject knowledge that was equivalent to three years of the total program study time and learned how to teach for the equivalent of one year, both sets of skills interwoven throughout the four years. This schedule meant that these students carried out at least nine minor design projects during the first three years of their degree program followed by a major design project that lasted throughout their final year. This timetable provided plenty of opportunity to revisit misconceptions and misunderstandings about designing that enabled the students to develop conceptual tools and the procedural and physical skills required to carry out the processes. They also developed the ability to teach these skills during school placements, while developing understanding of the process, which helped them to refine both

Due to pressure from the government and competition between ITT institutions, Four-Year programs were re-designed to last for only three years. At the university in this study this was achieved by reducing the three D&T material specialisms (MT, ECT and TT) studied by all students in the Four-Year program to the government's minimum requirement (Design and Technology Association DATA, 2003) that students in ITT programs must study any two out of the four possibilities (MT, ECT, TT and FT).

At the same time in line with other ITT institutions, school placements and all knowledge, skills, and understanding concerned with learning how to teach were placed in the final "professional year" of all ITT programs, meaning that subject knowledge on Three-Year programs was undertaken only in the first two years of that program. Unfortunately, this has meant that students only have time to complete two minor and two major design projects meaning that there is not enough time to re-visit misconceptions and misunderstandings about the design process to the same extent as in the past. Nor, as mentioned previously, are students able to develop their understanding of how to teach pupils to design in parallel to the development of their personal understanding of that process.

In an even worse position are UG students in a shortened Two-Year program. These students will have already studied some aspect of D&T during a Two-Year Higher National Diploma (HND) course aimed at industry. These courses will not necessarily have included appropriate design activity and will have targeted one rather than two D&T material specialisms. In only one year these students must acquire enough physical and conceptual skills to address the D&T core and their two chosen material specialisms to degree level, for as already mentioned their second year is the professional year, which is devoted to learning how to teach. During the subject studies year these students can only complete one minor design project and one major design project, providing virtually no time for visiting misconceptions and misunderstandings.

In terms of PG provision, there are One-Year and Two-Year programs. Those in the Two-Year PG program will have studied at least one aspect of the D&T curriculum to degree level; however, that degree will not have covered a second specialism or in some cases aspects of the common core. These students like the Two-Year UG students will study one year of subject knowledge followed by the professional year, although they do have the advantage of having studied certain aspects to degree level rather than only to HND level. Finally there are One-Year PG students. These students have already successfully studied to degree level some aspect of D&T, although this will have been targeted at an industrial context and not aimed at developing the understanding of the subject required for teaching pupils in schools. These students devote the whole of their year at University to learning how to teach. There is no time for them to complete any design projects at all in order to develop their personal understanding of the process, even though like HND students, their first qualification may not have required them to design in a manner that is akin to the activity carried out in school D&T. Any limited subject knowledge time during the professional year is devoted to converting subject knowledge into school knowledge (Banks et al., 2004) referred to as Pedagogical Content Knowledge (PCK) by Shulman (1986, 1987) and others.

Observation of students training to become D&T teachers over many years has led the author to believe that students are unable to determine their PCK, how they will teach designing, unless they have a secure understanding of the activity of designing beyond that of the simple models many of them used in the past. Also, for these trainee teachers the development of their subject constructs using unsound content knowledge can lead to the next generation of pupils with unsound designing skills themselves and cyclically lead to the next generation of D&T teachers with misconceptions apropos the activity.

It was therefore decided to carry out a small-scale study looking at the attitude and beliefs of 83 D&T students at the University in the North East of England where Three- and Two-Year UG and One- and Two-Year PG ITT programs were all being studied. It was believed that the data from this project could add to the picture gained from earlier research (Atkinson, 2009) by indicating which program provided the students with the most positive attitude and beliefs about the subject they were training to teach.

Methodology

Measuring Instrument

A self-completed attitude measurement scale with 22 statements concerning beliefs and attitudes regarding D&T was developed through an analysis of existing attitude scales and the methodology surrounding them. The statements themselves were developed by a focus group of specialist D&T lecturers from the university involved in the study. The scale was then trialed using a small cohort of D&T students not involved in this study. Interviews with a selection of the sample after completing the scale led to changes in the wording of three statements—due to mixed understanding of the precise meaning of those statements.

Contextual data concerning the program being studied, how many years of study had been completed; and each student's major specialism was collected at the start of the questionnaire using a tick box system alongside a list of appropriate possibilities. This was followed by the 22 statements concerning a student's attitude to teaching D&T (5 statements), their beliefs about the subject (10 statements) and their perception of their own D&T ability with particular reference to design activity (7 statements) (see Appendix for a list of the 22 statements). These were placed in a mixed order. Dispersed at irregular intervals throughout the scale were 5 statements that were negatively scored. It was expected that a student with a positive attitude would disagree with these particular statements and therefore a high score for disagreeing with the statement was fitting. Students were asked to pick what they believed was the most appropriate response to each statement using a four-point Likert-type scale (strongly agree, agree, disagree, and strongly disagree).

There was an additional column that could be ticked at the right hand side of the table, for those who held no opinion on an individual statement. There is evidence (Robson, 1993) to suggest that if no option is given for those with no opinion, that a substantial number of people will manufacture an opinion, which could then provide inaccurate data. In this study the use of this column was highly insignificant at 1.2% (variance 1569992.000, df 1, chi-square 1569992.000 p-value <0.0001) compared to the 20% usage of a "no opinion" option generally expected when using Likert-type scales (Robson, 1993).

The Analysis of Each Statement to Check for Its Discriminative Power

In order to test the ability of the statements in the attitude scale to discriminate between a positive and negative attitude, each item (i.e., statement) in the scale was subjected to a measurement of its discriminative power (DP). That being its ability to discriminate between the responses of the upper quartile (25%) of respondents and the responses of the lower quartile using the overall mean attitude score for each member of the sample to establish a rank order.

Items with the highest DP indices were then chosen for the final scale. Five statements were not used because of their low DP values, meaning that 17 out of the 22 statements were retained when scoring overall beliefs and attitudes, although the data concerning these five statements were kept for analyses of individual statements when it was pertinent to do so.

Sample

The sample was made up of 83 students from seven program cohorts studying on the four D&T Education programs taught at the author's university. In terms of PG D&T students there were 30 One-Year students; 17 Year 1 students from the Two-Year PG and nine Year 2 students from the same program. In terms of the two UG programs, the cohorts from the Three-Year and Two-Year programs were amalgamated, as the two cohorts on the Two-Year UG program were so small (two students in each year). This provided an UG sample of 18

Year 1 UG students and nine Year 2 UG students. There were no Year 3 UG students as the program had only been running for two years.

In terms of the specialism choices of the sample, there were 30 whose major specialism was MT, three whose major specialism was ECT, 32 whose major specialism was TT and 18 whose major specialism was FT. As can be seen, students were unevenly distributed among the material specialisms, with nearly double the number of Material Technologists and Textile Technologists compared to Food Technologists. Because there were only three students studying ECT it was not viable to keep them as a separate group, and they were added to the MT cohort to form a single group of students studying what traditionally used to be the only specialism studied prior to 1994, that being the combined subjects of MT and ECT.

Data Collection

In terms of data collection, all students were given the single-sided attitude measurement scale to complete during a taught session toward the end of the Autumn Term 2009. This supported the high return rate of 98%. Only one Year 1 student from the Two-Year PG program and one Year 1 student from the Three-Year UG program were absent and therefore unable to take part in the study. After explaining to each cohort what the purpose of the research was and providing them with an assurance that individuals would not be identified from the information given, each member of each cohort completed the scale without discussing it with peers. It took between five and eight minutes to complete. Methods of coding had already been established when the attitude scale was designed enabling the researcher to score and analyze the data using the software package StatView

Results and Discussion

The mean score for the total sample in terms of attitudes and beliefs was 3.1 (the maximum possible score being 4 and the minimum possible score being 1). This result indicated that overall the students had an above average positive attitude. When the mean scores for each member of the total sample were scrutinized the highest score was 3.6 and the lowest score was 2.7. Therefore, even the least positive student achieved an attitude score above the mathematical mean—that being 2.5.

The Five Statements Gaining the Most Positive Mean Scores

Out of the five statements that gained the highest mean scores the two most positive statements were as predicted. One would expect potential teachers of D&T to be passionate about D&T education (mean score (*ms*) = 3.7) and also one would expect them to be looking forward to teaching the subject (*ms* = 3.7). It was also gratifying to see that being a creative person (*ms* = 3.5) and believing that pupils could be creative within D&T (*ms* = 3.5) both ranked highly in the students' beliefs. It was also heartening to see that students thought that it was important to invest time in teaching pupils to design (*ms* = 3.5), as this is something that OFSTED and many others have referred to as being problematic in schools today and is something that is discussed with all students during their training.

The Five Statements Gaining the Least Positive Mean Scores

In terms of the five statements with the least positive scores, although as already pointed out, these were all above the mathematical mean; it was disappointing to see the low score for the statement: Knowledge skills and understanding are better understood and remembered if they are acquired on a needs to know basis whilst designing and making (*ms* = 2.8) as the modules that the students study have been designed by academics in the belief that knowledge skills and understanding placed in a context rather than taught in isolation is a sound teaching/learning strategy and one that is often discussed with students.

In one of the statements that was scored negatively it was disappointing to find that there was a low score for Designing to meet assessment criteria is more important than designing to achieve a creative solution (*ms* = 2.8) as creativity and the lack of it in D&T in schools has been discussed at great length by OFSTED and educational researchers during recent years and the fact that well-designed creative outcomes can easily meet assessment criteria is often discussed with students during subject studies modules. Students with a true understanding of designing should have strongly disagreed with this statement and as it was negatively scored it had been expected that this statement would achieve a much higher mean score. It was especially disappointing as so many of the students had indicated that they were creative and believed that one could teach pupils to be creative. Nor did their indicated belief that it was possible to teach pupils to be creative marry with their lack of belief in the statement that pupils could be taught to design successfully (*ms* = 3.0).

In terms of finding it easy to design (*ms* = 2.9) the low mean score was disappointing, although it might help to explain why so many of the sample do not believe that pupils can be taught to design successfully if they themselves found it difficult.

Beliefs and Attitude Scores Split by Program

Once the attitude and beliefs data were split into the separate program cohorts the results supported the indications reported in earlier research (Atkinson, 2009) in that the length of study of D&T subject knowledge did appear to have a bearing upon how positive students' beliefs and attitudes were (see Table 2).

Table 2. The Mean Attitude Scores Split by Program with an Indication of Years Studying D&T

Program	Mean Score	Rank Order	Yrs studying D&T
Two-Year PG – Year 2	3.31	1	5
Two-Year PG – Year 1	3.19	2	4
UG – Year 2	3.16	3	2
One-Year PG	3.12	4	4
UG – Year 1	2.92	5	1

The data indicated that Two-Year PG students who had studied D&T for a total of five years (four years subject knowledge made up of three years on their UG degree and the first year of their Two-Year PG, followed by one year of learning how to teach) had the most positive attitude (*ms* = 3.31). First-year UG students, who had only studied D&T in Higher Education for one half of a year, had the least positive score (*ms* = 2.92). Students in Year 1 of their Two-Year PG program who had studied D&T for a total of four years had a mean score of 3.19, while second-year UG students had a mean score of 3.16. If the One-Year PG students were removed from the analysis it was evident that the longer students studied D&T the more positive they became. If the PG students were kept in the equation the analysis was not as clear-cut. They bucked the trend, for they were the second least positive cohort in terms of attitude and beliefs (*ms* = 3.12) and yet on completion of their program, these students would have studied for a total of four years in HE, one more year than any UG student.

In trying to tease out possible reasons for this result the differences in terms of the length of time students spent studying subject knowledge pertinent to teaching on a degree program specifically targeted at ITT and the time students spent studying subject knowledge for an industrial context on degree programs which were not designed to train students to become teachers was scrutinized. Analysis of this data suggested that the time spent studying subject knowledge pertinent to teaching D&T could be the factor that made the difference, for as already discussed One-Year PG students did not have the opportunity to study subject knowledge pertinent to teaching during any of their four years of university study.

However it was felt that the specialism of the students might have influenced the results, for as mentioned earlier there was an uneven distribution of students following the different material specialisms within each cohort (see Table 3).

Table 3. Percentage of Each Cohort Studying MT/ECT, TT and FT

Program	RO in terms of Attitude	%MT/ECT	%TT	%FT
Two-Year PG – Year 2	1	11	56	33
Two-Year PG – Year 1	2	41	47	12
UG – Year 2	3	33	22	45
One-Year PG	4	50	40	10
UG – Year 1	5	39	28	33

Beliefs and Attitudes Split by Specialism

The Beliefs and Attitude Data for the total sample indicated that there was indeed a difference in the attitude of those studying different material specialisms (see Table 4). Textile Technologists were the most positive (*ms* = 3.23). Food Technologists were the least positive (*ms* = 3.01), closely followed by Material Technologists (*ms* = 3.06).

When the relationship between specialism data and program data were combined the data continued to indicate differences that might affect the interpretation of the results. As can be seen from Table 3, 56% of the most positive

Table 4. The Overall Mean Scores of Textile Technologists, Material & ECT Technologists, and Food Technologists

Specialism	Mean Score	Rank Order
Textile Technology	3.23	1
Material Technology & ECT	3.06	2
Food Technology	3.01	3

Two-Year PG students were Textile Technologists (see Table 3). A conclusion from this finding could be that because there were fewer Textile Technologists with a positive attitude in the One-Year PG cohort that this could be the reason why they were less positive than Year 2 of the Two-Year PG program.

However when looking at the data for the least positive specialism in terms of attitude—Food Technology, it was found that only 10% of One-Year PG students were Food Technologists in comparison to 33% of Two-Year PG Year 2 (see Table 3). This data analysis would suggest that Year 2 of the Two-Year PG should be the least positive because such a large proportion of their cohort were Food Technologists, and yet as already discussed this was not the case (see Table 2).

Therefore to try to tease this out further a final analysis of the mean scores for each specialism split by the five program cohorts in the study were scrutinized and the rank order was calculated.

From these data (see Table 5) it can be seen that no matter which specialism was targeted Year 2 students from the Two-year PG were the most positive and One-Year PG students varied between third and fifth in the rankings.

Conclusion

In conclusion, it would seem that there is support for believing that in the context of the students within this small study, that in terms of attitude and beliefs about D&T those students in the UG ITT degree and the Two-Year PG programs benefitted from being taught subject knowledge that not only targeted personal knowledge and skill acquisition, but also set out to develop an understanding of the underlying processes that were pertinent to being able to teach those processes to pupils in school. It is therefore a concern that governmental pressure may close these very programs because it believes that a graduate with a degree targeted at industrial employment plus a one year ITT program will provide a better teacher than students trained on UG programs. This belief was not supported by the data collected in this research project.

Table 5. Mean Scores Split by Program and Specialism

Program	Overall RO	TT	RO	MT	RO	FT	RO
Two-Year PG – Year 2	1	3.33	1	3.25	1	3.30	1
Two-Year PG – Year 1	2	3.21	3	3.14	2	3.00	3
UG – Year 2	3	3.26	2	2.99	4	3.23	2
One-Year PG	4	3.19	4	3.08	3	2.82	5
UG – Year 1	5	2.97	5	2.98	5	2.99	3

The data also indicated that Textile Technology students had the most positive attitude and beliefs about the subject, and that their perceptions of their own D&T ability, with particular reference to design activity, was strongest. This would therefore suggest that more rigorous support mechanisms need to be put in place during subject knowledge inputs to help Material Technology, ECT, and Food Technology students to develop more positive attitudes and perceptions regarding their own ability, particularly in the field of designing, which is as stated at the start of this article, central and fundamental to D&T activity within schools in the United Kingdom.

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[1] GCSE is the General Certificate of Secondary Education that is taken by pupils at the end of compulsory education (Age 16). A Level is the Advanced GCSE which is taken two years later by those who continue to study in order to gain a qualification that will enable them to apply for a place at University

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Appendix

List of the statements used in the Beliefs and Attitude Scale

1 One must be a good designer to be a good teacher of D&T

2 I understand how to design in the context of D&T

3 Knowledge, skills & understanding of materials & processes must come before one is expected to design

4 I am passionate about D&T education

5 A well designed creative solution will achieve a high mark when assessed

6 One does not need to teach a pupil how to design as it is a skill that everyone has

7 I find it easy to design

8 Designing is a key feature of successful D&T education

9 I am a creative person

10 I am passionate about wanting to teach D&T

11 Knowledge, skills & understanding of materials & processes are better understood and remembered if they are acquired on a needs to know basis whilst designing and making

12 I think I am good at designing

13 I am more passionate about making things than designing things

14 The process of designing needs to be taught

15 All pupils can be creative in D&T

16 I understand enough about the processes involved in designing to help others to design

17 I am passionate about ‘designing’ as an activity in D&T education

18 I believe it is important to invest time in teaching pupils how to design

19 Designing isn’t something I need to think about, I just do it

20 Teachers need to understand the activity of designing to be successful D&T teachers

21 Designing to meet assessment criteria is more important than designing to achieve a creative solution

22 Everyone can design successfully if taught to do so

A Focus on Technological Literacy in Higher Education

John M. Ritz

Abstract

Technological literacy continues to be an important construct for learners in all societies.Quite often it is a knowledge area not required of university students unless they are engineering or technology majors. If the mission of design and technology education is literacy for all, this same mission should apply at the university level. An analysis was made of 256 students to determine their attitudes of knowledge gained from a general studies technological literacy course. The course was offered at the 100 level and was designed to expose students to various technologies so they would have a better foundation for selecting a major. It was found that this was the first time that 64% of the students studied technology. It also was noted that students gained improved understandings of the effects of technology, a working knowledge of technology, and technology and careers.

Literacy is an important term when one judges the capabilities of people. Connotations of the term literacy reflect on citizens' abilities to read, write, and use basic mathematics. Countries, where average adult literacy rates are low, often are referred to as developing countries. The levels of literacy are not equal around the globe. Often literacy is associated with a country's ability to graduate its youth from high school. These rates are important considerations when one applies for a position at a company in the developing and developed world (e.g., high school graduate, college graduate, graduate with a master's degree). In the U.S. Workforce Investment Act of 1998, literacy is defined as "an individual's ability to read, write, speak in English, compute and solve problems at levels of proficiency necessary to function on the job, in the family of the individual and in society" (p. 131).

Demographics on worldwide education can be used to compare the education rates of different countries. According to Huebler (2008),

> The unweighted mean of the adult literacy rate is 81.2 percent. In 71 countries – including most of Eastern Europe, East and Southeast Asia, and Latin America – 90 percent or more of the adult population can read and write. The highest adult literacy rate, 99.8 percent, is reported for Cuba, Estonia and Latvia. Most countries without data are in the group of industrialized countries, where literacy rates are also likely to be above 90 percent. In 23 countries, the adult literacy rate is between 80 and 90 percent. (para. 2)
>
> At the other extreme are eight countries with literacy rates below 40 percent: Mali (23.3), Chad (25.7), Afghanistan (28.0), Burkina Faso (28.7), Guinea (29.5), Niger (30.4), Ethiopia (35.9), and Sierra Leone (38.1). Another 16 countries have literacy rates between 40 and 60 percent: Benin (40.5), Senegal (42.6), Mozambique (44.4), Central African Republic (48.6), Cote d'Ivoire (48.7), Togo (53.2), Bangladesh (53.5), Pakistan (54.9), Liberia (55.5), Morocco (55.6), Bhutan (55.6), Mauritania (55.8), Nepal (56.5), Papua New Guinea (57.8), Yemen (58.9), and Burundi (59.3). Almost all of these countries are in Sub-Saharan Africa and South Asia. (para. 3)
>
> Finally, the world's two largest countries in terms of population have very different literacy rates. In China, the adult literacy rate is 93.3 percent. In India, only 66 percent of the adult population can read and write. (para. 4)

A useful demographic data source for analyzing adult literacy rates is NationMaster (2009), a massive central data source and a handy way to graphically compare nations. This tool is a vast compilation of data from such sources as the CIA World Factbook, United Nations (UN), and Organisation for Economic Co-operation and Development (OECD). This source lists the top 100 nations in the world by the average years of schooling completed by its youth. The top five countries cited include the United States, Norway, New Zealand, Canada, and Sweden.

The bottom five countries among the 100 noted for years of schooling includes the following: Guinea-Bissau, Mali, Niger, Mozambique, and Afghanistan.

Also, NationMaster (2009) lists the mathematical literacy found in countries; the top five were Japan, South Korea, New Zealand, Finland, and Australia. They include grade 12 advanced science students such as those in Norway, Sweden, Denmark, Slovenia, and Germany.

Why are these figures important? Governments from around the world are now taking a strong interest in the educational issues and barriers within their specific nations. Regarding high-tech industries, companies have been vying for the brightest graduates from science, computer science, and engineering. Developed countries continue to do this, but there is competition from Brazil, Russia, India, China, and South Korea, also known as the BRICK countries, and these countries fight immigration roadblocks from their own governments to increase their power in the world economy. What the countries seek in the form of education is the following:

> A new form of literacy – a technological literacy . . . This is a vital necessity if citizens are to participate in assessing and determining the relationship of technological systems to human needs. To function in this role requires that all citizens be conversant in the language of technological systems and comprehend basic concepts of the dynamics of the interrelated systems for all levels of society. (DeVore, 1980, p. 338)

Countries are reexamining their policies and educational systems to enhance the education of their citizens in the STEM subjects (Science, Technology, Engineering, and Mathematics). Although this push is for primary and secondary education systems to improve the education of their students, the word on U.S. campuses is STEM. Much of this is pushed by the funding avenues established by the National Science Foundation. This U.S. government foundation funded 138 STEM projects from September 2003 through April 2009. A total of $149,838,383 was approved to conduct research to improve the teaching of STEM subjects (NSF, 2010). A new objective for the NSF in recent years has been to fund innovative grants for kindergarten through high school (K-12) STEM enhancements.

STEM education and technological literacy are interwoven concepts, and many educators in design and technology education have focused their curriculum and student study in these knowledge areas. Technological literacy has become the aim of much of design and technology education that is being taught worldwide. It has been defined in *Standards for Technological Literacy* (ITEA, 2000) as "the ability to use, manage, understand, and assess technology" (p. 242). In practice, its study has been focused mainly on technical expertise, instead of how useful or pertinent technologies can be (Ginestié, 2008).

To "understand, use, assess, and manage technology" (ITEA, 2000, p. 242) is much different than to develop expertise in a few technologies. According to Pearson and Young (2002),

> Technological literacy is not the same as technical competency. Technically trained people have a high level of knowledge and skill related to one or more specific technologies or technical areas. . . a technologically literate person will not necessarily require extensive technical skills. Technological literacy is more a capacity to understand the broader technological world rather than an ability to work with specific pieces of it. (pp. 21-22)

However, tradition has led many educators to teach technical expertise. This may be in part because a design and technology teacher is given a laboratory with a variety of tools within its confines. It is natural for educators to teach these technologies when they are given these new tools. Might it be a systematic technology means-or-end problem that new technology creates?

Because much of the world continues to experience new technologies and changing economic situations, and the education system is almost void in explaining these developments and how or if they should be used for the betterment of society, these knowledge and abilities should eventually become one focus of teacher instruction through their design and technological studies programs. According to

DeVore (1972), "It is self evident that we can control only that which we know about and understand in behavioral terms" (p. 8).

School children (all ages) should become more literate about technologies. In some countries, the study of design and technology is mandatory. In others it is an elective subject. The design/technology/engineering education professionals are constantly working to get the study of technology into the required school curriculum. In different countries professionals have taken differing approaches to gain this leverage. Recently, in the United States, the decline of scientific, technological, engineering, and mathematics workers has led to a legislative act to increase STEM education (America Competes Act, 2007). Others are getting a nudge from the engineering professions to teach engineering principles at the high school level in order to attract more young people to engineering careers (e.g., Project Lead the Way in the U.S.A.). These trends are aimed at keeping the United States an economic leader through the generation of technological innovations. Industrialists believe that students should be taught how to innovate, using STEM skills, so they will become the generation that creates new technologies and products that the world's consumers will demand. Entrepreneurs also know that schooling in the sciences, technologies, engineering, and mathematics is crucial to their companies, if they are to remain productive and develop products that will gain an increased market share.

Pearson and Young (2002) stated that "technological literacy – an understanding of the nature and history of technology, a basic hands-on capability related to technology, and an ability to think critically about technological development – is essential for people living in a modern nation . . ." (pp. 11-12). Such people have knowledge of technology and are capable of using it effectively to accomplish various tasks. They can think critically about technological issues and act accordingly. Technological literate people would possess knowledge, ways of thinking and acting, and capabilities that assist them as they interact with the technology found in their environments (Pearson & Young, 2002). These "traits" include the following:

Knowledge

- Recognizes the pervasiveness of technology in everyday life.
- Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.
- Is familiar with the nature and limitations of the engineering design process.
- Knows some of the ways technology shapes human history and people shape technology.
- Knows that all technologies entail risk, some that can be anticipated and some that cannot.
- Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.
- Understands that technology reflects the values and culture of society.

Ways of Thinking and Acting

- Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.
- Seeks information about new technologies.
- Participates, when appropriate, in decisions about the development and use of technology.

Capabilities

- Has a range of hands-on skills, such as using a computer for word processing and surfing the Internet and operating a variety of home and office appliances.
- Can identify and fix simple mechanical or technological problems at home or work.
- Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits. (Pearson & Young, 2002, p. 17)

Context

At the author's university, faculty members have worked for the past 30 years to make technological literacy a general (or liberal) education requirement for all students. Faculty members have worked to put technology into the university curriculum, just as the social sciences and sciences are part of all students' liberal education. This work culminated in 1994 when the university decided it was time to re-visit its core liberal studies curriculum. At our university, this process occurs about every 10 years. (It was found that if one is not at the table when these study committees commence to work, it is very difficult to have an impact on the general studies offerings.) Thus, the author worked to get onto the committee that was responsible for the review.

The committee deliberated for two years, and much was to be said by the arts and letters and science faculty. The author worked with engineering and business faculty to have a voice to establish the importance and impacts that technology will continue to have on the graduates who studied at the university. The arts and science faculty listened. These faculty members needed to be educated in the idea that technological literacy was much more than the use of computers, although computer education was also needed and became a part of the curriculum.

This university included in its curriculum lower level (100/200) general education ***foundation*** courses and (300/400) level general education ***perspective*** courses. The technology education faculty members attempted to have one course in each category (foundations and perspectives), and they were successful in their endeavor. The 100-level course designed to meet the science and technology foundations is *Technology in Your World*. The intent of this course is to show the many technologies that impact and are used in differing careers. Through it students study the background of technological literacy, the systems of technology, such as medical, agricultural and bio-related, energy and power, information and communication, manufacturing, and construction technologies (ITEA, 2000), and careers that are found in these technologies. The intent is to help first-year students to be better educated when selecting a career and major.

At the 300/400 level, students can select cluster courses (focused study coming from an interdisciplinary perspective). Technology education faculty developed a 300-level course titled *Technology and Society* to meet this interdisciplinary study general education requirement (Old Dominion University, 2010).

The technology education faculty members have supplemented their programs by enrollments in these courses via general studies students (enrollment for the university is approximately 24,000 students). Annually, 14 sections of the 100-level course are offered and five sections of the 300-level course are offered. There is an additional section of the 300-level courses offered each fall on televised distance learning; enrollment averages 120 students. Old Dominion University has made technological literacy a mainstay of its course offerings. These courses enroll approximately 600 students annually.

The general studies program of the university was again reviewed in 2006. This review had a much smaller committee, and it did not include faculty from the technology education program. Faculty members knew that if they had data from assessments showing that students thought these technological literacy courses were important to their education and if it could be shown the types of knowledge students gained, there would be a much better chance of retaining this subject (technological literacy) as a general studies requirement at the university.

To enable this to happen, the author developed a survey that measured the educational objectives of the 100-level *Technology in Your World* course. This survey was administered for two years. The author was invited to a private meeting of the 2006 general education review committee to discuss changes the members were making to a computer literacy requirement for the university. The technology education program offers a course to meet this requirement in general education. Having the invitation, the author clarified questions the committee had about computer literacy. The committee praised the content that the technology education program covered in its information and computer literacy course (Word Suite plus information literacy, i.e., determining what was good information, searching the internet, and paper formatting), and it did not like the way that the other campus departments were teaching the course (Word Suite driven).

After this short discussion with the general studies committee, the author addressed the technological literacy courses that were offered and gave an overview of students' perceptions of the 100-level *Technology in Your World* course. Data had been gathered two years prior from students who were enrolled in this course.

Survey on Technological Literacy

In an effort to protect the gains made in bringing technological literacy into the university's general education program, our faculty decided that it would measure the educational progress of students who enrolled in *Technology in Your World*. Faculty decided to assess student progress according to the goals established by the general education committee for the technological literacy perspective: assessing the impacts technology has on humankind (us), the knowledge of the workings of technology, and the assistance given to students in making informed career decisions.

Over the two-year period that the survey was administered: 256 students participated. A five-point Likert-type scale was used to assess student opinions, with (5) representing strongly agree and (1) representing strongly disagree. It was found that taking this general studies course was the first time this group of students studied technology. Amazingly, it was the first such study for 64% of the general studies group. Following is an analysis of the survey findings.

Impacts of Technology

Questions 1-5 addressed the topic of impacts of technology and if these impacts had an effect on the students enrolled in the course. Question 1 stated: *I am aware of and understand how technology has evolved from the Stone Age to the present*. Many students (163) responded with strongly agree (52.0%), 103 (40.1%) agreed, 14 were uncertain (5.5%), 5 disagreed (2.0%), and 1 strongly disagreed (0.4%). The mean was 4.41, indicating agreement with this statement.

Question 2 read: *I understand the impact technology has on the development of society*. More than half (166) students responded strongly agree (64.8%), 87 agreed (34.0%), 1 was uncertain (0.4%), 1 disagreed (0.4%), and 1 strongly agreed (0.4%) with this statement. The mean score was 4.63, strongly agree.

Question 3 stated: I *feel comfortable in using the problem solving methods to solve a problem*. This was a teaching strategy used with hands-on knowledge reinforcement activities throughout the course. Less than half (110) strongly agreed (43.0%), 103 agreed (40.2%), 34 were uncertain (13.3%), 8 disagreed (3.1%), and 1 (0.4%) strongly disagreed with this statement. The mean score was 4.22, agree.

Question 4 read: *I understand that different career fields are based upon the application of technology*. Many students (130) strongly agreed (50.8%), 110 (43.0%) agreed, 14 were uncertain (5.5%), and 2 disagreed (0.8%) with this statement. The mean score was 4.44, agree.

Question 5 stated: *I have taken technology courses prior to this course*. Surprisingly, 64% indicated that this was the first course they had taken in the study of technology. This was an unexpected finding that these students had not taken courses in technology, either in high school or at the university, prior to enrollment in this course. This question points out that in the United States not as much emphasis is placed on the study of technology as should be. Table 1 presents a summary of impacts of technology information from university students in this study.

Technology Working Knowledge

The *Technology in Your World* course included readings, discussions, video information, and laboratory activities that focus on the systems of the technologically designed world. The next set of questions on the survey sought to measure students' understanding of concepts associated with these technological systems.

Question 6 read: *I understand the difference between energy sources*. One half of the students (128) strongly agreed (50.0%), 111 agreed (43.4%), 14 were uncertain, and 3 disagreed (1.1%) with this statement. The mean score was 4.43, agree.

Question 7 stated: *I understand that many products may be made from polymer and composite materials*. Less than half of the students (102 or 39.8%) strongly agreed, 109 agreed (42.6%), 36 responded uncertain (14.0%), 8 disagreed (3.1%), and 1 strongly disagreed (0.4%) to this statement. The mean score was 4.21, agree.

Question 8 asked: *I have used materials to*

Table 1. Impacts of Technology

Item	SA		A		U		D		SD		Mean
1. I am aware of and understand how technology has evolved from the Stone Age to the present.	133	52.0%	103	40.1%	14	5.5%	5	2.0%	1	0.4%	4.41
2. I understand the impact technology has on the development of society.	166	64.8%	87	34.0%	1	.4%	1	.4%	1	0.4%	4.63
3. I feel comfortable in using the problem solving method to solve a problem.	110	43.0%	103	40.2%	34	13.3%	8	3.1%	1	0.4%	4.22
4. I understand that differing career fields are based upon the application of technology.	130	50.8%	110	43.0%	14	5.5%	2	.8%	0	0.0%	4.44
5. I have taken technology courses prior to this course.	Yes	92	36%		No	164	64%				

construct/build something of my own. Many students (108 or 42.2%) strongly agreed, 105 agreed (41.0%), 16 were uncertain (6.2%), 24 disagreed (9.4%), and 3 strongly disagreed (1.2%) to this statement. The mean score was 4.14, agree.

Question 9 stated: *I know that technology evolves over time*. Seventy-six percent of the students (196) strongly agreed with this statement, fifty-eight (22.6%) agreed, 1 was uncertain (0.4%), and 1 disagreed (0.4%) with this statement. The mean score was 4.75, strongly agree.

Question 10 read: *I understand that all technologies have social, cultural, environmental, economic, and political impacts*. More than half of the students (164) strongly agreed (64.1%), 86 agreed (33.6%), 3 were uncertain (1.2%), 2 disagreed (0.8%), and 1 strongly agreed (0.4%) with this statement. The mean score was 4.50, strongly agree.

Question 11 asked: *I can identify the basic components of an electrical circuit.* Sixty-four students strongly agreed (25.0%), 112 agreed (43.8%), 44 were uncertain (17.2%), 26 disagreed (10.2%), and 10 strongly disagreed (3.76%) to this statement. The mean response to the statement was 3.76 or agree.

Question 12 inquired: I *enjoy working with my hands.* Ninety-six students strongly agreed (37.5%), 106 agreed (41.1%), 28 were uncertain (10.9%), 20 disagreed (7.8%), and 5 strongly disagreed (2.0%) with this statement. The mean response to this statement was 4.05 or agree.

Question 13 stated: *I use the Internet as a resource tool to locate information on topics of interest to me*. Two hundred-one students strongly agreed (78.5%), 49 agreed (19.1%), 39 were uncertain (15.2%), and 3 disagreed (1.2%) to this statement. The mean score was 4.75, strongly agree.

Question 14 determined: *I use the Internet on a daily basis*. Two hundred-eight students strongly agreed (81.2%), 46 agreed (18.0%), and 2 disagreed (0.8%) with this statement. The mean score for this statement was 4.80, strongly agree.

Question 15 sought: *I communicate mainly by e-mail/text messaging*. Eighty-six students responded strongly agree (33.6%), 97 agreed (37.9%), 20 were uncertain (7.8%), 51 disagreed (19.9%), and 2 strongly disagreed (0.8%) with this statement. The mean score was 3.84, agree.

Question 16 inquired: *I see that computers can be applied to various technologies*. One hundred-seventy-four students strongly agreed (68.0%), 81 agreed (31.6%), and 1 was uncertain (0.4%) with this statement. The mean score for this item was 4.68 or strongly agree.

Table 2. Technology Working Knowledge

Item	SA		A		U		D		SD		Mean
6. I understand the difference between energy sources.	128	50.0%	111	43.4%	14	5.5%	3	1.1%	0	0.0%	4.43
7. I understand that many products may be made from polymer and composite materials.	102	39.8%	109	42.6%	36	14.0%	8	3.1%	1	0.4%	4.21
8. I have used materials to construct/build something of my own.	108	42.2%	105	41.0%	16	6.2%	24	9.4%	3	1.2%	4.14
9. I know that technology evolves over time.	196	76.6%	58	22.6%	1	0.4%	1	0.4%	0	0.0%	4.75
10. I understand that all technologies have social, cultural, environmental, economic, and political impacts.	164	64.1%	86	33.6%	3	1.2%	2	0.8%	1	0.4%	4.60
11. I can identify the basic components of an electrical circuit.	64	25.0%	112	43.8%	44	17.2%	26	10.2%	10	3.9%	3.76
12. I enjoy working with my hands.	96	37.5%	106	41.4%	28	10.9%	20	7.8%	5	2.0%	4.05
13. I use the Internet as a resource tool to locate information on topics of interest to me.	201	78.5%	49	19.1%	39	15.2%	3	1.2%	0	0.0%	4.75
14. I use the Internet on a daily basis	208	81.2%	46	18.0%	0	0.0%	2	0.8%	0	0.0%	4.80
15. I communicate mainly by e-mail/text messaging.	86	33.6%	97	37.9%	20	7.8%	51	19.9	2	0.8%	3.84
16. I see that computers can be applied to various technologies.	174	68.0%	81	31.6%	1	0.4%	0	0.0%	0	0.0%	4.68
17. I understand the purpose of construction building codes.	104	40.6%	96	37.5%	38	14.8%	13	5.1%	5	2.0%	4.10
18. I know that different types of construction require different technologies.	130	50.8%	116	45.3%	8	3.1%	2	0.8%	0	0.0%	4.46
19. I understand how products are manufactured.	89	34.8%	127	49.6%	32	12.5%	7	2.7%	1	0.4%	4.16
20. I understand that transportation is a vital component of advanced societies.	178	69.5%	73	28.5%	5	2.0%	0	0.0%	0	0.0%	4.68
21. I know what is meant by biotechnologies.	124	48.4%	110	43.0%	19	7.4%	2	0.8%	1	0.4%	4.38
22. I know what is meant by nanotechnology.	78	30.5%	104	40.6%	42	16.4%	26	10.2%	6	2.3%	3.87

Question 17 stated: *I understand the purpose of construction building codes*. One hundred-four students strongly agreed (40.6%), 96 agreed (37.5%), 38 were uncertain (14.8%), 13 disagreed (5.1%), and 5 strongly disagreed (2.0%) with this statement. The mean was 4.10, agree.

Question 18 asked: *I know that different types of construction require different technologies*. One hundred-thirty students strongly agreed (50.8%), 116 agreed (45.3%), 8 were uncertain (3.1%), and 2 disagreed (0.8%) with this statement. The mean score was 4.46, agree.

Question 19 inquired: *I understand how products are manufactured*. Eighty-nine students strongly agreed (34.8%), 127 agreed (49.6%), 32 were uncertain (12.5%), seven disagreed (2.7%), and 1 strongly agreed (0.4%) with this statement. The mean score was 4.16, agree.

Question 20 stated: *I understand that transportation is a vital component of advanced*

Table 3. Career Decisions

Item	SA		A		U		D		SD		Mean
23. I understand the relationship between technology and the economy.	120	46.9%	119	46.5%	12	4.7%	4	1.6%	1	0.4%	4.38
24. I understand that the more I know how to use technology, the more valued I am to an employer.	156	60.9%	88	34.4%	6	2.3%	4	1.6%	0	0.0%	4.58
25. I realize technology will continue to affect my life.	193	75.4%	59	23.0%	3	1.2%	0	0.0%	1	0.4%	4.73
26. This course offered opportunities for me to use technologies associated with the workplace.	109	42.6%	100	39.0%	24	9.4%	16	6.3%	7	2.7%	4.13
27. This course provided experiences to assist me with future career selections.	88	34.4%	87	34.0%	46	18.0%	23	9.0%	12	4.7%	3.84

societies. One hundred-seventy-eight students strongly agreed (69.5%), 73 agreed (28.5%), and 5 were uncertain (2.0%) with this statement. The mean score was 4.68, strongly agree.

Question 21 asked: *I know what is meant by biotechnologies*. One hundred-twenty-four students strongly agreed (48.4%), 110 agreed (43.0%), 19 were uncertain (7.4%), 2 disagreed (0.8), and 1 strongly agreed (0.4%) with this statement. The mean was 4.38, agree.

Question 22 stated: *I know what is meant by nanotechnology.* Seventy-eight students strongly agreed (30.5%), 104 agreed (40.6%), 42 were uncertain (16.4%), 26 disagreed (10.2%), and 6 strongly agreed (2.3%) with this statement. The mean score was 3.87, agree.

Technology and Careers

The third part of the survey sought student responses to questions about technology and their careers. The *Technology in Your World* course covered content on technological systems. During this analysis implications were continually directed to the use of these technologies with various career fields. These were summary questions about these interrelationships.

Question 23 read: *I understand the relationship between technology and the economy*. One hundred-twenty students strongly agreed (46.9%), 119 agreed (46.5%), 12 were uncertain (4.7%), 4 disagreed (1.6%), and 1 disagreed (0.4%) with this statement. The mean score was 4.38, agree.

Question 24 stated: *I understand that the more I know how to use technology, the more valued I am to an employer*. One hundred-fifty-six students strongly agreed (60.9%), 88 agreed (34.4%), 6 were uncertain (2.3%), and 4 disagreed (1.6%) to this statement. The mean score was 4.58, strongly agree.

Question 25 said: *I realize technology will continue to affect my life*. One hundred-ninety-three students strongly agreed (75.4%), 59 agreed (23.0%), 3 were uncertain (1.2%), and 1 strongly disagreed (0.4%) to this statement. The mean score was 4.73, strongly agree.

Question 26 stated: *This course offered opportunities for me to use technologies associated with the workplace*. One hundred-nine students strongly agreed (42.6%), 100 agreed (39.0%), 24 were uncertain (9.4%), 16 disagreed (6.3%), and 7 strongly disagreed (2.7%) to this statement. The mean score was 4.13, agree.

Question 27 asked: *This course provided experiences to assist me with future career selections*. Eighty-eight students strongly agreed (34.4%), 87 agreed (34.0%), 46 were uncertain (18.0%), 23 disagreed (9.0%), and 12 strongly disagreed (4.7%) to this statement. The mean score was 3.84, agree.

Discussion

Literacy is important to citizens of the world. Literacy goes beyond the educational basics of reading, writing, and mathematics. Literacy has moved into other school subjects. For nations to prosper economically, the technological literacy capabilities of its citizens are important. University technology departments can contribute to the literacy of nations. Technological literacy courses at the university level can be used to support design and technology's contributions to the general education of all students. Student enrollment in general education courses can be used to support and further justify the very existence of our programs. Universities continually review program enrollments to make decisions on those that it wishes to support financially. If our design and technology program relies entirely on enrollments from teacher preparation students, it could become labeled as a low-enrolled program. By gaining support for technological literacy courses as a general education requirement, design and technology education programs can build enrollment and, at the same time, increase their teaching of technological literacy to a wider population of university students.

Having data from students who complete technological literacy courses can show the value of these courses and the data can be used as a tool to support discussions of why these courses should be offered. Faculty members of other technological literacy courses in the program at Old Dominion are now conducting this type of research, and they have noted the value of conducting such research.

The surprising response to this study was the lack of experiences students had with the study of technology, prior to the selection of this course. Sixty-four percent of the students indicated that they did not take a prior course on technology either in high school or at the university before this course. The first-year statistics for this study indicated that this number was as high a 70%. Students found that technology does have an impact on the world in which they live and the career path that they plan to purse.

There are many technologies that compose the designed world. Although each technology has its particular systems and subsystems, its development has progressed because of the innovative and problem solving abilities that people working in these areas have pursued. Students were exposed to many systems, including agriculture, communication and information, construction, energy and power, manufacturing, medical, agriculture and bio-related technologies, and transportation technologies. Students learned to use activities in these areas to solve problems. In doing this they were (and can be) exposed to some of the knowledge and skills needed if they pursued careers in these technologies. Students indicated the value of such courses in their preparation for careers after they complete their degrees.

Summary

Faculty members have found the importance of enabling students to study technological literacy at the university level. Technology can contribute to the education and literacy of university students. If one looks at the larger picture of education and the technological literacy of its students, is not this the mission that our profession has as design and technology educators? Expanding design and technology courses to the university general population can be used as numbers to support academic programs while also contributing to a wider student population. This helps us achieve technological literacy for all.

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Mentoring Teachers in Technology Education: Analyzing the Need

Luke J. Steinke and Alvin R. Putnam

Abstract

Mentoring programs have been shown to have an influence on the overall success of retaining teachers. Studies have shown that not only are teachers who participate in mentoring programs more likely to stay in teaching positions, but also the overall economic value of retaining teachers goes beyond the cost savings related to attrition. Beginning technology education teachers typically participate in the same traditional mentoring programs all teachers follow. These programs tend to overlook the unique nature of a technology education teacher's job. Because a technology education teacher's job generally requires additional and sometimes more stressful duties, such as lab components, this study sought to address the areas that traditional mentoring programs overlooked. Specific attention was paid to technology education teachers' need for assistance regarding technical experts and managing a laboratory environment.
This study applies the situational mentoring framework (SMF) model to address the issues related to mentoring programs for technology education teachers.

Purpose of this Paper

Although mentoring programs have been effective in retaining beginning teachers in general, a review of literature regarding mentoring programs for technology education teachers reveals limited to no research on the topic. More specifically, there is currently no research addressing the overall effectiveness of mentoring programs or the development of a mentoring program (model) for technology education teachers. The purpose of this article is to examine the current status of mentoring pr ograms within technology education by focusing on (a) the overall benefits and effectiveness of mentoring programs, (b) the unique aspects of technology education that are overlooked within traditional mentoring programs, and (c) the methods for developing and implementing effective mentoring programs within technology education. In order to address the unique aspects of technology education, the situational mentoring framework (SMF) will be applied for the systematic development of a model mentoring program for technology education teachers.

Teacher Shortage

Few would argue that the field of education is facing a significant teacher shortage. Numbers do not lie: there were more than 60,000 reported teaching vacancies in the United States during the 2003-2004 school year (Mihans, 2008). Even though many fields of education have experienced teacher shortages, several areas of study are particularly troubling. Technology education and its allied fields have been experiencing a shortage of qualified teachers for approximately 20 years. This problem is exacerbated because, as demands for a technologically literate society increase, so has the demand for technology- related subjects at the elementary, secondary, and post-secondary levels. Meade and Dugger (2004), Ndahi and Ritz (2003), Newberry (2001), Ritz (1999), and Weston (1997) indicated that technology education has experienced and will continue to experience a significant teacher shortage unless educators act to reverse this problem.

Teacher Attrition

Although there is a shortage of teachers, many studies have indicated that this is not necessarily the result of a lack of newly trained teachers. According to Ingersoll and Smith (2003), much of the teacher shortage issues are the result of a "revolving door," whereby teachers leave the profession early. An estimated 50% of new teachers leave the profession after 5 years (Ingersoll & Smith, 2004). Reasons a teacher might leave the profession vary.
In general, these factors include low salaries; lack of career advancement, professional development, or administrative support; student and peer issues; and other school/ environment-related concerns (Darling-Hammond, 2003; Ladwig, 1994; Marlow, Inman, & Betancourt-Smith, 1996; Marso & Pigge, 1997; McCreight, 2000). Researchers who specifically considered attrition rates in technology education found similar results, with additional frustrations for technology education teachers related to a lack of funding for

equipment, supplies, and facilities plus a lack of understanding and support for technology education by administrators and counselors (Wright, 1991; Wright & Custer, 1998).

These are all certainly important factors to address for schools systems, administrators, and other teachers who wish to retain teachers, but what factors typically result in a teacher's leaving after one year? Anyone who has taught can certainly remember the difficulties of the first year. Teaching is often done in isolation. Ingersoll (2003) likens a teacher's first year experience to being "lost at sea," because new teachers are often left to fend for themselves within the confines of their own classroom (also referred to as the sink-or-swim year).

Within any profession, new employees usually are at a significant disadvantage; most often they are not given much support during their first year on the job. (It takes an entire year in any job to begin to understand the subtleties of politics, the demands of people in charge and peers, and the quality and quantity of work that is expected.)

Technology education teachers in particular can face a significantly difficult first-year experience. On top of the same difficulties any new teacher would face, such as developing effective instruction and managing a classroom, technology education teachers have the tasks of trying to integrate various technologies into the classroom, managing labs, and developing hands-on projects. As new teachers focus more on surviving the first difficult years, they often focus less on pedagogical developments for the classroom. In addition, technology education courses have been and often continue to be perceived as "vocational." These classes can be filled with students who the administration and teachers believe are not college bound. The new technology education teacher therefore may have a classroom of many students, even classrooms of students, who are less prepared to learn. Even the most experienced teacher would have difficulties within this environment. Finally, new technology education teachers often have few colleagues to turn to for help. Depending on the school, many of the new technology education teachers' peers could have limited experience with a lab-based environment.

Therefore, all new teachers as well as new technology education teachers can experience many problems, challenges, and issues that could have a significant impact on whether they remain teachers.

Along with this overarching strain on the technology education teacher, the burden of teacher attrition places a significant hardship on schools as well. As schools must recruit new teachers to replace teachers who leave, and a job search can result in extensive resources plus significant costs for a school/school system. The turnover costs attributed to hiring, training, and adjusting to the learning curve of new teachers can be staggering (Texas State Board for Educator Certification, 2004). Schools (superintendents, principals, administrators, etc.) should spend the required time in effectively filling teaching positions, but they often settle for inexperienced teachers, teachers who meet only basic requirements, or substitute teachers who have limited knowledge of either the subject matter or teaching in general. As these new teachers adjust to the position's learning curve, their students' academic preparation may suffer, resulting in a negative impact on the school's overall performance.

Additional strain is placed on schools as teacher attrition increases. In particular, schools are burdened with hiring teachers with subject matter knowledge relevant for technology education. In the past, technology educators relied on two solutions for addressing teacher shortages: giving emergency certifications and hiring teachers from fields similar to technology education. Emergency certification is used when an individual has a bachelor's degree and technical knowledge but does not have teacher certification; this certification is given temporarily so a person can fill the open job. Such a teacher will go through an alternative certification process eventually to earn a teaching certification, but his/her first years of teaching are spent with limited knowledge of pedagogical techniques. Ruhland and Bremer (2002) found that alternatively certified teachers felt less prepared in the area of pedagogy than did traditionally certified teachers. The practice of hiring teachers from allied fields is also common within technology education to fill open teaching positions. Teachers from mathematics, biology, and other science subjects are hired to fill technology education positions. The case for hiring someone from an allied field is based on the idea that the knowledge areas are similar enough for the teacher to succeed.

In both cases, these new teachers experience issues within the classroom. The emergency certification teachers can have difficulties due to limited experiences as classroom teachers, and teachers hired based on having certification in a "similar area" can have limited experiences with an applied/hands-on environment that is typical of technology education. In either case, the school and students themselves often suffer while such new teachers develop the necessary skills to provide effective instruction. This time period could be weeks, months, or perhaps even years.

Induction and Mentoring Programs

To address the high teacher attrition rates, many schools have implemented induction and mentoring programs. Induction and mentoring programs have been designed to offer new teachers opportunities to share experiences and ideas; additionally, they can collaborate on classroom concerns with veteran teachers. The most common form of induction is the mentoring program (Feiman-Nemser, 1996). The purpose of the mentoring program is to establish a workplace relationship between a veteran and a beginning employee, and it is based around the premise that employees learn good practices through several years of study, consultation with experienced peers, and reflective practices (Fox & Certo, 1999). Researchers have continuously indicated that mentoring programs can increase the retention of beginning teachers (Brown, 2003; Darling-Hammond, 2003; Kajs, 2002; McCormick, 2001).

Overall Benefits of Mentoring Programs

Many teachers and administrators would agree with the research that induction and mentoring programs are effective in retaining teachers, but what makes these programs effective? Mihans (2008) pointed out that what makes mentoring of teachers so effective is purely the necessity of the profession. According to Mihans (2008), "teaching is the only profession that requires the same responsibilities of its beginning practitioners as its masters" (p. 763). This would seem to suggest that successful mentoring starts with the very existence of a mentoring program, but clearly effective mentoring goes deeper than the simple existence of a program. Regardless of type of mentoring program, several key benefits of mentoring programs have been identified.

One of the key and main benefits of a teacher mentoring program is increased teacher retention. Mentoring programs have been designed to address some of the key factors that result in beginning teachers' leaving the profession. Even though the level of increased retention will vary based on the type of program, Ingersoll and Smith (2004) pointed out that the probability of teacher turnover is reduced when teachers participate in induction and mentoring programs. This reduction in teacher turnover has other benefits than simply maintaining the number of teachers within the school district. For example, Villar and Strong (2007) conducted a benefit-cost analysis of teacher mentoring programs and found that increases in teacher effectiveness due to mentoring programs actually outweighed cost concerns related to attrition. Therefore, while mentoring programs can be beneficial in reducing the cost of turnover, the financial benefits go beyond simple turnover.

While assisting beginning teachers is the primary goal and benefit stream for mentoring programs, experienced teachers who participated as mentors can also benefit from such programs. Mihans (2008) indicated that experienced teachers can view mentoring as an incentive to stay in the teaching profession because they can learn from and share with colleagues, while providing the leadership roles that are important in retaining experienced teachers. This would indicate that the practice of mentoring for teachers may not only reduce the likelihood that beginning teachers would resign, but also it may help reduce the number of teachers who exit the teaching profession altogether.

Research conducted by Steinke and Putnam (2007) found that one of the primary influential factors in technology education teachers' staying in a teaching position is whether they participated in an induction and mentoring program. Therefore, the benefits associated with mentoring certainly are applicable to addressing attrition within technology education.

What Traditional Mentoring Programs Overlook

Despite the known benefits of mentoring programs, not all are effective. As Ingersoll and Smith (2004) pointed out, the kinds and numbers of support provided by schools to beginning teachers vary, as does their effect on retention. Currently, there are no standards for mentoring new teachers, and programs can vary from one school district to the next. In a 2001 study conducted by the American Federation of Teachers (AFT), only 21 states had established guidelines for the selection of mentors. The type of mentor selected and the overall mentoring process can have a significant impact on whether a mentoring program is effective. Gratch (1998) found that the simple presence of a mentor does not guarantee success. Mentors who are not given instructions on how to effectively teach adults, for example, probably will not create effective mentors (Gratch, 1998). Traditional programs that simply assign a mentor might overlook factors that are important to teachers within a particular field such as technology education.

Ingersoll and Smith (2004) indicated that one of the strongest factors related to retention is having a mentor from the same field. Within technology education, this establishes a problem because technology education already faces a significant lack of teachers within the field, so the odds for new technology education teachers having a mentor within the field are not great. Most schools will likely find that providing mentors from a "similar field" is a sufficient answer for mentoring teachers within technology education. The issue here is if teachers from science or mathematics have sufficient backgrounds in technology education to effectively mentor technology teachers. Brown (2003) indicated that lab environments are different than traditional classrooms and have different procedures than traditional classrooms. Additionally, Brown (2003) indicated that lab-based teaching environments, such as technology education, must also organize internships, service learning, and monitor cooperative learning activities. Mentors for teachers within these lab environments must be familiar with the procedures, equipment, and processes of a typical lab.

Because mentoring programs are designed to address teacher attrition, it is important for mentors to be familiar with key factors that impact whether teachers leave the profession. Certainly the typical mentoring program will be designed to address the reasons why the average teacher leaves, but technology education teachers have been found to leave for a variety of reasons. Wright and Custer (1998) and Steinke and Putnam (2007) found that a lack of funding for supplies and equipment can affect the retention of technology education teachers. Clearly mentors within technology education must be familiar with and able to address issues involving technology resources in classrooms and labs. In addition, Steinke and Putnam (2007) found that technology education teachers are concerned with the long hours required to deliver a quality program, the low status of technology education, and the lack of understanding of what technology education is among administrators and colleagues. These are all factors that affect the overall retention of technology education teachers that many traditional mentoring programs do not address.

Technology education teachers who do not receive the needed support in their first years are more likely to leave the teaching profession because technology education offers professionals the opportunity to make much higher wages working in non-teaching careers (National Association of State Boards of Education, 1998). It is therefore imperative to provide the proper support to technology education teachers early, including the development of mentoring programs that address the main areas of concern for technology education teachers. In order to develop a successful mentoring program for technology education teachers that address these concerns, a systematic approach should be used.

Technology Education Mentoring Programs

In designing an effective mentoring program for technology education teachers, there are many different factors to consider. Technology education teachers encounter different issues than the many teachers, but school districts may also have a difficult time addressing those issues through standard mentoring programs. School districts need a process for developing a mentoring program that is adjustable and allows for situational variability. Kajs (2002) suggested the situational mentoring framework (SMF). This model has four components that include: (a) mentor selection, (b) mentor and novice teacher preparation, (c) support team, and (d) accountability. The four components are interrelated and the approach is dynamic, allowing for changes related to technology, processes, and personnel. For this reason, the SMF is ideal for developing the foundations of an effective mentoring program for technology education teachers. Each of the four components is considered next and how each can specifically be used to design an effective mentoring program for technology education teachers are discussed.

Mentor Selection

Selecting the right mentors and matching those mentors with the proper protégés can be crucial in any mentoring relationship. The SMF model calls for a collaborative process to ensure the proper selection of mentors by using a systematic process for their selection (Kajs, 2002). Though it is the task of a selection committee during this component to develop criteria for potential mentor candidates and determine a pool of prospects, Allen, Eby, and Lentz (2006) pointed out that this process should really focus on allowing individuals to feel as though they have as much input into the matching process as possible. The more a formal mentoring program simulates an informal mentoring relationship, the more effective it will be (Allen, Eby, & Lentz, 2006).

During the mentor selection process, the process of creating an informal-feeling mentoring relationship begins with determining a pool of experienced expert teachers that are willing to take on the responsibility of mentoring (Kajs, 2002). Allen, Eby, and Lentz (2006) indicated that both creating a sense that the program is voluntary to potential mentors and looking at the proximity and background of the mentoring pool are important. For example, they found physical distance between mentors and protégés can be a challenge in a mentoring relationship, along with a mentor's overall knowledge of a department/area of study. Once a pool is identified, the prospective mentors and novice teachers should spend time discussing different viewpoints relating to mentoring, as well as potential relationships. This will create a sense of perceived input into the mentoring process between both groups, as well as provide needed input for properly matching mentors to protégés.

This process in particular can be beneficial for technology education teachers. First, actively identifying a pool of experienced teachers to be mentors through a formal process may increase the number and quality of teachers who are willing to participate. This is particularly important in technology education, given the nature of the lab-based teaching environment. Second, by focusing on the proper selection of mentors and allowing them to get to know the novice teachers, novice technology education teachers are more likely to be assigned a mentor who understands their jobs and potential difficulties. The prevailing practice of simply assigning an experienced teacher to mentor a novice certainly does not allow for this likelihood. Finally, if an insufficient number of qualified mentors are available or one is not identified for a technology education teacher, a formal mentoring selection process allows for a principal/committee to identify and request the participation of an experienced teacher to fill that need (Papalewis, Jordan, Cuellar, Gaulden, & Smith, 1991). Since a shortage of technology education teachers already exists, this may be necessary. If an experienced technology education teacher is unavailable, this issue could be addressed in the fourth component Support Team (discussed later).

Mentor and Novice Teacher Preparation

Many traditional mentoring programs assume that an experienced teacher has the knowledge and skills necessary to be an effective mentor. The reality is that the knowledge and skill set to be an effective teacher is different than the knowledge and skill set to effectively mentor a colleague. Although most formal mentoring programs offer some form of training (Allen, Eby, & Lentz, 2006), many tend to be more informational than knowledge based with skill development (Kajs, 2002). Therefore, the SMF model emphasizes the need for both mentors and novice teachers to develop skills to promote an effective relationship (Kajs, 2002).

A variety of different types of knowledge and skills are needed in order for a mentor to be successful. In particular, Hanuscin and Lee (2008) identified skills such as listening skills, knowledge of effective teaching, modeling inquiry, and helping a new teacher to focus on students' thinking as important. These identified knowledge and skills building on the work of Kajs, Willman, and Alaniz (1998) and others, who identified the stages of teacher development, adult learning principles, and professional development assessments as important for mentors. Additionally, the SMF model stresses the importance of developing the interpersonal skills of novice teachers. Eby and Lockwood (2005) indicated that providing training to help novice teachers develop appropriate expectations and clarify the objectives and purpose of the program should improve the quality of the mentorship.

By addressing the overall knowledge and skills of the mentors in the development of the mentoring program, there is an increased likelihood that the issues novice teachers face with be addressed. Within technology education, mentors, in particular, should be aware of and able to deal with the specific needs of new technology education teachers. For example, given the nature of the lab-based technology education classroom, mentors may need to be aware of and able to deal with specific safety- and technology-related concerns. This creates a two-fold advantage for technology education. It develops technology education mentors who can address a variety of concerns and feel comfortable dealing with different equipment, procedures, and classroom environments. Additionally, given the potential lack of experienced technology education teachers to participate as mentors, detailed mentor development may allow other teachers to provide valued assistant to novice technology education teachers.

Support Team

Providing a support team or supporting system for mentors is something few traditional mentoring programs offer. Hanson (1996) indicated that given the increased responsibility mentoring put on a teacher, the time constraints associated with mentoring can have a negative affect. As mentioned previously, given a potential lack of experienced teachers or teachers within a specific field of study, such as technology, mentors might experience frustration with these limitations (Kajs, 2002). The SMF model uses the development of a support team to address these limitations and frustrations.

Support teams can be designed to include a variety of different experts from areas such as different campuses and school districts; they can even incorporate university educators who demonstrate the necessary knowledge and skills to help novice teachers (Kajs, 2002). Support teams can be used to identify the necessary knowledge and skills needed for mentors and protégés, provide training, assist current mentors reducing their time commitment, and can be used to evaluate and improve the mentoring process. Since the physical distance between mentor and protégé can affect the success of the relationship (Allen, Eby, & Lentz, 2006), the use of support teams can also create a feeling of closeness between the mentor and protégé by providing more options for support. Finally, Kajs (2002) concluded that because the support team includes different participants from the school district, both the novice and the experienced teachers may feel a higher degree of commitment for the mentoring program.

Since many school districts may have very few experienced teachers who have lab and technology background to be effective mentors for novice technology education teachers, support teams may provide a solution to this issue. Technology educators specifically can see significant benefits of including and using a support team by identifying and providing a committee of individuals, both in the school district and out, who can be of assistance to technology education teachers. For example, the support team may consist of technology education professionals from within the school district, from a school district nearby, from a regional two- or four-year college, and from state and national teacher associations. Each member of the support team may have experiences with different concerns related to managing a lab, dealing with student, and developing programs and internships. The support team can work individually with each novice teacher to determine concerns and offer support in different ways, whether face-to-face or via electronic means. The advantages are that experienced technology education professional has a chance to collaborate, the mentor's time commitment is reduced, and the novice teacher gets the needed support.

Accountability

Many traditional mentoring programs lack a feedback loop or systematic method for measuring the success of the program. Even though all programs encounter various barriers to success, a systematic means for determining what is accomplished and how the process can be improved is important. The SMF model can be used to develop a systematic plan of program benchmarks. Kajs (2002) indicated that these benchmarks can be met through a series of observations to ensure: (a) appropriate pedagogy is modeled and practiced, (b) work in the classroom is assessed and improved, and (c) mentor/protégé interactions are constructive. The advantage of developing such a component allows for the overall assessment and improvement of the program. Additionally, building in accountability and benchmarks provides a guide for both mentors and protégés to strive toward. Providing measurable goals for both the mentor and protégé to follow also makes scheduling of visits easier and can be helpful in guiding development activities. Within technology education, the accountability component can provide an opportunity for both experienced and novice teachers to reflect on current practices and make improvements to enhance student learning. Given the changing nature of technology, it is particularly important for technology education teachers to reflect on their teaching methods and determine new ways to incorporate and change with technology.

Conclusion

An effective mentoring program not only can enhance the abilities of teachers, but it also can have a significant impact on overall retention of teachers. By successfully retaining more teachers, school districts can address the significant teacher shortage; additionally, costs may be contained or at the very least kept at an acceptable level. While the development of a comprehensive mentoring program using the SMF model may be more expensive and time consuming than a traditional mentoring program, such a cost would be offset by the overall reduction in cost related to teacher attrition (Villar & Strong, 2007). The SMF model provides a systematic approach and structure for the development of an effective mentoring program, and it can provide the needed components to address the issues currently overlooked by traditional mentoring programs (Kajs, 2002). In particular, this systemic approach is needed to address the issues that may be overlooked in a traditional mentoring program concerning technology education. The field of technology education continues to experience a significant teacher shortage (Meade & Dugger, 2004; Ndahi & Ritz, 2003; Newberry, 2001; Ritz, 1999; Weston, 1997), while traditional mentoring programs continue to overlook: (a) the lab-based nature of technology programs, (b) issues related to a lack of funding for supplies and equipment, and (c) the need for mentors with similar backgrounds and technical expertise.

Even though the SMF model is an appropriate step for developing effective mentoring programs for technology education, other areas of research must be undertaken to make this happen. First, given the need for the development of knowledge and skills for mentors, research should be conducted to determine the specific knowledge and skills needed for technology education mentors. A study could be developed to consider knowledge and skills, paying close attention to the knowledge and skills that are most frequently used, most critical, and most difficult to master. This study could then be used to develop effective development activities for technology education mentors. Another study could then be initiated to measure the overall effectiveness of these development activities, looking specifically at issues of mentor and protégé development, increases in teaching effectiveness of novice teachers, and the difficulties of retaining teachers.

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Discovering New Zealand Technology Teacher's PCK

P. John Williams and Mishack Gumbo

Abstract

An important and under-researched area of technology education is teachers' pedagogical content knowledge (PCK). This concept reflects the notion that expert teachers' knowledge is a unique integration of their pedagogical technique and their understanding of technology content as applied in a particular instance.

The authors are interested in inquiring into technology teachers' PCK from a comparative perspective between New Zealand and South African teachers, who have implemented and reviewed their technology education curriculum according to a similar timeframe. This article therefore reports on the first phase of this study on lower secondary technology teachers' PCK, with the focus on New Zealand. The ultimate aim is to compare the PCK of New Zealand technology teachers and the PCK of South African technology teachers via a case study approach. The findings in this paper are reported from the interviews, classroom observations, and document reviews of four New Zealand technology teachers.

Introduction

This ongoing study aims to inquire into the pedagogical content knowledge (PCK) of secondary school technology teachers. The study is a collaborative and comparative project between South Africa and New Zealand. In this article, the authors deal with the findings from the initial New Zealand-based inquiry. According to Nicholas and Lockley (2010), curricular changes have implications on classroom practice and teachers' concepts of what being a successful teacher of technology education means. Both South Africa and New Zealand have recently experienced curriculum transformation and change, which resulted in the introduction of technology education. New Zealand introduced and implemented technology education in 1997 (Jones & Moreland, 2004) and South Africa in 1998 (Stevens, 2005). Both countries have also had curriculum reviews, the latest in New Zealand was in 2007 (Nicholas & Lockley, 2010), and the latest in South Africa was in 2000 (Department of Education, 2000) and 2009 (Department of Education, 2009). These parallel processes motivated the authors to use a comparative study to investigate technology teachers' PCK. Technology education is a relatively new subject in both of these contexts, and research into this area has the capacity to enhance understanding of what constitutes an expert teacher. Thus, the research question arises: What is secondary technology teachers' pedagogical content knowledge?

This research question can be elaborated through the following subquestions that have been derived from the literature:

- What do technology teachers understand as the nature and purpose of technology education?
- What constitutes the technology teachers' knowledge of the technology education curriculum?
- What are the pedagogies that teachers believe are suitable to teaching technology?
- What types of assessment activities do the technology teachers utilize and how are these related to the content?
- What technological teaching and learning resources do the technology teachers use?
- How do the technology teachers integrate indigenous technology in their teaching?

Theoretical Framework

Literature relates the historical treatment of content knowledge and pedagogical knowledge by teachers in a dichotomized way (Ball & McDiarmid, 1990; Shulman, 1986a; Veal & MaKinster, 1999). For example, Veal and MaKinster (1999) became aware of this problem in the area of science and alluded to the traditional polarization of content knowledge (CK) and pedagogical knowledge (PK) that exists in science teacher preparation programs; however, it is counterproductive that these two concepts are treated in a dichotomized fashion (Gore, Griffiths, & Ladwig, 2004). In technology, the parallel dichotomy is often characterized as between theory and practice

(Williams, 2002) where the pressures of timetables, classrooms, and examinations encourage teachers to separate theory and practice, each accompanied by a suite of different conventions related to pedagogy and content.

The origins of PCK date back to 1986 (De Miranda, 2008) when the coiner of the concept, Lee Shulman, gave his presidential address to the American Educational Research Association (Van Driel, Veal, & Janssen, 2001). Van Driel et al. (2001, p. 2) related Shulman's conception of the idea:

> Shulman argued that, for a long time, research on teaching and teacher education had undeservedly ignored questions dealing with the content of the lessons taught. Shulman presented a strong case for pedagogical content knowledge (PCK) as a specific form of knowledge for teaching, which refers to the transformation of subject matter knowledge in the context of facilitating student understanding. Shulman emphasized the importance of research on PCK by referring to it as a "missing paradigm."

Shulman's concern lies at the foundation of transformation in the context of teaching – teachers transforming content into meaningful understanding by learners. Having realized the gap that exists between CK and PK, Shulman (1986a) developed a framework for teacher education by introducing the concept of PCK, such that teacher training programs should combine CK and PK to effectively prepare teachers. Teaching begins with an understanding of what is to be learned and what is to be taught (Shulman, 1987). Shulman and Sherin (2004) argued further, that teaching and learning to teach must be viewed in discipline-specific perspectives. As Geddis (1993) emphasized, "The outstanding teacher is not simply a 'teacher,' but rather a 'history teacher,' a 'chemistry teacher,' or an 'English teacher' (p. 675). The purpose of this study is to research the PCK of a technology teacher.

According to Shulman (1987), PCK includes special attributes that a teacher possesses, which help him/her to guide a student to understand content in a manner that is personally meaningful. Shulman (1987), having identified teacher knowledge as central to teacher quality, developed a seven-part classification of teacher knowledge built on elements that include knowledge of subject matter; pedagogical content knowledge; general pedagogical knowledge; knowledge of curriculum; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational aims, purposes, and values. In contrast, Cochran, King, and deRuiter (1991) were interested in four elements:

- Knowledge of the subject matter
- Knowledge of learners
- Knowledge of environmental contexts,
- Knowledge of pedagogy.

(cf. Veal & MaKinster, 1999; Smith & Neale, 1989).

Another alternative conceptualization of PCK was developed by Magnusson, Krajcik, and Borko (1999), which is helpful in clarifying this special form of a teacher's professional knowledge by proposing that PCK is made up of five components. In their view, an experienced teacher's PCK encompasses his/her:

- Orientations toward teaching (knowledge of their subject and beliefs about it)
- Knowledge of curriculum (what and when to teach)
- Knowledge of assessment (why, what, and how to assess)
- Knowledge of students' understanding of the subject, and
- Knowledge of instructional strategies.

PCK can further be viewed as a set of special attributes that help someone transfer the knowledge of content to others in a manner that will enable them to develop it in a personally meaningful way (Geddis, 1993; Shulman, 1986a, 1986b, 1987; Van Driel et al., 2001). Cochran, King and deRuiter (1991) defined PCK as the manner in which teachers relate their PK to their subject matter knowledge in the school context, for the teaching of specific students. The CK of PCK also implicates both Western and indigenous forms of technological knowledge. Hence, teachers also need to integrate indigenous technologies, understand their nature, and work to address the technological bias toward them (Gumbo, 2000; Maluleka, Wilkinson, & Gumbo, 2006).

There is a strong research history in the Technology Education community about pupils' attitudes toward technology (PATT) (Ankiewicz, Van Rensburg, & Myburgh, 2001; Burns, 1992; Rennie & Treagust, 1989; Van Rensburg & Ankiewicz, 1999; Volk & Wai Ming, 1999), but less related to PCK, which therefore presents an opportunity for research in technology education. The findings of a study by Rohaan, Taconis, and Jochems (2008, 2009) revealed that a link exists between teachers' knowledge and learners' concept of and attitude toward technology.

Jones and Moreland (2005) suggested that teachers require a clear understanding of the nature of technology and the conceptual and procedural aspects of the different technological areas. Reddy, Ankiewicz, De Swart, and Gross (2003) contended that technology teachers' inability to make technological experiences cumulative, purposeful, and empowering resides in their inability, for example, to see the inter-relationship between technological content knowledge, skills, attitudes, and values and technological capability.

In this article, the authors draw from this literature to continue the research into PCK in the context of technology education.

Research Design

A convenience sample of four schools was selected to become case studies, two in a city, one in a small town, and one in the countryside. In each case, the Head of the Technology Department was approached, and in two cases this person became the participating teacher, and in the other two cases, teachers in the department were delegated to be involved. In all cases, the participants were identified as expert teachers and were willing to cooperate.

A convenient day was negotiated with each teacher; during which time they would be teaching a lesson that could be observed and the teachers had time free for interview and discussion. Classes were observed by both researchers, in order to help validate the data; an observation schedule based on the elements of PCK derived from the literature was used. Observation is deemed important to counter possibilities of bias that could emerge during interviews (Kelly, 2006).

In general, observation was followed by the interview. An in-depth interview can be a qualitative research technique involving intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation (Boyce & Neale, 2006). The goal of an interview is to deeply explore the respondent's point of view, feelings, and perspectives (Guion, 2009).

Also, documents and resources used by the teachers were analyzed. According to Silverman (2005), qualitative researchers analyze a small number of texts to understand participants' categories and see how they are used in concrete activities.

Data analysis began with the interview data, adopting a variation of the coding strategy used by Marshall and Rossman (1999). This involved a stepped process moving from a general approach of listening to the recordings to initially develop themes and codes to noting the themes from the transcribed data, and then detailing the themes. The variation on this coding strategy was the use of analyst-constructed typologies, which were based on the principles of PCK developed from the literature. These typologies became the categories for analysis, but not exclusively so, in order to allow for emergent themes. The analyst-constructed themes were subject matter, curriculum, assessment, learners, pedagogy, educational context, educational aims, purposes and values, and indigenous dimensions.

Once the audio transcripts were analyzed, they were integrated with the teaching observation notes, the document analyses and incidental personal memos that the researchers had been keeping (Marshall &Rossman, 1999). The outcome was four integrated narratives about each of the cases; an alias was given in order to protect the teachers' identity.

Findings

In this section, the findings from the different sources of data are presented. Initially, each of the four cases were contextualized, noting some features of the observations that were made, and this was followed by a presentation of findings.

1. Morris

Morris, one of six technology teachers in a rural school that had approximately 700 students in Years 9-13, is 50 years old and has taught for 10 years; originally he was a mechanic.

This teacher was observed in a Year-10 class of 20 male students who were completing folios and final projects. The emphasis on folio work was in preparation for to the following year, that is, eventually to develop more significant portfolios to accompany projects. The teacher gave specific directions to students, including a handout pro forma to complete. This assignment was to be completed by the next class.

After 15 minutes of discussion, the students moved into an adjacent workshop to work on their projects. Without direction from the teacher the students continued their work. The atmosphere in the class was relaxed, and some stayed off task, but most got on with their work.

2. Fraser

Fraser is in an urban school with a population of 1800 students. The department has five technology teachers, a full-time technician, and spacious facilities. Fraser recently updated his teaching qualifications after teaching for 10 years.

We observed two classes of Year-10 students, which were team taught. Only one female student was present, who did not contribute to the class. Six male students were in an adjacent teaching room playing music from cell phones and a guitar.

After experiencing disciplinary problems with this group of students, the teacher decided to excuse them from the project, knowing that they would repeat the project during the following year. Many students wore their backpacks while in the workshop which hampered their movements somewhat, despite sufficient shelving for this purpose. Some students wore aprons, others not.

The class worked on a race car project. Each student fabricated a design from pine wood. The design specifications were met by three of the students, and all worked at their own pace with minimal supervision by the two teachers. The students were at different stages of their projects, some were consistently engaged, others were not. Some students approached the teachers for clarity on the challenging parts of the project. Eventually the teachers moved around the working stations to give support and guidance whenever needed, and to check if the projects were consistent with the specifications, and to call the roll. The teachers responded only to individual requests for assistance, and there was no conclusion to the lesson. The teachers instructed students to clean up and put tools back in order, however, there was no structure to cleaning and packing up. Some students left immediately at the sound of the bell. Others who stayed and cleaned, did not do a good job, and the researchers helped the teacher who had to finish cleaning.

3. Cam

Cam teaches at a coeducational state secondary school with about 1400 students in Grades 9 to 13, set in a town of about 20,000 that is surrounded by rural areas. The technology department includes seven teachers, and a new technology center is being built at the school entrance.

Cam teaches graphics in adjoining classrooms at the back of the school; the classrooms share a storage room of drawing equipment. One class of 22 Year-10 students included both females and males. The traditional seating arrangement had 28 old wooden single desks organized in rows; each with a drawing board angled on top. A laptop computer and data projector were used to present the activity; students assisted during setup, and a chalkboard was used to illustrate the drawing technique.

Cam, who has built a positive teacher-student rapport over time, demonstrated how he freely related to students. The class began with a “question of the day” (for e.g., favorite comfort food), and students responded to the roll call by answering the question. The atmosphere in class was quite relaxed while students worked on drawings while chatting and moving around freely. Cam kept the noise level in check. He also provided individual support to students and reminded the class of the following 4 x B’s sequence:

Brains: first try and think it through.

Board: use black board support to assist.

Bro: ask a classmate to help.

Boss: ask the teacher.

Very few students requested teacher assistance, and most problems were solved with the help of other students. The students stopped work, packed up, and departed while the teacher was talking to the researchers.

4. John

John teaches in an urban boys' school of 660 students with six other teachers in the Technology Department. He is 50+ and has been teaching for 20 years following a career as an automotive engineer.

A Year-8 class of 14 students (both male and female) was engaged in completing a range of projects. These students spent two hrs/week in the technology workshop at the high school to which they traveled by bus from their local primary school. They were in various stages of completing a range of projects based on their individual designs. The general design context was small souvenir items of wood or acrylic, which were to represent New Zealand. A small band saw, sander, and drill press were located on the wall benches, which the students were allowed to use, but they could ask the teacher to handle cutting with the band saw. A high level of organization was evident, and the teacher trusted the students who helped themselves to supplies as needed.

The teacher wanted to get the students "hooked" on technology, give them an attractive project to take home, and enable them to engage in some design work that included skills and materials knowledge. They completed a small portfolio, which was used to assess their work against Level 1 or 2 of the curriculum.

In the following section, the authors summarize their findings in terms of research questions.

Q 1: What do technology teachers understand as the nature and purpose of technology education?

Two teachers believed that skill development and vocational goals were the main purposes of technology education, and they thought that general problem solving and creativity skills were extremely important. In a practical way, these philosophies were evident in the school provision of vocational unit standards or more general achievement standards. The external measure of success in achieving the goals of technology education was competitive for some teachers; for example it helped teachers to discuss their students' work at standardization meetings, and some teachers feared being embarrassed by the quality of student work. Other teachers mentioned the measure was the number of "Excellences" that students achieved.

Regardless of the overall purpose, all teachers recognized that student conceptual development, through the medium of design and making, was a significant goal. They believed strongly that a major goal was to develop research and thinking skills in their students because that reflects the reality of life. Using a process to make decisions is a part of everyday activity, regardless of what vocation students eventually pursue: "[Students] still have to make informed decisions about what they're doing," "it reflects the reality of life and it provides a process of problem solving and thinking about things, [that is] coming up with answers and being able to discuss ideas with other people."

Underpinning this cognitive goal was the belief that all students have this ability. This was made explicit because there are some technology teachers who believe that their students have limited abilities, which prevent the development of cognitive skills and the documenting of design processes. One teacher who had been a national assessor and moderator stated: "If the teacher says, 'I had a bad group of kids this year, they didn't work hard,' instantly you know it's the teacher's fault."

Skills that could be generalized were prioritized by one teacher to include developing an understanding of how things are made, how they work, and how they are manipulated; he believed that "[students] can learn lots of other stuff, but that practical aspect is so, so important …"

The teachers emphasized the need to progressively work toward the development of thinking and research skills, considering that students have to start thinking and recording their ideas at least in Year 9. There was recognition also that the culture of the technology area is a significant factor: "If kids come into an untidy and dirty workshop expecting not to have to think at all from day one, having the attitude that we're just going to make stuff in here and the teacher just focuses on manipulative skills, then it becomes the culture of that department and is very difficult to break in later years."

One teacher placed the rationale for his student goals within a national context, recognizing that New Zealand is a small country that does not have a broad manufacturing base; thus, there is a need to be at the cutting-edge of inventing and making things by teaching design and technology in schools.

After a review which focused the technology curriculum more on students understanding of the nature of technology, a number of teachers considered that technology wasn't adequately developing or promoting a practical approach.

Q 2: What is the technology teachers' knowledge of the technology education curriculum?

The depth of understanding of the curriculum was polarized, with one teacher being involved in the national curriculum development and implementation and another aware of neither the changes in the new curriculum nor the extensive, available support material. This latter teacher offered students a range of unrelated projects which were also unrelated to the curriculum.

All the teachers were aware of the curriculum, particularly as changes (adding two new strands, the Knowledge and the Nature of technology) were being implemented at the time of this study. The degree of curriculum accountability has changed over time. When the terminal qualification was the High School Certificate there was no external accountability for technology teachers, but since the National Certificate of Educational Achievement was introduced to Years 11-13, specified standards and levels of attainment must be achieved, which are moderated, some of which are externally assessed.

Achievement standards and unit standards have caused a division among teachers. Unit Standards are vocationally aligned, skills oriented, competency based; they were developed by industry. Achievement standards are related to technological literacy. Some teachers offer both, and others offer only one.

One teacher had a unit standards class to teach, but believed that the students were capable of achieving more than a range of skills competencies:

> I thought, I am going to teach these kids Technology. So we did a huge project, and went through it using very much the same process that I would have done with Achievement Standards, slightly watered down in some areas, and probably with a slightly more practical focus . . . . These students are just absolutely firing ahead because they can do practical stuff and they can think. The folders they produced were equal to [those at] any school around that is doing Achievement Standards.

This teacher is contrasted with another who offers vocationally oriented unit standards in areas of furniture making, carpentry, engineering and automotive technology; however, he also offered a couple of achievement standards, "Because if we don't – then we would lose the students who need the achievement standards."

One argument for the offering of unit standards is that the achievement standards are too theoretical for the type of students attracted to technology. Conversely, another teacher believed that achievement standards offered a good balance: "When they first started a lot of the teachers felt that skills had been taken out of the achievement standards, but we've demonstrated that there's plenty of room for you to make something worthwhile, which is supported by relevant theory."

A related issue is the expectation from industry that standards above Level 2 must be offered in an industrial context. Historically, Level 1-3 was aligned with the last three years of schooling, Years 11-13. Consequently, the concern is that there are few standards now available for Year 13 students.

All teachers agreed that a sequence of technology activity is necessary in order for students to achieve to their potential by the end of secondary schooling at Year 13. Students are not usually admitted to Year 13 classes unless they have done preparatory work during the previous two years. There was a strong objection to students entering technology classes "because they want to come and make something, or because timetabling says so; well, they just have to go away."

Teachers perceived the sequence, however, to involve different elements. One teacher thought progress could be measured through student conceptual idea development, where in Year 9, students' different concepts are really just one idea that has been changed slightly, and the progress toward diversified thinking peaks in Year 13 with a range of genuinely diverse ideas.

For another teacher, progress developed through increasingly broad design briefs in which there were rigorous limitations on Year 11 students, but by Year 13, it is quite open and students can mostly do what they want. "In Year 13 students [take on] a client with a genuine issue that has to be solved. The teacher's role is to make sure it's not too expensive or out of control, [that the project offers depth], and that the stakeholders are available to talk to the students."

Q 3: What pedagogies do technology teachers believe are suitable to teaching technology?

Though some teachers found it difficult to explain their pedagogies, through discussion and observation it became clear that these varied. One teacher had a limited repertoire of strategies to use with students; mainly consisting of demonstrating skills followed by responding to individual needs. On the other hand, another teacher indicated a range of pedagogical strategies, which varied by year of the students, the goal of the activity, and the nature of the project.

Often, pedagogy was linked to the nature of the laboratory. One teacher emphasized that the physical state of the workshop affected students' attitudes and productivity, and if the workshop is dirty and untidy, then the students will respond in kind and not take pride in their work.

Another teacher used the physical arrangement of the workshop to complement pedagogies. Three hexagonal island benches with vices were available as was one long bench where the entire class could sit to work on their portfolios. This bench arrangement, according to the teacher, demonstrated a balance between theory and practice in the teaching of technology by enabling students to move easily between practical work and theoretical work on their portfolios.

One teacher commonly used small groups, which were observed to be engaged and cooperated in completing their projects. The teacher generally decided on the group members to ensure that weaker students were teamed with stronger designers, and like-minded students did not always work together.

All teachers mentioned some form of sequencing student work. It was a common perception that when students begin technology classes, they just want to do practical work, but they must have the understanding from early on that there is theory to be done.

One teacher particularly stressed that students only need to know what they need to know at a specific point in time. For example, "I'm not going to waste their time telling them how steel is produced because they don't need to know about it." Another teacher reinforced this just-in-time approach, by providing new information and demonstrating new skills to students when they need to know it, when the students see it as relevant. This teacher saw a fine line between teaching the students so they are not put under stress, but stretching their cognitive skills enough to make them think critically about what they were doing.

This teacher considered it important to initially develop a toolbox of hand skills, thus providing a foundation from which the students can move on to solving problems and dealing with briefs and stakeholders, and, finally, researching and presenting their work.

In contrast, the experience of another teacher was that if students are left to their own devices to work at their own pace, "they tend to back off a bit, so we need to keep onto them." But conversely, he also found that too much pressure on students to progress had a negative effect. He provided one sheet or one section of a workbook at a time to the students so as not to overwhelm them and thought this was effective.

The ability to have a flexible approach to classroom management and to respond to the needs of students at a given time was a common thread among the teachers' methods. All the teachers reinforced the need to have a personal relationship with students, though through observation this did not seem to be the case in reality with all the teachers. One teacher only taught content areas or projects that he personally found interesting and exciting.

Another teacher's focus was on the pedagogies of management, which "is quite difficult at Year 10, where one student is making a skateboard, another is making a scooter, and another a surfboard." He found this management a lot easier at the higher levels of study, for example in Year 13, because the students have stronger skills, a grasp of personal management issues, and a level of maturity that facilitates focused constructive work.

Q 4: What types of assessment activities do the technology teachers utilize and how are these related to the content?

Student achievement in the New Zealand curriculum in each subject is described by means of progression through eight levels of attainment, from entry to school to Year 13. Years 11-13 are the post-compulsory years and students in these years can achieve, accordingly, the National Certificate of Educational Achievement (NCEA) at Levels 1, 2, or 3. The NCEA is comprised of a range of achievement standards around which teachers can organize the learning programs they offer to their students. The Achievement Standards at Level 1 line up with progression indicators of the preceding years.

The coverage of technology education at middle schools (Years 7-8) in New Zealand is various, and students progress to Year 9 and secondary school with a range of different experiences and performing at different levels. Many secondary schools attempt to develop students' performance to Level 6 of attainment by Year 11, which corresponds to NCEA Level 1. This reasonably enables students to finish their secondary schooling in Year 13 with an NCEA Level 3 qualification, but teachers noted such progress was often difficult for students in years 9-10.

Within this context, the assessment strategies used by teachers were diverse, some involving the simple addition of numerical values for certain specified criteria seemingly unrelated to the formal curriculum, and others developed from assessment matrices that, in turn, were based on statements of levels of attainment. For all teachers, however, assessment was based on activity rather than a task (e.g., examination) designed specifically for assessment purposes.

One teacher saw progression through assessment as a theory – skills balance: "In Year 9, I'm probably looking at 80% skills and 20% theory; in Year 10, I'm probably presenting 60-65% skills and the rest of it is in the theory; and of course once they get to Year 11, the theory side of it is just as important as making it."

Another teacher's focus for assessment was to evaluate the students' level of planning, their understanding of the processes, and their ability to evaluate whether they have achieved their goals.

The teacher who used small groups extensively in his class organization also used the groups to determine peer assessments. One teacher was concerned about the reporting of student achievements to parents. This teacher did not explain achievement in terms of levels to the parent but instead explained students' work in terms of "excellent ability to select materials." At the upper secondary levels, the assessment structure is predetermined. The assessment of vocational pathways consisted of noting the mastery of skill achievement, and the assessment of Achievement Standards according to the standard and developed from the indicators of progression.

Q 5: What technological teaching and learning resources do the technology teachers use?

Resources used by teachers tend not to be books, unless some specific information is required. Technology education departments had libraries of technology education books, but no class sets, so these were used mainly as reference resources.

Colleagues commonly used each other as a resource to bounce ideas off, either visiting each other in schools or meeting at the regular opportunities for professional development. The internet was also commonly used, both in general terms as a source of information, and by specifically using the TechLink website, which has been developed with government support as a resource for technology teachers and contains a significant amount of curriculum support material. One teacher, however, was not aware of any available internet based support material.

Teachers maintained a constant lookout for resources, one stating: "I spend a lot of time in toyshops … I go into lots of home appliance and hardware shops." It seemed common for teachers to utilize a range of technologies that they coincidentally come into contact with.

In the senior curriculum, one of the objectives is for students to work with an external client; consequently, some teachers build a significant network of industry contacts for their students. One teacher used these contacts as his main resource.

Q 6: How do the technology teachers integrate indigenous technology in their teaching?

The teachers were generally a bit bemused about indigenous issues in their technology education program. Two teachers related the issue to the low numbers of Maori students in their classes, and so believed it was not important and did not incorporate it into their practice. However one teacher believed that when this was done properly, it can benefit many people: "Other students need to know about it but we also need to know about other things as well, so it's a matter of getting the mix right."

Teachers' understanding about the incorporation of indigenous technology seemed fairly superficial. One school included cultural heritage as a faculty goal each year, but examples which achieve that goal seemed elementary.

In a context in which students are encouraged to develop their own designs as solutions to problems, teachers seemed content to allow that latitude to encompass the inclusion of indigenous influences, often exhibited as a form of decoration that has cultural significance. There was no structure evident in any of the sources of data to permit a planned instructional sequence that would enhance all students' understanding of indigenous technology.

Conclusions

Teachers' PCK varied significantly in these case studies, which confirms the research that PCK is individual, unique, varies from class to class, and changes over time. As a framework for developing an understanding of teachers' PCK, the methodology used in this project seems to be appropriate. The observation of the teachers' context and of their teaching, the interviews, and to a lesser extent the document analysis provided for the collection of a rich data source for each teacher, and generally triangulated to provide valid results (Cohen, Manion & Morrison, 2007). Where triangulation did not validate data, for example, where the teachers' interviews did not match the observations of their class, the dual sources of data are particularly important.

Although all the participating teachers in this project were teaching the same year span of students and followed the same curriculum, quite diverse PCK was revealed across all the components: the subject matter that was taught, the interpretation of the curriculum, strategies for assessment, conceptions of the learner, and the purpose and aims of technology education.

The curriculum context in which this research took place possibly had a clarifying effect on teachers' PCK. A revised technology education curriculum was currently being implemented, which was perceived by many to present a more theoretical approach to the subject, at the same time that the opportunity for schools to offer vocational qualifications was being limited.

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Impact of Climate and Geographic Location on Moisture Transport in Wood Construction Walls and Implications for Selecting Vapor Retards

Kennard G. Larson

Abstract

This research effort studied two similarly built homes in two different geographic locations in an attempt to demonstrate the affect that climatic conditions have on the selection and installation of appropriate vapor diffusion retarders to control moisture transport in wood-framed structures. Much misinformation and suppositions exist regarding which vapor diffusion retarder to use, where to place it within the structure, and whether it is even necessary. As a result, uncontrolled moisture transport is often a significant factor in the premature degradation of a structure; this also adds to poor indoor air quality resulting from the growth of mold and mildew. Nine climatic values of temperature, humidity, and air pressure were recorded at 20-30 minute intervals at various locations within the wall cavities and the outside of both test structures, for a 12-week period from January to March. These data allowed the researchers to perform calculations to predict the potential for growth of mold or mildew within the structure. Ultimately, these data were further compared for moisture transport behavior with the simulation software WUFI ("Wärme und Feuchtigkeit Instationären), a PC program developed by the Institute for Building Physics in Germany and the Oak Ridge National Laboratories in Tennessee for calculating coupled heat and moisture transfer in building components.
Keywords: wood-framed house, sheathing, fiberglass insulation, moisture barriers, vapor barriers, intelligent vapor diffusion retarders, vapor diffusion retarders, moisture-thermal properties

Introduction

Moisture in buildings in the United States is considered one of the single, largest factors limiting the service life of a building (Lstiburek, 1991). In addition to the obvious liquid water, or rain, that can permeate the building envelope, the infusion of water vapor is of equal or greater concern because it is not visible or readily recognized. Water vapor can be controlled by placing the proper vapor diffusion retarder at proper locations within the wall components. A vapor diffusion retarder is typically, and less accurately, referenced in most literature as a "vapor barrier." However, a vapor retarder does not prevent all moisture from passing through as does a barrier (U.S. DOE, 2011).

Problem Statement

Incorrect use of vapor diffusion retarders ranks high on the list or controversial techniques and incorrect applications in construction (Laliberte, 2008). Much misinformation exists about which kind of vapor diffusion retarder to use, where it should be located, and if it is necessary. Illustrating this point, an Internet search at a do-it-yourself construction website revealed the following post: "Everything I've read says to put up a vapor barrier between the insulation and the drywall. They mention plastic sheeting, but nothing tells what (thickness) to use." The answers varied from: "Any plastic sheeting will provide a substantial barrier. The cheaper the better," to more accurate, scientific solutions (Tribe, 2007). Not only must vapor diffusion retarders limit moisture from getting into the construction, they also must let moisture out if indeed it does permeate the construction (Lstiburek, 2011). As such, the "plastic sheeting" mentioned in the blog as a solution, is not suitable in many climates. The goals of this research effort were to determine (a) the moisture transport activity in exterior walls of wood-framed construction, (b) the extent that geographical elevation above sea level affects the climatic and moisture transport behavior in similarly designed and constructed buildings, (c) if there is a preferred position/location for various types of vapor retarders (i.e., on the interior or exterior surface of the wood frame), and (d) which of the tested vapor retarder materials, if any, provides an adequate level of moisture control to inhibit the development of mold or fungus.

The test structures for this research were residential, single-family homes typical to the Midwest region in the United States. The Energy Efficient Building Association (EEBA) classifies this region as a "Heating Climate" region (Lstiburek, 2011) and recommends different moisture control methods for specific regions. Figure 1 shows Test Structure 1, later referenced as the Kearney Project, located in Kearney, Nebraska, with latitude 40° 44' N, elevation 652 meters above sea level. Figure 2 shows Test Structure 2, later referenced as the Laramie Project, located in Laramie, Wyoming, with a latitude 41° 3' N, elevation 2193 meters above sea level. Because the EEBA does not differentiate for elevation values above sea level, it was of interest to see if elevation and the impact of atmospheric air pressure may be a factor in potential for mold growth.

Wall Construction and Material Combinations

Figure 1. Kearney Test Project

Figure 2. Laramie Test Project

As is typical in most North American wood-frame construction (ICC 2006), the material assemblies of the exterior wall frames of both structures were constructed according to Table 1. The types of construction materials that comprise the wall assemblies are listed from exterior to interior, and the thicknesses (t) of various building components is listed in millimeters. In both test structures, the walls that were tested faced north. All measurements referenced in this paper are listed in metric equivalent values. The materials used in the construction of the walls of both test structures were identical with the exception of a kraftpaper vapor retarder and hardboard siding in the Kearney project versus a nonpermeable polyethylene vapor barrier and fiber cement siding in the Laramie project. Because the influence that climate had on mold development was the variable in question, these material differences were insignificant. Figure 3 and Figure 4 illustrate the different vapor retarders at the location of the measurements.

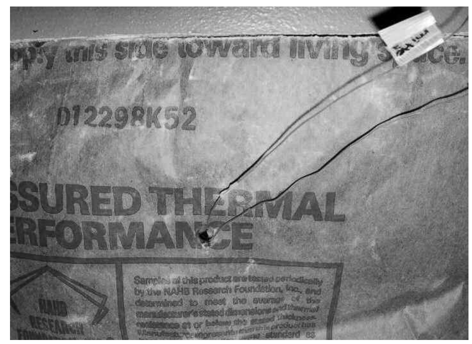

Figure 3. Kraftpaper Vapor Retarder, Kearney

Research Methodology

Data were collected using a "data logger" capable of capturing and storing nine measurement values every 20 to 30 seconds in the computer memory. All data were recorded in metric units, and this collection continued for at least three months at each location. Data were downloaded to a spreadsheet to generate graphic

Table 1. Sizes and Material Types of Wall Layer Components of the Test Structures

Layer	t [mm]	Kearney material	t [mm]	Laramie material
Exterior paint		prepainted		1 coat latex primer 2 coats latex topcoat
Siding	10	"lapped" hardboard "Masonite Colorlok"	10	"lapped" fiber cement "Hardiboard"
Wind and water retarder		"Tyvek" (58 Perm)		"Tyvek" (58 Perm)
External sheathing	13	OSB	13	OSB
Insulation	89	R-11 Fibre glass batt	135	R-19 Fibre glass batt
Vapor retarder		kraftpaper	0,15	PE-foil (6 mil)
Internal sheathing	13	gypsum board (drywall)	13	gypsum board (drywall)
Interior paint		1 coat latex primer 1 coat latex topcoat		none

Figure 4. Polyethylene Vapor Retarder, Laramie

Figure 5. Data Logger and Interior Climate Sensors, Kearney

impressions of what was occurring within the walls regarding the development of moisture and the consequential potential for mold growth. Ultimately, anticipating the relative humidity (RH) on the inside surface of the oriented strand board (OSB) exterior sheathing was of interest due to the potential for mold growth at levels above 60% RH. For the Kearney project, the

Figure 6. In-Wall Temperature and Humidity Measurement Devices, Laramie

climatic data were collected for 12 weeks during winter 2006. For the Laramie project, the climatic data were collected for 12 weeks during fall 2004. For consistency, the measuring instruments were arranged in identical fashion in both structures, as illustrated in Figures 5 and 6. Care was taken to ensure that the same distances from reference surfaces were maintained.

Figures 7 and 8 illustrate location details and various positions of the sensors relative to the interior cavity of the wall and exterior atmosphere of the structure. The exterior temperature/moisture sensor is visible in Figure 7, while the Ahlborn data-logger, interior temperature/moisture sensor, and air pressure sensor are visible in Figure 8.

Table 2. Figure Code, Channels, Sensors, Values, Units, and Location of Sensors

Figure Code	Measure Channel	Sensor Type Temp	RH	Measured Values	Units	Location
i	M04	PT 100	Cond.	temperature and rel. humidity	°C %	air interior
i1	M00	Coup.		temperature	°C	air interior
i/e 0,0	M01	Coup.		temperature	°C	inner surface of drywall
i/e 0,5	M02	Coup.		temperature	°C	in insulation at 60 / 80 % away from ext. sheathing
i/e 0,8	M03	Coup.		temperature	°C	in insulation 40 / 50 % away from ext. sheathing
i/e 1,0/150	M05	PT 100	Cond.	temperature and rel. humidity	°C %	inside of the ext. sheathing and 150mm from ceiling
i/e 1,0/ 350	M06	PT 100	Cond.	temperature and rel. humidity	°C %	inside of the ext. sheathing and 350mm from ceiling
e	M07	PT 100	Cond.	temperature and rel. humidity	°C %	air exterior
pA	M08			air pressure	haPa	interior of room

Figure 7. Location of Exterior Climate Sensor

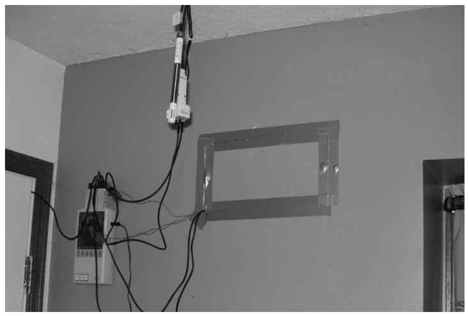

Figure 8. Room Climate Sensors and Sealed Cavity with Interior Sensors

Recording and Measuring Equipment

An Ahlborn data-logger, model 2590-9 recording instrument, allows logging of up to nine data inputs on channels 00 through 08. The data-logger was calibrated to record at 20-minute intervals for the Kearney project and 30-minute intervals for the Laramie project. The shorter interval was used to improve the accuracy of the measurements taken at Kearney in order to determine if the output graphic data might be easier to view. However, there appeared to be no significant difference. A typical display of the data-logger is observed in Figure 9. The nine channels recorded temperature, air pressure, and relative humidity at various locations on the structure.

The data sensors located throughout the construction included four PT100/condensator combination sensors to measure temperature and relative humidity, four thermocouple (Coup.) bimetallic temperature sensors, and one atmospheric pressure sensor. Table 2 describes which sensors were connected to respective channels, the variable that the sensor measured, the units of measurement, and the location of the sensors. The "Figure Code" column identified in Table 2 is for the purpose of viewing the "daily mean" values, relative to their location in the structure, in Figures 10 through 13. Rows of data in Table 2 are listed beginning with interior

Figure. 9 Ahlborn Data-Logger

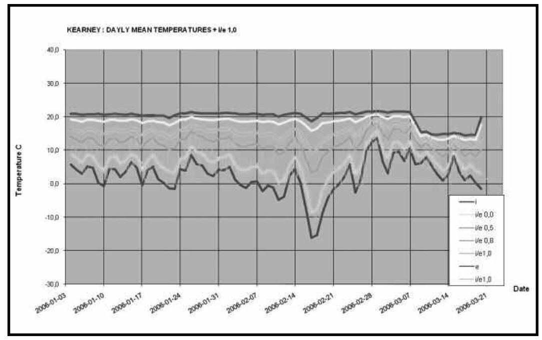

Figure 10. Temperature (C) from Interior to Exterior, Kearney

room measurement locations, moving throughout the wall, and ultimately to the exterior of the structure. The figure code column correlates to the "Location" column to observe where the sensors were placed in the assembly. For example, the sensor "i" was located in the interior of the room and measured temperature (degrees Celsius) and relative humidity (percentage) on channel M04 with a PT100 condensator instrument. In contrast, sensor "i/e 0, 05" was in the insulation but closer to the interior wall surface and only measured temperature (degrees Celsius) with a thermocouple on channel M02.

Measurement Results

After the data were collected, they were downloaded from the logger to a spreadsheet to generate the following figures. Figure 10 illustrates the daily temperatures for the Kearney project. The red line is the room interior temperature; subsequent colors measured temperature at increasingly further distances from the interior, progressing to the blue line, which represents the exterior temperature. The interior room temperature remained relatively constant with the exception of an extremely cold period beginning on Feb. 17, shown by the dark blue line. In contrast, the drop in interior room temperature beginning on March 7, shown by the red line, is attributed to the owner setting back the thermostat 7 degrees C (12 degrees F) during a two-week spring break.

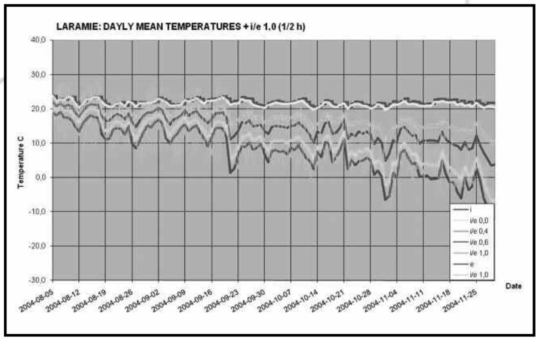

Figure 11. Temperature (C) from Interior to Exterior, Laramie

Figure 11 shows similar results with the exception of a somewhat higher and more variable indoor temperature. Possible explanations include perhaps the occasional use of an auxilliary heating device, such as a space heater or fireplace—they could also be the result of solar heat gain on sunny days.

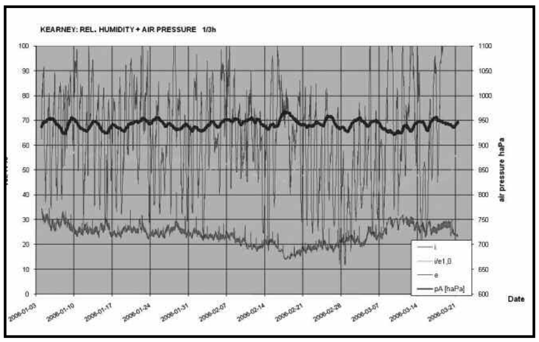

Figure 12. Relative Humidity and Atmospheric Pressure, Kearney

The critical consideration for mold potential is located at the interior surface of the OSB sheathing. Figure 12 graphs relative humidity (RH) levels at three locations: interior of room (red line), the interior surface of the OSB exterior sheathing (light blue line), and the exterior (dark blue line). In addition, atmospheric pressure (magenta line) was recorded in the interior of the room because of its influence on RH. Although the extremes in outdoor RH (dark blue) in the exterior atmosphere were great as noted by the wide range of readings, the RH within the wall construction (light blue), specifically on the inside surface of the OSB sheathing, was generally between 50% and 60%. At this low level of RH, no condensation would be expected, and therefore the development of mold would not be expected. A further observation is the relatively low RH within the living space of the room. It is likely that the lack of air tightness of the structure would explain this phenomenon by which moisture would escape via the high air exchange rate of the structure. Hagentoft (1996)

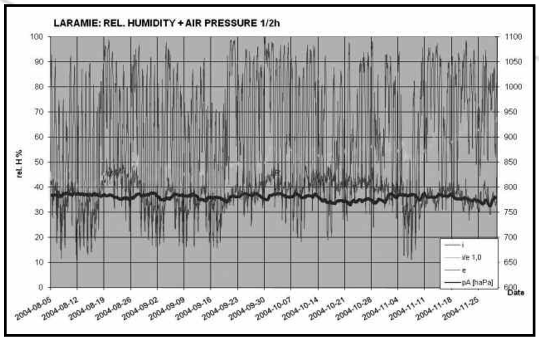

Figure 13. Relative Humidity and Atmospheric Pressure, Laramie

concluded similar results regarding air leakage carrying moist air into the construction that leads to unacceptably high values even for moderate indoor moisture levels.

Figure 13 demonstrates that low RH rates in the Laramie project at the interior surface of the OSB sheathing are attributed to the low air pressure (magenta line, ave. 750 haPa) at the relatively high elevation of 2193 meters above sea level. The low atmospheric pressure would lead to a high evaporation rate resulting in the low RH levels. Of special note is the increase of the RH from 40% in fall to 70 % at the beginning of winter. This would explain the appropriateness of using the nonpermeable PE vapor retarder at the much higher elevation without a concern for trapping moisture.

Simulation Models with WUFI

In an effort to determine if similar results could be attained through computer simulation, the researcher utilized the PC program WUFI ("Wärme und Feuchtigkeit Instationären Übertragung," loosely translated "Unsteady Heat and Moisture Transfer"). The program allows the selection of different types of vapor retarder materials, the location/position of the vapor retarder within the construction, warm or cold climate conditions, and geographic conditions including longitude, latitude, and elevation. The advantage of using such simulation is that it eliminates the need to physically install sensors within wall cavities, thus reducing corresponding damage to the wall surfaces. Simulation also allowed the researcher to conduct a full one-year calculation in a matter of minutes.

Tests were conducted using common types of vapor retarder scenarios, including no vapor retarder, kraftpaper, polyethylene film (PE), and "intelligent" film (PA) on the inside surface of the insulation. Tests were also done to determine if exterior air barriers, such as "Tyvek" or kraft-paper, would influence the results. Intelligent vapor retarders are made of polyacetate or nylon and have a variable permeability rate that allows moisture to pass through the film depending on temperature and moisture conditions. PA allows the material to keep most moisture vapor out, but it also allows moisture vapor to dry out if a high level does infiltrate the wall cavity. As would be expected in standard construction, the vapor retarders that were tested were located directly under the interior gypsum board and on the interior surface of the OSB sheathing. A cold Test Reference Year (TRY) was calculated for Laramie, but for Kearney both a cold TRY and a warm TRY were calculated because of the higher humidity and the concern for potential mold development in summer. A TRY represents a time period beginning January 1 and concluding December 31.

Though TRY climatic data for either Kearney or Laramie does not exist in the WUFI (North American version), climate data were available in the WUFI for Omaha, Nebraska, and Casper, Wyoming, respectively. These available climate data were deemed adequate because Omaha and Casper represent a more severe climate for potential mold growth than either Kearney or Laramie, respectively. The preferred indoor climate was designed at a temperature 20°C and a relative humidity of 30% and 50%.

Three typical examples of the 24 simulations are presented in Figures 14 through 16. These sample simulation graphs were selected because they represent the exact construction materials of the Kearney and Laramie projects assuming a cold climate, with the additional simulation for Kearney in a warm climate. Two monitor positions (measuring points) were installed to record the temperature and the relative humidity at the exterior (position 3: red) and interior (position 4: blue) sides of the insulation. In Figures 14 through16, the Y-axis represents the temperature C and RH% (Feuchte), while the X-axis represents time (Zeit) over one TRY or 1-365 days. In Figure 14, the crucial summer months from day 125 to day 250 show the RH values well below 50%, thus showing no risk of mold growth in Kearney. For a very short period beginning on day 92, the RH may increase up to 100% at the inside of the OSB, but this risk is minimal because the Kraftpaper is relatively vapor open.

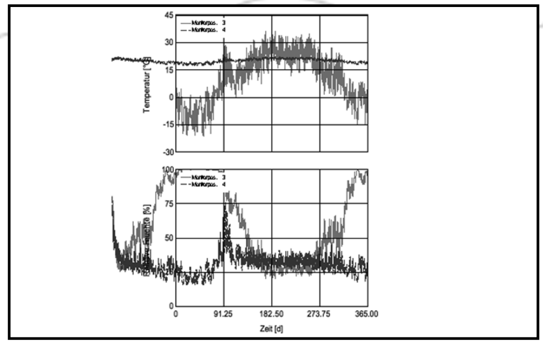

Figure 14. Kearney, Warm TRY with Kraftpaper Vapor Retarder and Indoor RH 30%

The simulation allowed the substitution of PE for kraftpaper in the Kearney project to see the how the results might vary. Thus, Figure 15 shows that even though PE foil would be an adequate vapor retarder in the winter (days 1-90 and days 275-365), during the summer the the PE foil would allow a higher RH of 50%-85% on both sides of the insulation, which would be a minor concern for mold damage. Therefore, kraftpaper is the recommended vapor diffusion retarder for the Kearney climate. It is relatively inexpensive and provides adequate potection without any risk of mold.

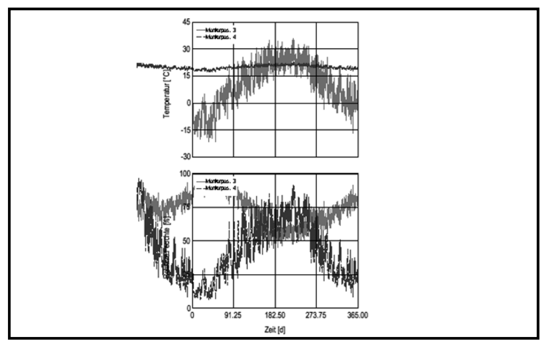

Figure 15. Kearney, Cold TRY with PE Foil Vapor Retarder and Indoor RH 50%

Figure 16 shows that PE foil is an acceptable vapor diffusion retarder for the Laramie climate, which has RH values below 50% in the

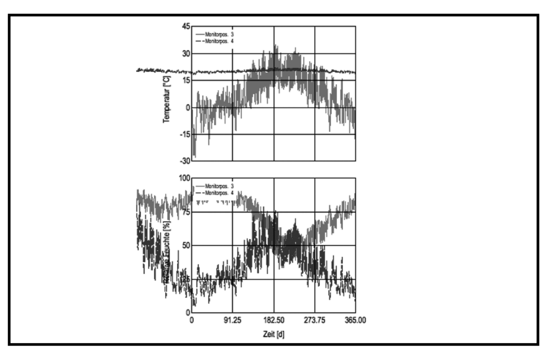

Figure 16. Laramie, Cold TRY with P.E. Foil Vapor Retarder and Indoor RH 50%

winter. Though in the summer the interior RH values can be above 50%, the high elevation and the associated low atmospheric pressure promotes rapid evaporation/drying and thus there is little concern for mold. This appears to be compatible with Lstiburek's recommendations (1991) for a maximum 35% indoor RH at 70 degrees F (20 C) during heating periods and when using PE foil as a vapor retarder.

The results of the WUFI simulations studies are shown in Table 3. It represents the results of the 24 simulations adjusted for the variables selected for the study. Data in the table are indicative of water per square meter (units in kilograms) (kg/m2) that could be expected on the interior surface of the OSB sheathing, depending on the type of vapor retarder. An assumption is made that values of less than 1 kg/m2 would be of little concern regarding mold development or condensed water. Values with an underscore are greater than 1kg/m2 ; they indicate that a particular vapor retarder would not be acceptable. Values in bold indicate the maximum result recorded for that test. Table 3 also illustrates that either in Laramie or Casper, there is little chance for mold to develop, regardless of the type of vapor retarder or whether a vapor retarder is even used. In contrast, it is apparent that while the type of vapor retarder used either in the Kearney or Omaha climate is of little consequence, not using a vapor retarder would be a genuine risk for mold. Regardless of the location of the vapor retarder or whether the climate data used was cold or warm, when using some type of vapor retarder, values were well within the acceptable limit of 1 kg/m2. Similarly, Levin and Gudmundsson (1999) concluded that when moisture loads are low, perhaps a vapor retarder is not necessary. However, indoor moisture conditions that exceed 2 kg/m3 will cause condensation on the inside of the external sheathing and high relative humidity in the insulation. This poses a significant potential for mold growth, structural damage, or both resulting from the degradation of the materials. Elevations above sea level are indicated in meters for all four cities. The data suggests that if an exterior air and moisture barrier, such as Tyvek or kraftpaper, was not used, then perhaps a vapor diffuser would not be necessary, explaining why many older homes without exterior air barriers do not have mold problems. Yet it is important to note that the advantage of exterior air and moisture barriers in reducing energy costs and preventing the exterior sheathing from becoming wet cannot be ignored.

Conclusions

The issue of mold growth and the consequential negative effect it has on structural damage to homes (e.g., wood members) as well as the impact mold can have on indoor air quality has become an increasing concern to builders and homeowners alike. This research concludes that the selection of proper vapor retarders to minimize the extent of damage is dependent on geographic location, elevation, and the choice of

Table 3: Need for Vapor Diffusion Retarders in Kearney and Laramie

Mineral Wool Insulation		**Values**		**Omaha**	Kearney	Insulation		**Casper**	Laramie	Insulation	
Water content				298 m El.	652 m El.	8,9 mm		1612 m El.	2293 m El.	12,5 mm	
[kg/m_]		**maximum**	start calc.:	0.16				0.24			
		interior VaporRetarder		none	kraft p.	PE	PA	none	kraft p.	PE	PA
Test Reference Year	warm	exterior Air Bar.	none	0.18	0.17	0.04	0.05	0.62	0.5	0.06	0.06
			(Tyvek)	**1.63**	**0.96**	**0.16**	**0.16**	**0.79**	**0.6**	**0.24**	**0.24**
	cold	exterior Air Bar.	none	0.19	0.17	0.04	0.03	0.53	0.43	0.05	0.06
			(Tyvek)	**1.96**	**0.96**	**0.16**	**0.16**	**1.1**	**0.78**	**0.24**	**0.24**
			none	0.19	0.17	0.04	0.05	0.53	0.43	0.05	0.06
			kraftp.	**1.96**	**0.97**	**0.16**	**0.16**	**1.1**	**0.78**	**0.24**	**0.24**

appropriate vapor retarders. It appears that the risk of mold is minimal at high elevations (such as Laramie) because of the rapid evaporation of moisture as a result of low atmospheric air pressure. It is apparent that a kraftpaper vapor retarder is adequate to control condensation within the walls of structures in geographic locations similar to Kearney; this can be accomplished with a minimal financial investment. In contrast, not to include a vapor retarder would pose a significant potential for mold growth in the Kearney climate. In any case, a vapor retarder at the inside surface of the insulation using foils that are open to vapor diffusion (e.g., kraftpaper or PA) is recommended. To conclude, during the winter, the temperatures in the Midwest United States are similar to those in Scandinavia. In contrast, during the summer, the United States has a tropical climate, very much unlike Scandinavia. Thus, the question of the location of the vapor retarder could not be directly correlated to previous studies from Scandinavia, some of which are cited in this article.

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