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W. J. Haynie, III, Editor
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Comparing Computer Usage by Students in Education Programs to Technology Education Majors

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Abstract

In the Fall of 1999, the College of Education and Psychology at NC State University undertook a survey of its majors to gain an accurate "snapshot" of many issues surrounding the use of computers and information technology as teacher education continues to grow into the 21st century. Specifically, the researchers were interested in how students use computers in leisure, work (paid), and school related activities. The survey asked specific questions about time and perceived skill levels associated with computer applications for the following areas: Internet (WWW), e-mail, word-processing, database/spreadsheets, presentation graphics, technical graphics (CAD), and statistical analysis. The study analyzed how students were using computers as an information technology source and perceived notions about how students spend their time on the computer. The researchers hope that this study will help provide a template for other institutions with teacher education programs, and especially technology education programs, plan their future computing needs and understand the role that information technology is playing in all disciplines related to teacher education.

Introduction

The 1990's have been an era of growth in computer usage for campuses across the United States. Green (1996) reported that by 1995, over one half of all college students and faculty had continuous usage and experiences with information technology (i.e. computers) and more than half of all college students and three-fourths of faculty had access to the Internet. Also, recent surveys (McCollum, 1997; Yahoo, 1998) continue to show an upward trend in the usage and perceived importance of computing activities.

Paralleling this trend of computing activities, post-secondary education has seen an increase in use of computers and information technology for K-12 schools. Between 1994 and 1998, the number of public primary and secondary schools with Internet access increased from 35% to 78% (NCES, 1998). Though this study focused specifically on Internet access, the use of computers and the Internet go hand in hand. This expanding use of the Internet and other information technologies in the public schools is one of the forces driving Colleges and Universities to keep pace with secondary education. The College of Education and Psychology at North Carolina State University (NC State) has been under considerable pressure to provide the most up-to-date information technology for use in classroom instruction and outreach activities. This pressure became even more acute when, in 1996, the State Board of Education adopted required statewide technology competencies for both current and future teachers (TAP, 1999). The result of this was considerable improvement of computing infrastructure in the College of Education and Psychology. Though every faculty member in the College has a computer and four computer labs are available for both student use and instruction, there are still unanswered issues concerning reasonable expectations faculty members can make concerning student computer access and proficiency when developing instructional materials.

In the Fall of 1999, the College of Education and Psychology at NC State undertook a survey of its majors for all disciplines, including technology education, to gain an accurate look at many of these issues surrounding the use of computers and information technology. The researchers were not only interested in the level and type of computing activity at the College and within the technology education program, but also whether it was justifiable to treat all logical groupings of students as having equivalent access and experience with computing. The faculty and administration wanted to know if computing needs differed between certain demographic elements (e.g. gender, age, and ethnicity) and the effect these have on computing needs. In order to rationalize these needs, the researchers decided to look at the following areas. First was computer ownership by students and how students use computers for school, work, and leisure activities. Work was defined to the students as being paid to work on a computer. Next, the researchers also wanted to find out the computing competency level of students and their perceived importance of specific computing skills that included the Internet, E-mail, word processing, spread sheets, statistical packages, presentation graphics, and technical graphics (i.e. CAD).

Methodology

The surveys for both the College and for technology education majors were designed to specifically gather information on the computing issues of interest. Computer ownership was determined by asking whether the respondent owned their own computer. In addition to ownership, the age of the computer was also of interest. Computer age can be roughly equated to computer capability (e.g., power) and is a simpler question to answer than specific features of the machine (i.e., RAM, hard drive capacity, CPU model and speed, etc.) or its cost new.

Another critical component of the surveys was computer usage. Frequency and duration are the most common scales used to measure usage (Deane, Podd & Henderson, 1998). Previous observations of student computer usage in the College revealed that duration of individual sessions on the computer were highly variable and, therefore, frequency was not likely to give a good measure of usage. For that reason, duration was used as the operational definition of usage.

The respondents were also asked to report on specific types of activities for which they used the computer. These computer-based applications, closely related to basic computer competencies, included electronic mail, World Wide Web (Internet), word processing, presentation graphics, database/spreadsheet, and statistics. Besides being asked to report their weekly usage, respondents were asked to rate their level of skill in each application area using a 5-point Likert-type scale (No Skill to Expert).

Survey Sample

As of the Fall of 1999, the College of Education and Psychology had 1695 undergraduate and graduate majors. A stratified random sample of one third of these majors (565) was mailed the student survey through the U.S. Postal Service. Stratification was done on the basis of department and year in school. The stratification was done by department rather than by program area primarily because of the small numbers contained within many of the specialized programs.

A second survey was developed that mirrored the college-wide survey. This survey was sent to students in technology education classes after the college-wide assessment was completed. A total of 86 students or 79 percent responded to the survey. In order to compare between technology education majors and other education majors within the College, information on other education-related majors was abstracted from the college-wide survey.

Findings

The surveys asked questions related to demographics for those that participated in the study. Table 1 shows the "key" areas of concern that were related to gender, race, and student status (i.e. full-time or part-time). The majority of respondents from

Table 1.

Key Demographics by Major

	Major	
Gender	TED	Other Ed.
Female	8	28
Male	43	7
Race		

White	40	30
Non-White	10	4
FT/PT		
Full-time	50	30
Part-time	1	5

undergraduate technology education majors were white males attending college full-time. The majority of undergraduate respondents from other education majors within the college were white females attending college full-time. Another important demographic was the age range of respondents. Majority of respondents were between ages 19-21, but technology education had no respondents 18 or younger, while 37% of other education majors responding were 18 or younger. Also, technology education had more respondents 22 or older than other education majors within the College. Nineteen technology education majors responded as being 22 or older, as compared to only eight in other education programs. See Figure 1 for a bar chart indicating the number of respondents for each age range for both technology education majors and other education majors within the college.

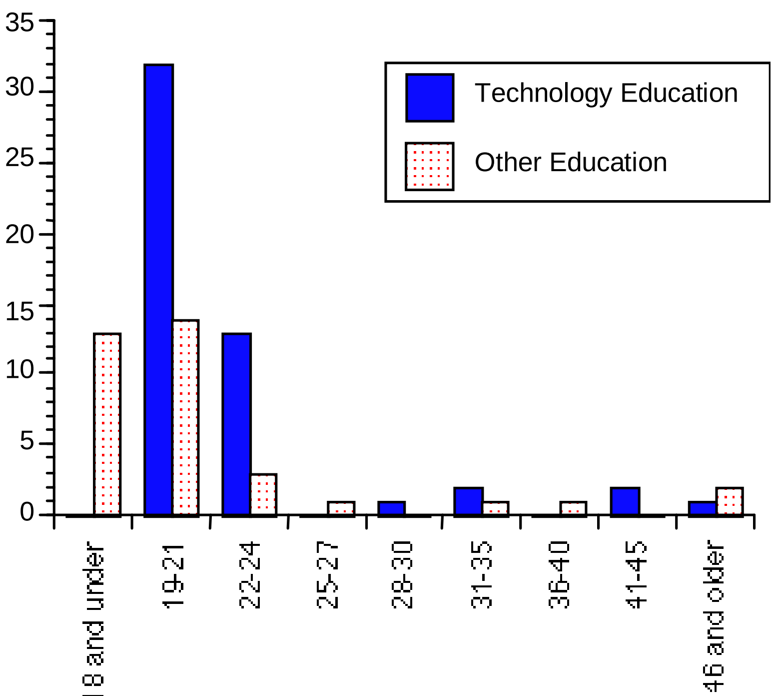

Figure 1. Respondents by Age

Eighty-seven percent of all education majors (75 respondents) indicated they have a personal computer they own and use. Breaking this down further, 43 (or 84%) of technology education majors own a personal computer, while 32 (or 91%) respondents from other education majors within the College own a personal computer.

The survey also identified the age of the computers that students own. Most computers owned by both sets of respondents were between one and three years of age. Figure 2 shows a bar graph indicating the age of the computer for technology education majors and other majors within the college and the total percentage for each computer age group.

The demographic statistics and computer ownership were analyzed to see if any interaction or significant difference exists between these sets of data. Using an ANOVA test (Alpha level of =.05), no significant interaction between majors for technology education and other education majors in either gender or race was found when looking at levels of computer ownership. Also, using this same ANOVA test, no significant difference in areas of computer ownership based on major, gender, or race was found for both groups participating in the study.

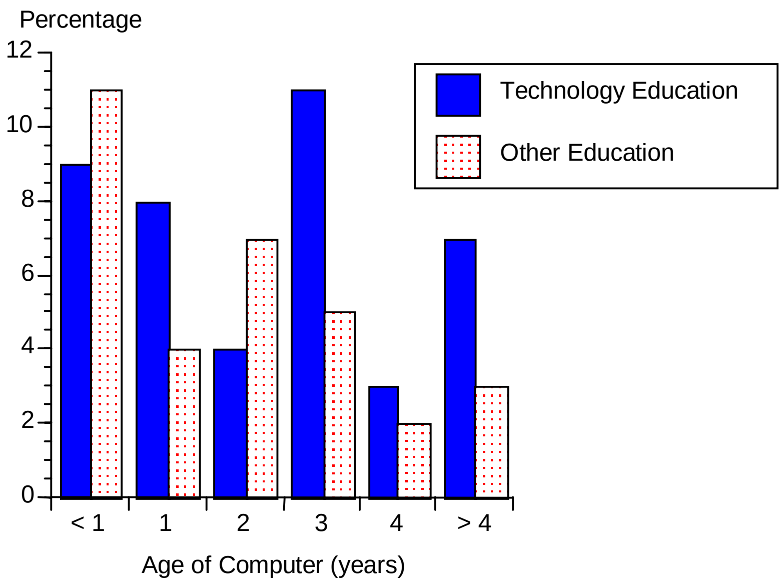

Figure 2. Computer Age

While performing ANOVA tests on relationships between computer age and demographic information, the researchers found no significant interaction between major (technology education vs. other education majors) for either gender or race when looking at computer age. Also, no significant difference in computer age based on major, gender, or race was found. But, significant positive correlation (p<.0065) was found between age of student and age of the computer for the total population that participated in the study.

The next series of questions asked in the survey looked at the number of hours spent using a computer. To better understand how students spend their time at the computer, questions were asked about the number of hours each week students use a computer for school, work, and leisure activities. Note, that work is defined as time being paid to perform a task outside of school assignments. Overall, technology education majors spend more time at a computer each week on one or more of the above mentioned three activities than other education majors within the College. See Figure 3 for a breakdown by student majors as to the total time spent using a computer each week.

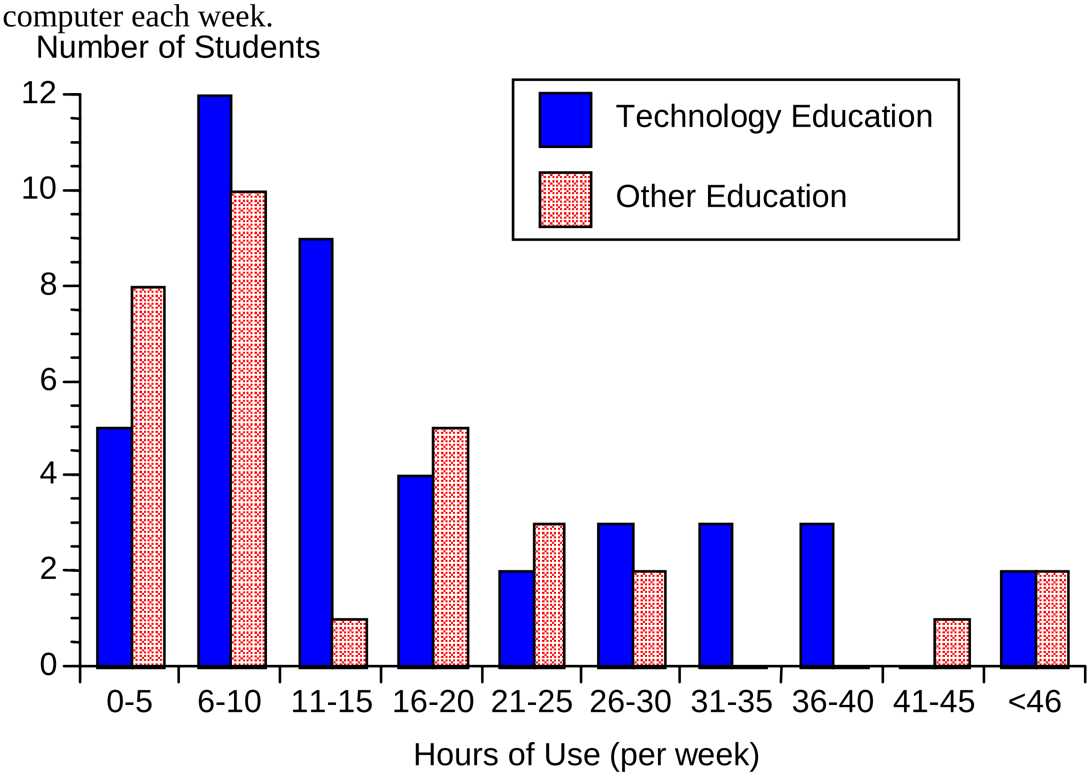

Figure 3. Total computer usage by Technology and other Education Majors

The researchers wanted to see if computing needs and time spent at a computer differs between year in school (i.e. freshman, sophomore, junior, senior) and how much time, on average, each year classification spend at school, work, and leisure computing activities. Table 2 shows the average (mean) hours spent per week by year in school (classification) for each of the three computing activities for both technology and other education majors. Note that freshmen were not a part of the statistical analysis for this study due to having no technology education respondents with that classification. To better analyze this information, Figure 4 shows a composite chart indicating the mean hours spent by technology education majors on leisure, work, and school-related computing activities per week. Figure 5 shows the same information for other education majors(non-technology) within the College.

The researchers tested the interaction between the total computer usage for all education majors combined together and in separate groups for technology education majors and other education majors in the College using an ANOVA test (Alpha level=.05).

Table 2

Average Hours Per Week Spent on Computing Activities for Technology Education Majors

Computing Activity	Yr. in School	Average(M) Hrs. per Wk. Tech. Ed/Other Ed.
School	Sophomore	8.75 / 9.33
	Junior	8.50 / 5.25
	Senior	10.8 / 4.58
Work	Sophomore	3.57 / 1.83
	Junior	2.60 / 0.00
	Senior	2.27 / 1.66
Leisure	Sophomore	10.26 / 9.83
	Junior	7.75 / 1.50
	Senior	2.81 / 0.91

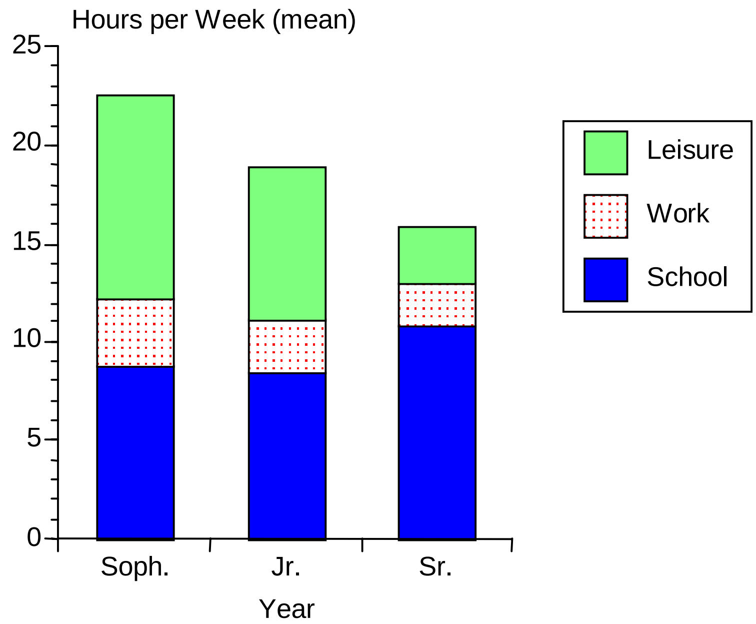

Figure 4. Computer usage by year in school - Technology Education majors

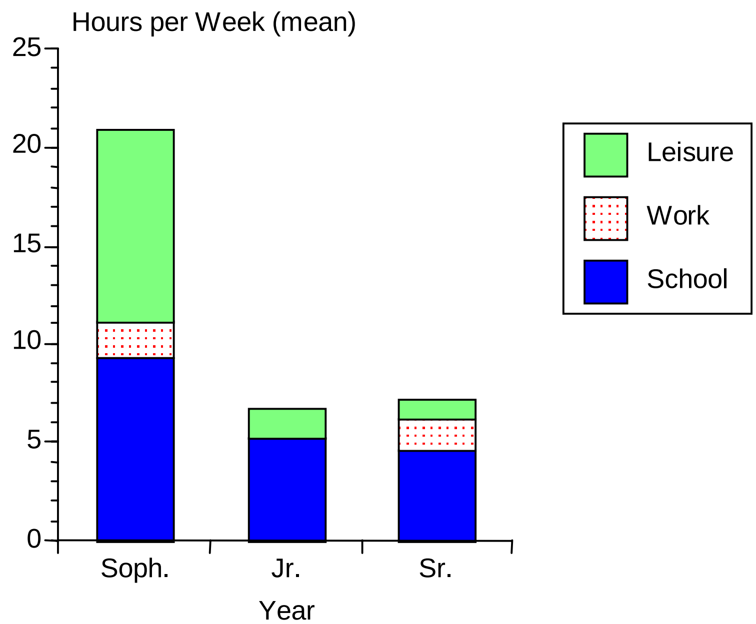

Figure 5. Computer usage by year in school - Other Education majors

No significant interaction was found in total computer usage between all participants and the year in school (e.g. sophomore, junior, senior). Also, no significant difference was found for total usage by year in school for all education majors, including technology education majors in this group. The researchers decided to breakdown each variable to see if any interaction takes place for the entire group for year in school and the independent variables of school, work, and leisure computing. Again, no significant interaction or significant difference was found between the students broken-out by year in school and the total population together as related to school and work related computing. Although there was no significant interaction in leisure usage by the total group of participants and their year in school, significant difference (p.<.0363) was indicated for leisure usage and by year in school between seniors and the other two student classifications.

The researchers wanted to focus in on seven computing areas identified in the review of literature (i.e. E-mail, word processing, data/spreadsheet, statistics, presentation graphics, and technical graphics (CAD)) for this study and see how technology education majors and other majors in the College are using these tools. Specifically, how much time do students spend each week doing tasks in these seven areas of computing and what is their perceived skill level for each of the seven areas. Table 3 shows the average number of hours each week technology education and other education majors spend on the seven computing areas. For a better visual comparison, Figure 6 shows a bar chart for these seven computing areas for both technology education majors and non-technology education majors that participated in the study.

Table 3

Average (M) Hours per Week Spent on Academic Computing Areas (n=86)

Computing Area	Tech. Ed. Majors	Other Ed. Majors
E-mail	3.90	3.77
WWW	7.73	5.48
Word Processing	3.66	4.81
Presentation Graphics	2.24	.25
Database/Spread Sheet	1.50	.53
Statistics	.12	.32
Technical Graphics (CAD)	6.41	.03

Using the ANOVA, no interaction or significant difference was found in E-mail usage and the year in school for the combined (total) group surveyed and the independent groups of technology education majors and other education majors within the College. Also, no interaction or significant difference was found between WWW usage and word processing and the year in school for the entire population and by major. Although no interaction was found for the hours spent each week using presentation graphics and year in school, significant difference was shown in the ANOVA test for year in school and presentation graphics (p<.0439). Also, significant difference was found for the total (combined) population and the use of presentation graphics (p<.0010). Seniors had significantly higher usage than freshmen and sophomores for this computing area.

The ANOVA and Duncan Grouping tests indicated that no interaction exists for the data when analyzing the number of hour's students spend each week, both as a whole

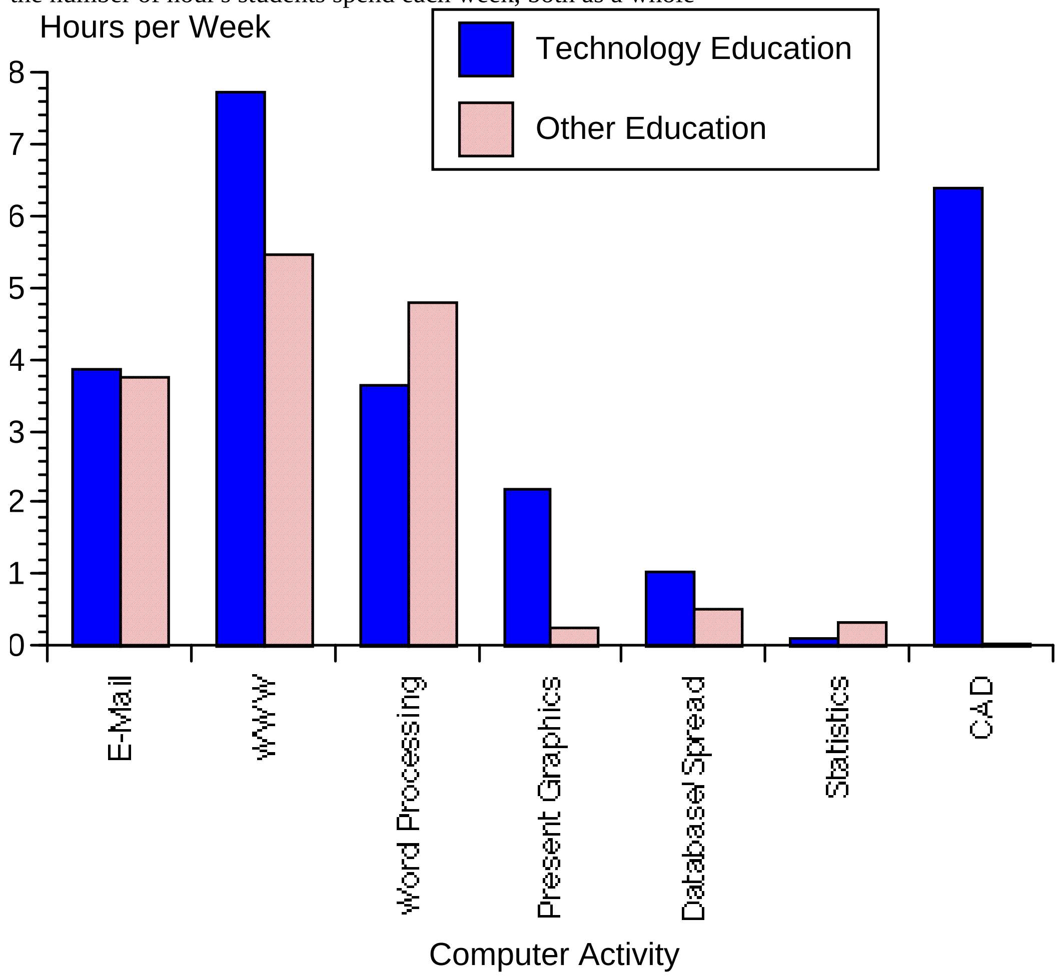

Figure 7. Hours per week in the seven computing activities for technology and non-technology education majors.

group and by year in school, on database or spreadsheets. The same held true for statistics, no interaction or significant difference was shown when comparing the total group and the number of hours each student spends on statistics software, as well as

dividing the group and comparing statistics usage and year in school. Although, no interaction was found between the entire group and CAD or technical graphics usage, significant difference was found (p<.0057) in the ANOVA test for CAD usage and year in school and even a greater statistical difference (p<.0001) when comparing CAD usage between technology education majors and other education majors.

The study compared the age of the participants to see if age correlated with any of the seven computing areas. Signification negative correlation between age and E-mail was found using the Spearman Correlation Coefficient test (R2=-.355, p<.001). Using this same test, positive correlation's to age and presentation graphics (R2=.337, p<.004) and CAD usage (R2=.354, p<.002) were also found. Significant positive correlation's were also found between WWW usage and E-mail (R2=.457, p<.0001), as well as between WWW and CAD (R2=.293, p<.012).

The study asked questions related to students' perceived skill level for each of the seven areas related to academic computing. Students were asked, using a Likert Scale, to rate their skill level for E-mail, WWW, word processing, database/spreadsheet, statistics, presentation graphics, and technical graphics (CAD). The scale used had 1- representing no skill for that area, 2- represented a novice skill level, 3- represented that the student had used the software with some competence, 4- represented proficiently and a regular user, and 5- represented that the student knows the area well enough to teach someone how to use it. The researchers used the data and compared the information to overall usage (time spent weekly for each area) of computing for each area and their perceived skill level for a particular area and compared that to the perceived level for other computing areas studied in this research project (i.e. E-mail, WWW, etc). A Spearman Correlation Coefficient test was conducted on computer usage and perceived skill for all seven academic computing areas using the entire population of both technology education majors and other education majors within the College. Significant correlations were found for the entire population on computer usage and students' perceived skill level for a given area. Significant positive correlation for usage and perceived skill level were found for E-mail (R2=.316, p<.006), WWW (R2=.269, p,.020), presentation graphics (R2=.461,p<.0001), database/spreadsheet (R2=.309, p<.008), CAD (R2=.741, p<.0001), and statistics (R2=.285, p<.019). Please note that the only computing area with no significant correlation was word processing.

The researchers also looked at correlations between computer usage for each area by the total population and compared the different areas to one another. Significant positive correlations were found between: presentation graphics skill levels and CAD usage (R2=.330, p<.005), database/spreadsheet skill levels and presentation graphics usage (R2=.301, p.<.011), statistics skill levels and presentation graphics usage (R2=.328, p.<.005), and CAD skill levels correlated with presentation graphics usage (R2=.469, p.<.0001) for the total population studied. Significant positive correlations were found between presentation graphics and statistics (R2=.515, p<.0001) and between presentation graphics and CAD (R2=628, p<.0001).

The survey also asked that students rate their opinion as to the computing skills needed for students in their major for the seven computing areas. A Likert Scale with a rating system of 1 to 5 was used with; 1-represented no importance, 2-represented little importance, 3-important to know, 4-represented very important, and 5-represented a skill proficiency that everyone needs. The researchers tested the data for correlations between students' actual usage (time spent per week) of each of the seven computing areas and how the students rated their importance to their major field of study. A Spearman Correlation Coefficient test was used for each of these computing areas for the total population of the study. Significant positive correlations were found between students' usage and their rating of importance for E-mail (R2=.425, p.<.0002), database/spreadsheet (R2=.285, p.<.015), and CAD (R2=.580, p.<.0001).

During the development of the survey instrument, the researchers wanted to investigate students' perceptions as to their skill level for each academic computing area and how students rate these same areas in order of importance to their major. Therefore, the researchers wanted to see if any significant correlation's exist between student skill levels for each of the seven computing areas and how they rated each area's importance. Again, the Spearman Correlation Coefficient was used for the total population to see if these correlations exist. After the test was conducted, significant positive correlations were found between skill level and their rated importance for E-mail (R2=.461, p.<.0001), word processing (R2=.364, p.<.001), database/spreadsheet (R2=.366, p.<.001), and CAD (R2=.969, p.<.0001).

After analyzing the entire population of the study as one group, the researchers decided to break the survey participants into two separate groups, one group representing all technology education majors and the other group was comprised of other education majors within the College. These same tests for correlation were conducted looking at age of participants, computer usage, perceived skill level, and importance to a major as indicated by students for the seven computing areas. Once the population was divided into these two groups, tests were conducted to see if the age of students correlated with computer usage for the seven academic computing areas. A Spearman Correlation Coefficient test was conducted using the Alpha of .05 for acceptance as significant correlation. For the technology education majors, only word processing usage was found to be statistically correlated to the age of students (R2=.473, p.<.001). The group that represented other education majors in the college, excluding technology education majors, had correlation between age of student and E-mail (R2=.598, p.<.0004), as well as with age and WWW usage (R2=.525, p.<.002).

The study analyzed the data to see if any correlation existed between hours spent (usage) on each of the seven computing areas by major. For technology education majors, significant correlation was found between WWW (Internet) and E-mail usage (R2=.539, p.<.0002). Also, database/spreadsheet and presentation graphics (R2=.546, p.<.0002), as well as database/spreadsheet and statistics (R2=.434, p.<.005) had positive correlations. As for the other education majors, positive correlations existed between WWW and E-mail (R2=.350, p.<.053), database/spread sheet and E-mail (R2=.365, p.<.047), and statistics and E-mail (R2=.363, p.<.052).

Next, the researchers compared student usage (time spent) of each of the seven academic computing areas to their perceived skill level. This was done to see if student usage of a particular computing area was related to the answer they gave as their perceived skill level for that particular computing area. A Spearman Correlation Coefficient test was used for both technology education majors and other education majors within the College. Technology education majors had significant positive correlation between computer usage (time spent) and their perceived skill level for that same area in presentation graphics (R2=-.437, p.<.004) and CAD (R2=-.324, p.<.035) computing areas. As for other education majors, a positive correlation was found between computer usage (time spent) and their perceived skill level for E-mail (R2=.413, p.<.020), presentation graphics (R2=.380, p.<.045), database/spreadsheet (R2=.374, p.<.043), and statistics (R2=.377, p.<.043).

Analysis was conducted on the usage level (time spent) for each of the seven computing areas as compared to students' rated importance for these areas. The researchers wanted to know if the number of hours spent on each computing area directly correlated with their perceived importance for that area. Technology education majors had significant positive correlation between usage and perceived importance for E-mail (R2=.526, p.<.0003). Other education majors had significant positive correlation between usage and perceived importance for database/spread sheet (R2=.474, p.<.008).

Finally, the researchers wanted to compare students' perceived skill level for each of the seven computing areas to their perceived importance. Again, a Spearman Correlation Coefficient test was used to determine if skill level and rated importance were significantly correlated for any of the computing areas. Technology education majors had significant positive correlation between perceived skill level and rated importance for E-mail (R2=.476, p.<.001), word processing (R2=.355, p.<.019), and database/spread sheet (R2=.367, p.<.016) computing areas. Correlation for these three computing areas indicated to the researchers that for E-mail, word processing, and data/spread sheet computing areas, technology education rated their perceived skill level and importance for these areas high and important to their major. Other education majors in the College had significant positive correlation between student perceived skill level and students' rated importance for E-mail use (R2=.465, p.<.007), database and spreadsheets(R2=.389, p.<.027), and statistics (R2=.429, p.<.014).

Conclusions and Recommendations

The researchers for this study decided that conclusions for this study could only be related to the population surveyed at NC State University due to the population sampled and the uniqueness each College or University has in the areas of academic computing. But, some conclusions are worth discussing and questioning to the profession at large due to their unique nature that separates technology education from other education majors within the College. First, from the review of literature, there is a growing trend of computer usage and perceived importance for computing literacy in our Colleges (McCollum, 1997; Yahoo, 1998). This trend parallels public secondary schools for which these future teachers (i.e. technology education) will seek employment. Therefore, Colleges and Universities need to seek better ways to meet demands in student computer ownership, usage, and attitudes of students towards computing. Second, from the demographic data, white males are still dominating our technology education classrooms but, as indicated in the research for this study, there are no differences in computer literacy between race and gender. Therefore, computing and teaching subject matter based on computer technology could become a focus of recruitment and not negatively impact the goal to bring a more diverse population into the profession.

As for the information found within the study through statistical analysis, technology education majors seem to spend more time on the computer, overall, than other majors within the College of Education and Psychology at NC State University. Also, when breaking-out time spent on leisure, work, and school-based computing, when students start college, more time is spent on leisure computing activities and less on school-based computing activities. But, as students rise in classification (year in school), less time is spent on leisure-based computing and more time allocated for school computing. Overall, technology education students spend more time than other education majors in E-mail activities, presentation graphics, database/spreadsheets, WWW (Internet), and

CAD. Other education majors, as compared to technology education majors, used word processing and statistics more.

When considering all education majors that responded to the survey, both technology and other education majors, the following correlations were found throughout the study. First, presentation graphics is a key indicator of software usage in the other computing areas. If students use presentation graphics, they are also more likely to use software for other computing areas mentioned in the study. Next, significant correlations were found between student usage and their rating of importance for E-mail, database/spread sheet, and CAD. This indicates that students use these computing areas more per week and therefore, rated their importance higher for their major. Students also had the tendency to rate their perceived skill levels high and importance to their major for the computing areas of E-mail, word processing, database/spread sheet, and CAD. This indicated that the higher students rated their skills for these computing areas, these same areas were rated high as important to know for their major area. When the researchers divided the population by major (technology education and other education majors), age correlated with E-mail for both groups and WWW usage correlated with age for other education majors. This indicated that some age groups, as identified within the study, use these computing areas significantly more that other age groups for the same computing area(s). Other correlations found for the two groups studied concerning E-mail and WWW can be explained by understanding that if students spend time on the Internet (WWW), they are more likely to spend time using E-mail. Also, if students are using E-mail, then they are more likely using the other computing areas such as database/spread sheet, statistic, and the Internet (WWW).

Technology education majors had significant correlation between usage and perceived importance of E-mail. This indicated that E-mail was significantly reported as being important to their major and also, since the correlation was positive, indicated that students spend, on average, more time at this computing activity. Other education majors within the College had significant positive correlation between usage and perceived level of importance for database/ spreadsheet. Database and spreadsheet usage by students was deemed important by education majors and this directly correlated with the amount of time they spend doing this computer task each week.

Throughout the study, two correlations were found repeatedly The first is a negative correlation between E-mail usage and age. Overall, it seems that older students are less likely to use E-mail than younger students but considered it's perceived importance to be high for the teaching profession. The second correlation that kept coming up during the analysis of the data was the link between database/spreadsheet and statistics. This can be easily explained by understanding that most statistics are first started in spreadsheets to organize data. Therefore, this correlation has no true meaning and it just reflects the computing process and how these areas are all tied together in many cases.

In conclusion, more research is needed in this area to better understand our students' computing abilities and how they perceive the usage of computers in their everyday activities. Also, by conducting studies on student computing, our profession can better understand current and future trends of student computer usage and help to better facilitate their needs. Overall, the computer has become a tool that is required for all of our technology education majors to know and use, and later, incorporate into their classrooms as we teach a new generation the knowledge needed to be technically literate for the 21st century.

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Creativity and Problem Solving in Technology Education

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Creative problem solving is intrinsic to the study of technology. Technology is a human creation--it begins with a problem and progresses through the cumulative efforts of people who apply their creative abilities to satisfy the needs and wants of society. Throughout history problems have been solved through the development and application of technology.

The accumulated knowledge of generations has expanded the base of information from which technology has evolved. The evolution of technology, assisted by a dramatic increase in our knowledge base, creates a new understanding that is constantly changing the context of the problems that people face and the solutions that are possible.

A broad base of creative problem solving skills is essential to a complete understanding of technology. Students who are able to utilize creative problem solving skills are gaining direct experience with a process that is foundational to technology. By engaging students in creative problem solving, students will develop the skills needed to learn and change with a dynamic technological environment.

Technology begins with a problem and develops as it responds to the needs and problems in society. As a need becomes evident, if it is important enough, and if the need has sufficient reward for a solution, then an individual or group will undertake the search for a better way. The processes that technologists have used to find better ways of doing things were researched by Harold Halfin. He studied eminent technologists and found that they used the following processes to solve technological problems.

1. Defining the problem or opportunity operationally
2. Observing
3. Analyzing
4. Visualizing
5. Computing
6. Communicating
7. Measuring
8. Predicting
9. Questioning and hypothesizing
10. Interpreting data
11. Constructing models and prototypes
12. Experimenting
13. Testing
14. Designing
15. Modeling
16. Creating
17. Managing

(Haflin, 1980, p.230)

Figure 1. Intellectual processes used by technologists.

It is helpful to have these processes identified because the same processes should be used in creative problem solving activities in the technology education classroom. Students should be aware of these processes and technology education activities should be designed to insure that all students develop skills in using each process.

Problems range in level from simple to complex and can be solved using a wide variety of strategies. Some problems are well defined and rules are easily applied to find an answer. Creativity is not a requirement to solve these types of problems.

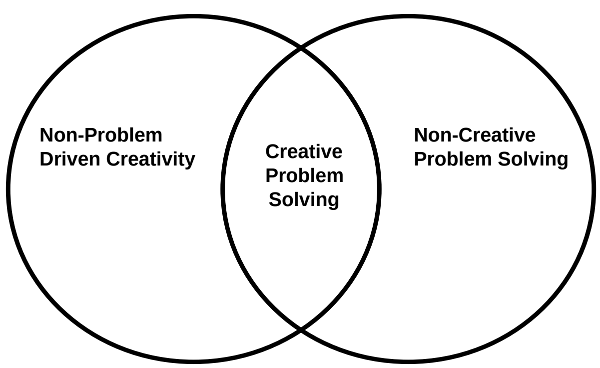

Figure 2. The relationship between creativity and problem solving.

It is also possible to be creative without solving a problem or being directed by any search for a solution. Pure artistic creativity could be an example of this type of creativity. Non-problem driven creativity is outside the domain of creative problem solving in technology. However, the practical orientation of technology suggests a search for a better response to a problem.

Creativity and problem solving intersect at a point where the problem requires the use of creativity to accomplish the best solution. The problem requires a unique solution and the consideration of a variety of alternative possibilities to achieve the best possible result.

The Creative Factor

Some problems can be solved without the need for creative behavior. Others problems may require highly creative solutions. The range of problems from simple and concrete to abstract and complex, determines the level of creativity that is required to solve the problem. It is the use of creativity in solving the problem, i.e. the creative factor, determines the success of a solution.

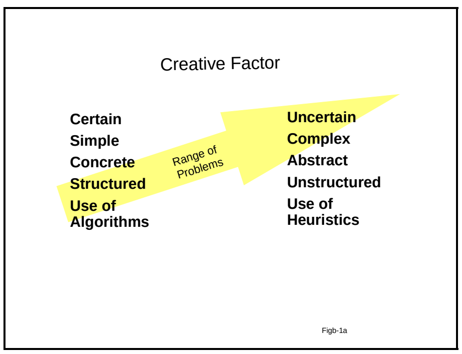

Figure 3. The creative factor.

Creativity requires that something new be created from what exits. This involves combining variables in a new way, or creating new variables out of what was seemingly a constant. When the problem parameters and possible solutions are certain, the need for creative behavior is low. Structured problems often imply probable solutions and many technological problems have algorithms designed by experts that lead to solutions. The need for creative behavior increases when solutions require new tools, materials, or processes. Creative thinking increases in importance when the variables that can be manipulated are uncertain or problem parameters are not well defined. When it is difficult to define the problem, the solution becomes more abstract, therefore the creative factor increases.

Types of Creativity

Creativity can be exhibited in several different areas. Just because a person is creative in one area doesn't mean that they are creative in another. It is important to recognize that creativity can be exhibited in a number of different ways. Howard Gardner's theory of multiple intelligences can easily be applied to areas in which a person can exhibit creativity. Gardner argues that creativity is not a "singular capacity for originality applicable to whatever people do." (Gardner, 1992, p. 72) In solving technological problems it may be helpful to utilize a team approach where individual members have creative abilities in the following diverse areas.

Language--poets and lyricists, writers and orators;

Math and Logic--scientists, mathematicians, and others who use logic;

Music--musicians, appealing combinations of sound;

Spatial Reasoning--designers, craftsman, engineers; skill in building things, ability to envision, assemble, and take apart mechanical devices;

Movement--athletes, dancers, actors, potters, etc.; ability to reason with and use their body in innovative ways;

Interpersonal--leaders, politicians, teachers; the ability to understand other people, what motivates them, how to work effectively with them;

Intrapersonal--psychologists; knowing oneself, knowledge of strengths and weaknesses, self-discipline and the ability to persevere.

(Gardner, 1992, pp. 73-79)

Figure 4. Multiple intelligences.

Creativity in Technology

Creativity in technology can manifest itself in many ways and there are many unique opportunities for the development of creative problem solving abilities in technology education. It is exciting to view technology education from the perspective of the creative opportunities that exist in each area of study in technology.

communication: the fundamental creative challenge in communication is to develop a system to exchange meaning between people and or machines over time and distance.

construction: the fundamental creative challenge in construction is to use appropriate materials to provide structures for protection from the environment, and to span distances to facilitate transportation.

manufacturing: the fundamental creative challenge in manufacturing is to produce goods that satisfy a need, in the most efficient and effective way.

transportation: the fundamental creative challenge in transportation is to move people and/or materials in the most efficient and effective way.

Figure 5. Creative challenges in technology.

Sam Micklus, founder of the international creative problem solving competition, Odyssey of the Mind, indicates that the statement of the problem is the most important part of encouraging a person to think creatively. His example of a poorly stated problem is "design a boat to cross a small pond." To avoid obvious and stereotypical solutions, problem statements must be broadly stated and encourage students to develop a variety of possible solutions. A preferred problem statement would be, "design a device which will transport one individual across a pond." (Micklus, 1984, p.31). This statement opens the imagination to envision a wide range of creative possibilities.

Assessing Creativity

Creativity in technology is manifest at several levels. At the highest level are those breakthroughs which have never been done before and have a significant impact on society. Creativity at this level can be studied in the form of case studies and individual biographies. Students need to be exposed to this dimension of technology to challenge and inspire them to develop their fullest potential.

Public school students will probably not be capable of achieving this highest level of creativity because they lack the requisite experience and knowledge. However, creativity can be displayed by every individual. Creativity is a human quality that invites development and improves with experience.

It is important to recognize that what is creative to one individual may not be creative to another. If behavior is unique and novel, i.e. it has not been previously demonstrated by that individual, then it is creative to that individual. It is important to encourage this creative development, to sustain higher levels of creative development in the future.

One difficulty in the classroom relates to assessing the creativity exhibited by students in technology education. Criteria to assess the products of creativity has been developed by Besemer and O'Quin. Their research developed the Creative Product Analysis Matrix (CPAM) to help analyze and assess the results of creative efforts.

> 1. Novelty--a product must be novel before it can be creative; combining elements in a way that breaks through tradition and leads to a new perspective or way of viewing reality. For a product to be creative it must be original, germinal, and startling. It must use new ideas, concepts, processes, and/or materials.
> 2. Resolution--somehow mere oddities and serendipity must be weeded out. A product must fit the demands of the situation and the needs of the creator. The product must be logical, useful, appropriate, and functional to resolve the problem identified.
> 3. Elaboration and Synthesis--creative products also have an aesthetic component that reflects the values associated with the solution. The simple and elegant solution to a complex problem, the beauty of function, the well-crafted solution, and the organic beauty of a harmonious solution are all examples of this dimension of creative products.
>
> (Besemer and O'Quin, 1987, pp. 344-347)

Figure 6. Creative product assessment matrix.

Professional judgment is particularly important when undertaking an activity designed to use creative problem solving. Creativity is a fragile quality that requires encouragement and support. The focus for the teacher must be on the individual. Creative abilities reside within each person and await the proper circumstances to be developed. Insights unique to the individual are creative and have the same excitement of discovery as the breakthroughs of great inventors. Without encouragement the flame of creativity is easily extinguished. The criteria identified by Besemer and O'Quin can be useful to students to understand creativity and assess their individual progress and to teachers to assess the elements of a student's creative problem solving efforts in technology education.

Summary

Creative problem solving is intrinsic to the study of technology. Using the problem solving processes that technologists use can provide students with experiences that are fundamental to the study of technology. Creative talents exist in many areas that contribute solutions to technological problems. The challenge to teachers is to structure technology-based problems that develop creative talents. It is also important to assess creativity in a way that supports the excitement of individual discovery and encourages future creativity.

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