Volume 1 Number 1

Summer 2013

# The CTE Journal

An International Peer Reviewed Career and Technical Education Online Journal

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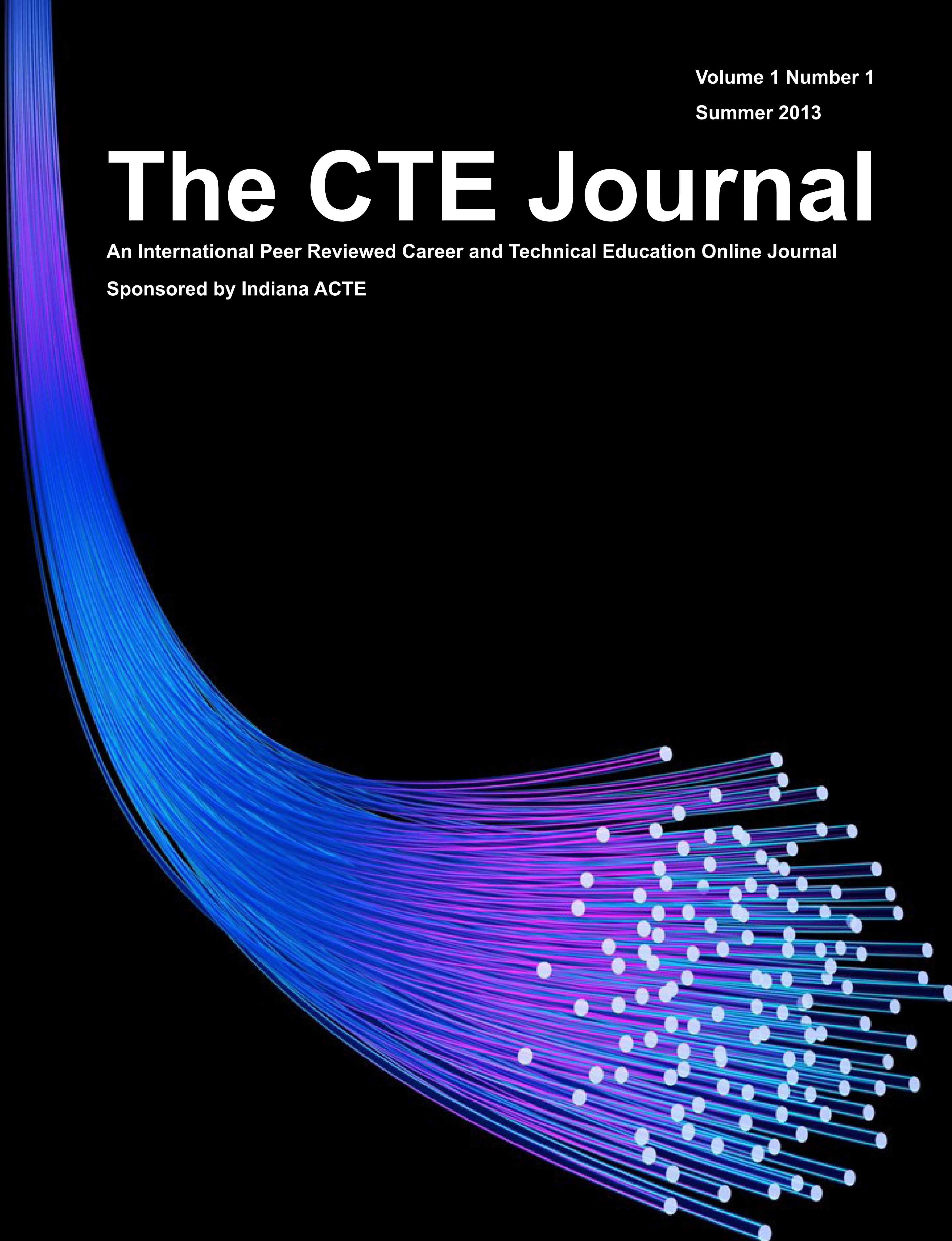

# The CTE Journal

**An International Peer Reviewed Career and Technical Education Online Journal**

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**Peer Review Board**

ISSN 2327-0160 (Online)
*Volume 1. Number 1.*

# Table of Contents

**Volume 1, Number 1, Summer 2013**

**Strategies for Establishing an Advanced Manufacturing Program in Urban Indiana High Schools**

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**Abstract**

This qualitative action research case study documents the procedure used by a first year teacher to make recommendations to administrators for a new Advanced Manufacturing program of study at the career center of a large urban high school in Indiana. The research conducted in this project focuses on three areas; program justification, selection of curriculum, and effective recruitment techniques. A review of the literature demonstrated the need for the program in this area and uncovered curriculum and recruiting options for the program. Further research was conducted through visits to three area career centers offering advanced manufacturing programs. Instructors and students were interviewed to determine perceptions and observations were made by the investigator regarding the facilities and instructional environment. When available, quantitative data were used to verify the perceptions of the interview subjects. Finally, input from career center directors was solicited through the use of an e-mailed questionnaire. The data collected were coded and analyzed and the results of this analysis were presented in the form of formal recommendations for the adoption of curriculum and recruiting techniques.

## Introduction

After over a decade of decline and stagnation, manufacturing in the United States is poised to make a comeback. A number of factors including rising transportation costs because of the current energy situation, increasing labor costs in formerly low wage regions, and increased domestic productivity are spurring this potential rebirth (Thompson, 2011). As manufacturing opportunities increase employers are faced with the challenge of finding qualified replacements for the experienced workers of the “Baby Boom” generation as they retire. Their departure from the workforce will create a significant demand for qualified replacements. The term “qualified” is important because even though the unemployment rate remains relatively high, manufacturers have been unable to fill vacancies in their workforce because available candidates lack the necessary skill set to perform in the current manufacturing environment (Stanczykiewicz, 2011). The term “middle-skilled” is being used to describe this new skill set. Additionally new workers are needed to meet rising production requirements (National Association of Manufacturers, 2010).

Approximately one half of the projected job openings in the state of Indiana in the 2006 to 2016 time period will require middle-skilled workers (National Skills Coalition, 2010). These workers must be highly adaptable and comfortable working in a dynamic environment. They must be technologically literate to effectively operate the automated systems, robotics and computers and computer controlled systems that are prevalent in modern manufacturing facilities (The Manufacturing Institute, 2009). Acquiring these skills typically requires more than a high school education but less than a traditional four year degree. Approximately 57% of Indiana's manufacturing jobs are classified as middle-skilled and 45% of the job openings between 2004 and 2014 are expected to be middle-skilled (Holzer & Lerman, 2007).

Clearly, this situation presents Indiana's secondary and post secondary education system with the challenge of providing adequate training for these middle-skill positions. The Indiana Department of Education has implemented an Advanced Manufacturing Career Pathway Plan designed to address this challenge (Indiana Department of Education, 2011). This plan combines three years of secondary instruction at either a participating high school or career center with an additional two year post secondary program of study at either Ivy Tech Community College or Vincennes University. Students completing this course of study will receive either Associate of Science or Associate of Applied Science degrees in one of four Advanced Manufacturing specialty areas. This study will help determine if and how the Advanced Manufacturing Career Pathway Plan should be instituted at a large, urban high school in Indiana.

## Literature Review

The review of currently available literature focused on three distinct and important aspects of implementing the Advanced Manufacturing program; justification for the program itself, development of an appropriate and engaging curriculum, and recruitment and retention of students. A summary of all research concludes the literature review. The results of this review are presented in the following sections.

### Program Justification

In a report prepared for the Skills2Compete-Indiana campaign, the National Skills Coalition (2010) provided the following summary of the middle-skill training program in Indiana:

> "Indiana has made significant investments in education and training for its workforce. However, those investments have not kept up with demand for middle-skill workers. Indiana must take proactive policy actions to align its workforce and education resources to better meet the state's labor market demand. Indiana must also make significant investments in programs that will train many more of its residents who are laid off, or working in low-wage jobs, for better middle-skill jobs and careers."

The report concluded that training at both the secondary and post secondary levels is a vital component in preparing the workforce for new middle-skilled jobs and maintaining economic productivity. Illinois State University in June 2009 hosted a series of discussion forums to gauge the state of workforce preparedness in the McLean County Illinois area. The proceedings of these forums (Folse, et al., 2009) presented similar recommendations. Reports from similar studies conducted by New Mexico Community College (Pleil, 2008) and the Education Development Center in Newton, Massachusetts (Richardson, Berns, & Marco, 2010) also found that the supply of workers and potential workers with the desired technical skills was not sufficient to meet current demand.

### Curriculum Development

The Indiana Department of Education has developed an Advanced Manufacturing Career Pathway Plan for secondary level instruction as well as academic standards content frameworks for the three Advanced Manufacturing specific courses required to complete this career pathway. (Indiana Department of Education, 2011) These documents provide a sound basis for developing an Advanced Manufacturing curriculum but stop short of providing specific recommendations for either texts or required student activities or detailed lesson plans and timing.

The Manufacturing Skill Standards Council (MSSC) is an organization composed of members from industry, labor, and education with the goal of providing uniform and comprehensive training to current and prospective manufacturing employees (Manufacturing Skill Standards Council, 2011). To achieve this goal the organization has developed training curricula to provide industry recognized certification in the areas of manufacturing and logistics. The courses within these curricula are a combination of self-paced Internet based and instructor led lecture and laboratory modules.

The manufacturing curriculum is composed of modules emphasizing four areas; Safety, Quality Practices and Measurement, Manufacturing Processes and Production, and Maintenance Awareness. Students who successfully complete these four modules and an additional end of program assessment earn a Certified Production Technician (CPT) certification. The MSSC courses are proprietary and require the certification of both training facilities and instructors.

Project Lead the Way (PLTW) is a non-profit organization focused on advancing Science, Technology, Engineering, and Mathematics (STEM) education at the middle school and high school levels throughout the United States (Project Lead the Way, 2011). This organization has developed a wide variety of activity; project and problem based instructional programs.

Of particular interest to this study is the Computer Integrated Manufacturing (CIM) course. This course focuses on acquiring skills in computer modeling, factory automation, robotics and computer numerically controlled (CNC) machining as well as an exploration of the history of manufacturing. The structure of this course emphasizes teamwork and the development of communication, critical thinking and problem solving skills, all of which are essential in the emerging mid-skill career path.

## Student Recruitment and Retention

The review of the literature illustrated a wide variety of recruitment and retention strategies. Squires and Case (2007) advocate a process of guidance counselor involvement, instructor recruiting visits to high school classrooms, and student follow-up visits to the Career Center classroom. Their research found that increasing guidance counselor awareness of both the income potential of technical workers and the importance of these workers to the local and national economy was a critical factor in directing interested and qualified students into high school technical programs.

Adrion, et al. (2008) outline a strategy of active high school outreach and clearly defined career paths when recruiting students for a community college information technology program. The outreach program utilizes a combination of events such as college recruiting fairs, career fairs, seminars, workshops and contests, and Web and print materials to enhance student awareness of the community college and its programs. The career paths provide a clear goal for the students and allow them to easily visualize the course work required to complete the degree program as well the career opportunities that exist after obtaining their degree.

In their Bachelor of Science qualifying project report, Ambrosino & Frasier (2008) studied the effect of after school clubs on inner city high school student interest in careers in science and engineering. The clubs were designed to provide the students with an understanding of the careers available in engineering through the use of guest speakers and to engage them in engineering related activities and projects. Their research indicated that these clubs were effective in increasing student interest in engineering, dispelling negative stereotypes types about the engineering profession, and reaching a wide range of students in terms of ethnicity, gender, and socio-economic status.

A study conducted by Jacobs-Rose & Harris (2010) investigated the impact of a summer camp program on female awareness and perceptions of high school technology programs. The camp infused technology awareness sessions into a cheerleading and dance program. The technology awareness sessions discussed career opportunities in engineering and also related technology to the dance and cheerleading routines being performed by the students. Based on survey data collected from the participants, the camp resulted in increased student interest in technology programs and a more positive perception of technology and engineering as career fields.

## Methodology

The goal of any action research project is to use information gathered from the teaching/learning environment to improve student outcomes through the implementation of positive changes in educational practices and school environment (Mills, 2011). This action research project was conducted using a qualitative exploratory case study methodology. Case studies are the preferred research strategy when how and why questions are being posed and when the focus of the study is on a contemporary problem with some real-life context (Yin, 2003). This study focused on determining effective recruiting methods and course curriculum by analyzing the results of interviews conducted with administrators, instructors, and students at career centers with established Advanced Manufacturing programs.

The intended purpose of this action research project was two-fold:

1. To assist the researcher in the development of an effective recruiting program for a newly established Advanced Manufacturing program at Midwestern, large, urban High School.
2. To assist the researcher in the selection and implementation of a state of the art curriculum for the Advanced Manufacturing program.
3.

### Participants

Cresswell (2009) writes that "the idea behind qualitative research is to purposefully select participants or sites that will best help the researcher understand the problem and the research question." Acting under these guidelines, three Indiana area career centers were chosen as case study subjects for this project. These institutions were chosen because of their established Advanced Manufacturing or Computer Integrated Manufacturing programs.

Administrators, instructors, and students from each of these programs served as individual participants in the study. While the administrators and instructors were defined by their positions, the student participants were chosen at random from the classes at each career center. Identities of all study participants were kept completely confidential and anonymous.

### Data Collection

This study employed five data collection techniques; archival sources, interviews, observations, questionnaires, and photography. This process assured that data would be collected from each of "The Three Es", experiencing, enquiring, and examining, cited by Mills (2011).

The primary form of data collection for this project was interviews conducted with the instructors (See Appendix I) and students (See Appendix II) who participated in the study. Creswell (2009) stresses the importance of conducting qualitative research within a natural setting for the participants. Therefore, these interviews were conducted at the career centers to maintain this natural setting. The interviews were documented using a digital voice recorder to maintain an accurate accounting of the proceedings. Further data were collected by soliciting information from career center directors by using e-mailed questionnaires (See Appendix III).

Mills (2011) documents two methods for conducting interviews, the informal ethnographic interview and the structured formal interview. Structured formal interviews are structured to allow the interviewer to "ask all the participants the same series of questions". Because the interviews between the researcher and the instructors occurred on a professional level the structured formal interview method was employed for this purpose. Interviews with students were conducted on a less formal level. The informal ethnographic method was used in this case because of its informal, less threatening style.

Because thorough qualitative studies rely on multiple sources of data (Creswell, 2009) additional methods of data collection were employed in this study. Program data were gathered from each participating career center. This data included program participation rates, retention rates, and completion rates. If available, placement data in either secondary educational institutions or the manufacturing workforce was also collected. Finally, researcher observations were performed during interviews and school visits. These observations were in the form of researcher notes and digital photographs of the participating school facilities.

The combination of data gathered from each of these sources provided the triangulation necessary to provide validity to this study (Creswell, 2009).

**Data Analysis**

Qualitative data analysis can be conducted in a variety of ways. Mills (2011) outlines a strategy of identifying themes, coding and analyzing interviews, asking key questions, conducting organizational reviews, developing concept maps, analyzing antecedents and consequences, displaying findings, and finally stating what is missing in the research. Because the data for this study were gathered primarily through the use of interviews, the analysis techniques used focused on indentifying themes and coding and analyzing interviews.

Table 1 below illustrates the themes and codes for this study. The first column of the table lists the general patterns that were found during the analysis of the transcribed interviews and observations. These patterns were further broken down into categories which are shown in the second column of the table. Finally, the categories were broken down into individual data pieces. These are listed in the last column of the table.

Table 1 - Data Coding Convention

| Patterns | Categories | Data Pieces |
| --- | --- | --- |
| Instructional Activities | Instructional materials | Texts |
| | | Equipment |
| | | Curriculum |
| | Instructional style | Group instruction |
| | | Individual instruction |
| | | Differentiation |
| Recruiting activities | On campus | Clubs |
| | | Posters and bulletin boards |
| | | Classroom tours |
| | | Classroom visits |
| | Off campus | Career fairs |
| | | Remote visits |
| | | Competitions |
| Administrative support | Instructional support | Professional development |
| | | Capital support |
| | | Updating curriculum |
| | Recruiting support | Student identification |
| | | Student screening |
| | | Counselor involvement |

**Reliability, Validity, and Generalizability**

Creswell (2009) lists methods recommended by both Yin (2003) and Gibbs (2007) for determining the reliability of qualitative research. Yin (2003) espouses thorough documentation of the procedures and procedural steps employed in case study research. The voice recordings, researcher observations, and photographic documentation that were employed in this project satisfy this requirement.

Gibbs (2007) recommends verifying reliability by checking for transcription errors and verifying that code definitions do not drift during the data analysis process, The researcher continually reviewed the digital audio files of the interviews to verify their accuracy, thus satisfying the first criteria. Code definition drift was monitored through constant cross referencing of the data analysis tables during the analysis process.

ISSN 2327-0160 (Online)
*Volume 1. Number 1.*

According to Creswell (2009) qualitative validity "is based on determining whether the findings are accurate from the standpoint of the researcher, the participant or the readers of an account." Of the strategies listed by Cresswell (2009), triangulation, member checking, clarification of researcher bias, and peer debriefing were utilized in this project.

Triangulation was accomplished by comparing the perceptions of the administrators, instructors, and students interviewed from each program with one another and with the program data. Copies of the final draft of the finished report were provided to the project participants in either hard copy or digital form for their review and comment to meet the member checking criteria. Peer debriefing criteria were addressed through the review of the project report by the faculty review committee.

## Results

The data collection stage of this project was conducted during the January 2012 to March 2012 time frame. Interviews with instructors and students as well as personal observations were performed in person at the three participating career centers. The data collected during this process were summarized by institution. The participating career centers were referred to as Career Center A (CC-A), Career Center B (CC-B), and Career Center C (CC-C) to ensure confidentiality and anonymity.

### Career Center A

The Advanced Manufacturing program at Career Center A was in its second year and was based on the MSSC Certified Production Technician curriculum. While it is possible to complete this program in an entirely virtual environment, CC-A complimented the virtual instruction with a variety of hands-on activities and training stations.

The facility itself was modern and inviting. Glass enclosed wall mounted display cases contained a variety of information pertaining to the Advanced Manufacturing program and associated career and continuing study opportunities as well as information about other programs offered by the career center.

The instructional area was contained in one room measuring approximately 40'x 60'. The room contained a computer lab area with 27 workstations and a workshop area containing a variety of benchtop CNC equipment. In addition to the CNC equipment the workshop area also contained six Amatrol ® learning stations. These learning stations were used to provide the students with practical experience to enhance the instruction they received via computer and lecture. Print outs of student work as well as numerous manufacturing related posters and displays were prominently displayed throughout the room.

The Advanced Manufacturing classes themselves were one period, approximately 50 minutes, in duration and met each day. Advanced Manufacturing 2 covering MSSC modules 3 and 4 was offered in the morning and was populated with a mix of students from the host school and sending schools. Enrollment in the class was 21 students. Advanced Manufacturing 1 covering MSSC modules 1 and 2 was offered in the afternoon. This class was populated exclusively with students from the host high school and enrollment was seven students.


Figure 1 – Hydraulic Training Station at Career Center A

The program instructor was a fifth year teacher who also taught the Construction Technology classes at CC-A. This instructor preferred to employ a blended approach to instruction with an emphasis placed on maximizing the students' interactive learning time. He found that the students performed very well to the challenges presented by a project based learning environment where they work both individually and in teams to develop solutions to open ended design problems. He also noted that the students responded well to the virtual learning environment utilized by the MSSC curriculum.

Recruiting activities at CC-A were varied and included a mixture of both formal and informal strategies. Some of the formal strategies employed were direct mailing of program fliers to families with students residing in the area served by the center, recruiting trips to sending schools where both faculty and students delivered presentations regarding the program, conducting formal tours of the classes by ninth and tenth grade students, participating in career center open houses, producing and showing course recruiting videos periodically during the daily announcement time, and holding informational meetings with parents. Informal recruiting techniques were based heavily on establishing strong teacher/student relationships. These relationships enabled the teacher to influence the students' choice of classes and promote the students' involvement in these classes. The students themselves then became effective recruiting ambassadors for the program as they discussed it with their peers.

Four students graduated from the program in its first year. Of these four, two currently held positions in manufacturing facilities while the remaining two were enrolled in four year college degree programs. Of the 21 students enrolled in the Advanced Manufacturing 2 course, approximately five students were on track to receive the full MSSC CPT certification.

Two students from this program were interviewed. Both were juniors and were enrolled in the Advanced Manufacturing 1 class. Each had been enrolled in a construction technology class lead by the same instructor the previous year and decided to enroll in the Advanced Manufacturing program based on the instructor's recommendation. One student entered the program without any expectations of its outcome while the other thought it would simply be a course about operating manufacturing equipment. Both students said the course had exceeded their expectations. One student planned on pursuing a college degree in a manufacturing related field while the other planned to acquire a welding certification through a community college or tech school program.

Finally, the Director of CC-A was provided a questionnaire and reported that the Advanced Manufacturing program was not any more or less important than the other 39 programs offered at the career center and nothing special was done to promote the program. He was proud of the fact that there was an a.m. and p.m. class, that both sections were filled with students and all students were on track to graduate.

**Career Center B**

Career Center B offered the Project Lead the Way Computer Integrated Manufacturing class as part of a well integrated PLTW pre-engineering curriculum. This course had been offered for six years and focused on developing students' abilities with parametric computer modeling of devices, virtual simulation of manufacturing systems, development of CNC tool paths, and part production using computer controlled equipment and was targeted at students in the eleventh and twelfth grades.

CC-B was a modern two story facility featuring a combination of large workshops located on the ground level and smaller instructional rooms located mainly on the second floor. The CIM instructional area was contained in one of the ground floor workshops. The dimensions of the room were approximately 60'x 80' and the room was divided into a computer lab area with 28 workstations and a workshop area containing a variety of conventional and computer controlled machine tools. A white board and a projection system were located in the computer lab area of the room. Examples of student work as well as numerous manufacturing related posters and displays were prominently displayed throughout the room.

Figure 2 – Computer Lab area at Career Center B

One CIM class was offered and met for one period, approximately 50 minutes, in the morning. The class was populated exclusively with students from the host high school and had an enrollment of 24 students.

The course instructor was a Project Lead the Way master CIM teacher and was an active participant in the development of the CIM curriculum. CC-B chose to offer the CIM course because it was believed to be a good fit with its existing precision machining and manufacturing processes programs. This instructor preferred to divide the course instruction into short periods of lecture followed by extended periods of laboratory activities to provide reinforcement for the subject and skills being covered.

This instructor preferred to leverage his influence with students in other classes he teaches to fill the CIM class. He built strong relationships with his students who, in return, respected his guidance and recommendations on course selection. CC-B also used such formal techniques as recruiting videos, career fairs demonstrating student work, and parent nights for middle and high school students. They also held spring break and summer camps to increase the level of student interest. The instructor was quite proud of this program's record of placing students in both colleges and industry.

One student from CC-B was interviewed for this project. He was a junior and found out about the program from an older sibling who had taken the class. He decided to enroll in the class out of curiosity and because of his interest in automotive design. This student planned to pursue a career in engineering, preferably in the automotive field.

The Director of CC-B responded to the questionnaire and stated that the CIM program was a great compliment to the PLTW Pathway and he felt fortunate to have the equipment and facility to support the program. Like CC-A Director, he stated that there is an overall marketing plan for all programs at CC-B and nothing special was done to promote the CIM program.

**Career Center C**

The formal Advanced Manufacturing program at Career Center C was suspended this year for a variety of internal reasons. These reasons included a high teacher turnover rate and low student interest in the program. Because of this it was almost excluded from the results of this report.

The instructor interviewed at Career Center C was a veteran career center instructor who came out of retirement to take over the PLTW Introduction to Engineering Design course mid-year. Because of the suspended status of the formal Advanced Manufacturing program, most of the questions developed for the interview were not applicable. However, his comments regarding recruiting and program effectiveness were quite pertinent. He believed that the key to an effective recruiting program was peer to peer interaction between students. Formal techniques such as visits to sending schools and middle schools, parent nights, and open houses were employed to generate interest in the program, but student opinion and recommendations have proven to be the most effective techniques in his experience. He related that the high instructor turnover at the career center had adversely affected the effectiveness of the program.

Two students from CC-C were interviewed. Their responses were limited to those pertaining to the MSSC portion of the program and their future career or educational plans. The first student enrolled in the career center to study drafting and CAD and had not heard of MSSC until it was incorporated into the PLTW curriculum. She decided to continue with the class because she thought it would be beneficial to her career plans. The MSSC instruction met her expectations, proved to be challenging, and exposed her to a variety fields she would otherwise not have pursued. The second student learned about the course offerings through a teacher presentation at his home school and decided to participate because his father was an engineer and because he was interested in a career in mechanical engineering. This student expected the class to be hands-on and team oriented and was pleased with it overall but felt the instructor situation had negatively affected the effectiveness of the class.

The Director of CC-C responded to the questionnaire and stated that there was a lack of interested students in the advanced manufacturing program and the program has not been offered since 2011, however, CC-B continues to provide MSSC training for students enrolled in advanced manufacturing program areas such as PLTW Engineering, welding, drafting, precision machine, etc. In terms of promoting the program, the administration funded personnel to market the advanced manufacturing and other programs at area middle and high schools. A trailer was purchased and outfitted to support the activities of students in advanced manufacturing programs and to serve as a marketing tool at school open houses and career fairs. The general perceptions of the CC-B Director regarding the effectiveness of the program included a perception that efforts needed to be taken (statewide) to promote the field of advanced manufacturing.

ISSN 2327-0160 (Online)
*Volume 1. Number 1.*

## Conclusions

Analysis of the data gathered during the literature review and from the three participating career centers allowed the following conclusions to be reached considering program justification, curriculum and recruiting:

### Program Justification

The results of the literature review clearly indicated that a shortage of mid skill workers currently existed. Although the purpose of the Career and Technical Center at the large, urban school trying to decide whether to implement an advanced manufacturing program was to provide students with the necessary training to pursue careers current job environment, it did not offer a training program to fill the mid skill worker shortage. Establishing an advanced manufacturing program would clearly meet this gap in instruction.

### Curriculum

Evaluation of the two main curriculum choices using this criterion led to the conclusion that the MSSC CPT curriculum was the most suitable for an Advanced Manufacturing program for the large, urban CTE center in question. This curriculum was designed specifically to achieve the required certification and thoroughly covered all required assessment areas. This certification requires that students pass assessments in four areas of instruction; safety, quality and continuous improvement, manufacturing process and production, and maintenance awareness.

While the Project Lead the Way Computer Integrated Manufacturing course was fundamentally sound, it was designed to be one piece of an integrated pre-engineering program and not a standalone course of study. Because it was part of a pre-engineering curriculum its focus was on students who intended to pursue at least a four year post secondary engineering degree. Furthermore, this course focused on only two of the four areas required for MSSC certification. These were quality and continuous improvement and manufacturing process and production. Additionally, PLTW had very specific equipment and software specifications that made the start-up costs of this program cost prohibitive.

### Recruiting

Analysis of the data gathered showed that all of the participating career centers used formal recruiting techniques as open houses, career fairs, parent nights, promotional mailings, recruiting videos, and instructor and student visits to sending schools to promote their Advanced Manufacturing or Computer Integrated Manufacturing programs. For two of the three programs, recruiting techniques were successful and for one, they were not.

Input from students indicated that their decision to enroll in a course or program of study was highly influenced by input from teachers, parents and most importantly other students who had participated in the course. This finding illustrated the importance of building quality student/teacher relationships and then leveraging those relationships through the students to their circle of peers. Emphasis should also be placed on establishing effective teacher/parent relationships to illustrate the relevance of the program and to expand the awareness of the program into the community.

Two of the participating career centers made prominent use of student work as a recruiting tool. High visibility, student built products that are displayed in the school and partner with the community can help with the goals of increasing student interest and participation and adding relevance to the course work.

Observations of class sizes during the data gathering process showed that the Project Lead the Way classes were consistently at or near capacity. This indicated that the overall design of the PLTW system was effective in student recruitment. Project Lead the Way was structured to initiate student participation in the program at the middle school level through the Gateway to Technology program. Students from this program were then encouraged to participate in the PLTW Introduction to Engineering Design class during their freshman year in high school, providing an effective feeder system of students for the subsequent courses in the PLTW program. Adopting a similar system for a Career Technology program would prove beneficial in increasing student enrollment.

Unfortunately, none of these recruitment techniques offered the potential for rapid increases in program enrollment. Building and fostering teacher/student and teacher/parent relationships requires a period of time as does the process of establishing a tiered recruiting system such as the one employed by Project Lead the Way.

## Recommendations

As a result of this research, the recommendations below were made to the administration of the large, urban high school that was attempting to decide whether/how to institute the IDOE Advanced Manufacturing Career Pathways Plan.

### Curriculum

Following the guidelines established by the IDOE and based on the data gathered in this study, it was recommended that the MSSC Certified Production Technician curriculum be adopted for use in the large, urban school that was the focus of this study. This curriculum should be presented as two courses, Advanced Manufacturing 1 and Advanced Manufacturing 2, over a two year time frame. The Advanced Manufacturing 1 course should be comprised of the MSSC Safety and Quality and Continuous Improvement modules and should be targeted to students in the eleventh grade. The Advanced Manufacturing 2 course should be comprised of the remaining two MSSC modules, Manufacturing Process and Production and Maintenance Students who successfully complete the MSSC assessments in each of these areas will earn the Certified Production Technician certification and therefore meet the IDOE end of course assessment requirements.

To support this curriculum and to provide the students with meaningful activities to reinforce the instruction they will receive, a number of improvements and additions to the Advanced Manufacturing laboratory are required:

- Computer workstations capable of accessing the MSSC curriculum and containing computer aided design software with parametric solid modeling capabilities and computer numerically controlled tool path generation software are required in sufficient quantities to meet anticipated class sizes.
- Existing manually controlled vertical milling machines require the installation of CNC control systems.

- Training stations covering the areas of quality control and measurement, blueprint reading, electrical systems, mechanical systems, and pneumatic and hydraulic systems are required.
- Additional computer controlled equipment such as benchtop lathes, robotics, and programmable logic controllers will be required over a period of time as the program grows.

**Recruiting**

The recruiting program for the Advanced Manufacturing course of study at the large, urban school that is the focus of this study should be improved by implementing the following recommendations:

- Secure administrative support of the program for a period of at least three years. This will allow the instructor the opportunity to build the necessary relationships with students, parents, and other faculty and leverage those relationships to build the program.
- Establish a freshman orientation program that would allow incoming freshmen to participate in a series of mini-courses in various career and technology programs. The students would then be able to make more informed educational choices based on their experience in the programs.
- Establish a focal point program or project that would increase student awareness of the Advanced Manufacturing program. This could take the form of an extracurricular activity that would be open to students throughout the school, an instructional activity such as producing and marketing a product as part of a class project, or a combination of extracurricular and instructional activities.
- Develop, produce and disseminate more effective promotional materials in a variety of media forms. This could be accomplished through a joint project with other career and technology programs such as digital graphics and printing. These materials would be distributed through a combination of conventional mailings, e-mail, school Web site video postings, and lunch time video presentations in the school cafeteria.

Additional research should be performed to determine if the recommendations are useful for large, urban CTE Centers as they attempt to determine whether/how to implement an Advanced Manufacturing Pathways Program. A longitudinal study following numerous existing and recently developed programs is recommended.

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ISSN 2327-0160 (Online)
*Volume 1. Number 1.*

**Appendix I**

Interview Questions for Program Instructors
1. What curriculum is currently employed in the program?
2. What factors led to the choice of this curriculum?
3. What instructional methods do you, as a teacher, employ?
4. What facilities and equipment are available for use in the program?
5. What recruiting techniques and activities do you use?
6. What are your general perceptions on the effectiveness of the program?

**Appendix II**

Interview Questions for Career Center Students
1. How did you become aware of the Advanced Manufacturing program?
2. Why did you decide to participate in the program?
3. What expectations did you have of the program when you enrolled?
4. Has the program met your expectations?
5. What are your future career or educational plans?
6. What are your general perceptions on the effectiveness of the program?

**Appendix III**

Questions for Career Center Directors
1. When was the Advanced Manufacturing program established at your school?
2. How important is the Advanced Manufacturing program to your schools overall curriculum?
3. What efforts does the school administration take to promote the program?
4. Are the classes consistently filled with interested students?
5. How large is the waiting list for the program?
6. What is the graduation rate of students enrolled in the Advanced Manufacturing program?
7. What are your general perceptions on the effectiveness of the program?

## Troubleshooting Random Access Memory Hard Errors

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**Abstract**
This manuscript discusses some of the history of Random Access Memory (RAM) and some of the evolutionary steps that occurred as the technology developed. In addition to the history of RAM, how it is incorporated in the modern computer, as well as the function that it serves are topics discussed in this manuscript. The relationship between RAM, the Central Processing Unit (CPU), and computer performance will be presented at length. Types of RAM that are available in today's market are discussed as well as some potential developments for the future. Hard errors caused by hardware failure can render a computer inoperable. An activity allowing students to troubleshoot RAM modules will be presented.

**An Introduction to Random Access Memory**
To make an analogy, a physical working area is similar to a computer. The hard drive is the filing cabinet where documents are stored, and RAM is the desk where the work occurs (Gulens, 2012). When the working area is full, it won't hold all of the work. It is slower to find things and it becomes more difficult in general. This is a similar thing that happens when operating with smaller than required RAM. The hard drive on a computer stores the operating system, applications, and data that users require. The CPU, however, is unable to directly access any of this information from the hard drive. In order for the CPU to access any information, it must first be loaded into RAM. That means that RAM has to hold the operating system, applications that are currently running and the corresponding user files in order to get anything done. When the RAM on a computer starts to reach its capacity, the computer will commandeer a portion of the hard drive and use it as if it were RAM. When the hard drive is used for RAM storage it is referred to as virtual memory. While this increases the amount of "workspace" available to the computer, virtual memory is significantly slower than actual RAM modules. Virtual memory is used while large programs are running, such as games, video editing, streaming videos, or photo editing (Gulens, 2012). Virtual memory can also be used in large portions when two or more programs are open and operating at once (Allbritton, 2002). The rate at which physical RAM modules transfer data to the CPU is significantly faster than the virtual memory space on hard drives. It is this difference in transfer rates that prompted the recommendation that adding RAM to a computer is the cheapest and easiest way to speed up a computer. It is not that the existing hardware is operating any faster with the additional RAM. The resulting performance boost is a result of the CPU no longer having to access the slower virtual memory.

CPU speed appears to be an easy number to advertise to consumers, but the dirty secret is that CPU speed does not matter much anymore, it's all about RAM (Allbritton, 2002). To illustrate this point, computers back in the early nineteen nineties were shipped with 16-MHz CPUs. Today, they operate at 2.4 GHz, which is roughly one hundred and fifty times faster, but one will notice that they are not one hundred and fifty times more powerful. While CPU speed is a factor, RAM is essential to today's computer speed (Allbritton, 2002; Smith, 2010). RAM is the computer's main memory. There are two distinct types of RAM that serve different purposes and have different requirements they are: Static RAM (SRAM) and Dynamic RAM (DRAM) (Schmidt, 2013).

SRAM chips store only a single binary digit, or bit, in each of their memory cells (Tyson & Couston, 2000). Each cell has transistors that act as an on/off switch. When the switch is on, electricity constantly flows through the cell indicating a binary digit of 1. When the switch is off, the electricity stops and the computer registers that cell as a binary digit of 0. The advantage of this architecture is that it is very fast. It would seem that if SRAM is so fast, it should be the de facto architecture for all RAM. One of the limitations of SRAM is that it requires relatively more hardware components when compared to DRAM. Because of this, the amount of physical space required to provide the same amount of storage capacity that is capable with DRAM would be prohibitively large. The second issue is that constant flow of electricity required for each cell in memory that is representing a binary value of 1. This increase in power consumption would make SRAM a less sustainable and more expensive option than DRAM. SRAM is typically used in computer design as cache memory that holds the data most frequently accessed by the CPU (Schmidt, 2013).

A DRAM chip requires the charge on the individual cells to be refreshed periodically to retain the data. DRAM also requires less space than SRAM since it has fewer components. The result is a higher storage density that allows DRAM modules to store more data and be less expensive than SRAM. DRAM is also a more sustainable alternative since it consumes less electricity. What DRAM gains in memory, it loses in speed (Soper, Mueller, & Prowse, 2010). Both of these are used in computers today, with the SRAM used to help the CPU's speed while the DRAM forms the larger system RAM space (Tyson & Couston, 2000), DRAM is the most common.

Chips for RAM are only available as a piece of a card called a module (Tyson & Couston, 2000). These modules have their memory listed by two numbers. The first number is the amount of chips on the module and the second number is the amount of capacity for each individual chip measured in megabits (one million bits). Expressed in common numerical form, it looks like this: 8x32. With this example, there are eight chips on the module and each of the chips capacity is thirty two megabits. To get the total power, you multiply the two numbers together. For this example, we get a total of 256 megabits. RAM is traditionally measured in bytes. A simple conversion (1 byte = 8 bits) leads us to the conclusion that our example module is 32 megabytes. Trading up from a 4x32 module to a 8x32 module will cause a jump from 16 megabytes to double that at 32 megabytes. Increasing the amount of RAM typically improves the overall speed of computer by reducing the need to access slower virtual RAM on the hard drive. RAM now is available in a variety of sizes ranging from 2-GB to 8-GB modules. As stated earlier, RAM is measured in bytes; 1 gigabyte (GB) is equivalent to 1,024 megabytes (MB) which is equivalent to 1,048,576 kilobytes (KB) (Gulens, 2012).

Once the form factor of RAM was standardized, there has been a race to fit increasing amounts of memory in each RAM module (Smith, 2010). For the near future, it appears that improvements to the current system of RAM will follow the smaller and more mantra. Some of the possible new avenues for RAM include: RAM memory that will not be erased with inconsistent power, using magnetic plastics, quantum dots, and carbon nanotubes (Smith, 2010).

**Purpose of Activity**

The purpose of this activity is to educate students about the functionality and role RAM plays in a computer and engage them in problem solving and troubleshooting techniques. Students will identify RAM, determine if it is functioning properly, and learn how to replace it safely. Students will discover how to interpret the beep patterns emitted by a computer that is registering a hardware component failure.

Students pursuing a career in information technology are likely to begin their careers as computer repair technicians. As with any computer hardware component, RAM modules are subject to errors and failures. Errors in RAM can have a significant impact on computer reliability. Memory errors due to RAM can result in a range of errors from software failure (Murphy, 2004) to an overall system failure (Tang, Carruthers, Totari, & Shapiro, 2006). The source of these errors can be hard errors caused by physical failure requiring replacement of the RAM modules. They can also be caused by soft errors which are transient errors resulting from a temporary anomaly (Messer et al., 2004). Aspiring IT professionals need to be able to diagnose and fix these types of errors. The transient nature of soft errors makes it difficult to troubleshoot and repair them. The process of doing so is beyond the scope of this activity.

Hard errors are relatively straightforward. They are the result of a hardware failure that prevents the CPU from being able to communicate with the memory cells contained in RAM modules. Symptoms of hard errors typically manifest in two outcomes. It is not uncommon for RAM modules to fail intermittently before complete hardware failure. The hard errors created by this condition typically cause the computer to stop functioning and display a blue screen containing cryptic error messages and hexadecimal string. This is typically referred to as the "blue screen of death".

**Activity Learning Objectives**

Upon completion of the activity:

1. The student will be able to identify what a RAM module is and how to determine its specifications accurately.
2. The student will be able to locate, remove, and replace RAM modules in a desktop computer.
3. The student will be able to determine which RAM module in a bank of memory is not functional.

**Key Definitions**

**BIOS:** The BIOS is a low-level coding embedded on a computer's motherboard. The BIOS is responsible for managing the input and output of data between hardware components. Errors in these communications between components cause the BIOS to issue a beep pattern at startup indicating a hardware error.

**CPU:** The central processing unit (CPU) is commonly referred to as the “brains” of the computer. The CPU executes commands required by the operating system and applications.

**RAM:** Temporary storage where a computer’s CPU retrieves data to be processed. Contents of RAM are lost when power is interrupted or the computer is turned off.

**RAM Module:** This is the physical component in which RAM resides (See Figure 5). RAM modules can be purchased in a variety of form factors, capacities, and speeds based

**Hard Error:** This is an error caused by a hardware failure that prevents the CPU from being able to communicate with the RAM module’s memory cells.

**Materials**

- Desktop computer
- One Non-functional RAM module
- Screwdriver
- Anti-static wrist guard
- Anti-static bag

**Procedure**

Prior to the activity, the instructor should place one non-functioning RAM module into a randomly determined RAM slot in a working desktop computer. The remaining RAM slot(s) should contain functional RAM modules. The activity should begin with the computer turned off.

1 The student should turn on the computer. This should result in a series of beeps as the computer tries to read the non-functioning RAM module.
2 The student should document the beep pattern and power off the computer.
3 To determine what the beep pattern signifies, the student will need to determine the version of the BIOS being used by the computer. The student should turn the computer back on. As the computer tries to boot up, it will present the name of the BIOS manufacturer (See Figure 1).


Figure 1

4 The student should conduct an Internet search of the BIOS manufacturer’s beep codes. For example, if the student saw the screen output seen in Figure 1, the student would enter “Phoenix BIOS beep codes” into an Internet search engine.

5 Once the student has found the BIOS manufacturer's beep codes, the student should find the documented beep pattern that was heard and determine its significance.

6 The student should have found that the beep pattern indicated a RAM failure. It should be noted to the student at this time that non-functioning RAM modules will always cause system beeps at startup.

7 Replacing or removing the non-functioning RAM module is the only solution to the problem. The task is to determine which of the RAM modules is non-functioning.

8 The students will ground themselves to avoid electrostatic shock damaging computer components by putting on the grounding strap provided. The clip should then be attached to a metallic portion of the computer case (See Figure 2).

Figure 2

9 The student should open the computer to expose the interior of the computer. How this is accomplished is dependent on the case design. Typically, a cover panel can be removed by latches or screws located on the back of the computer case (See Figure 3).

Figure 3

10 The students will locate the RAM card slots on the computer motherboard.

11 The student should remove the first RAM module by pressing down on the tabs holding the RAM module. This should cause the RAM module to lift partially out of the RAM slot (See Figure 4).

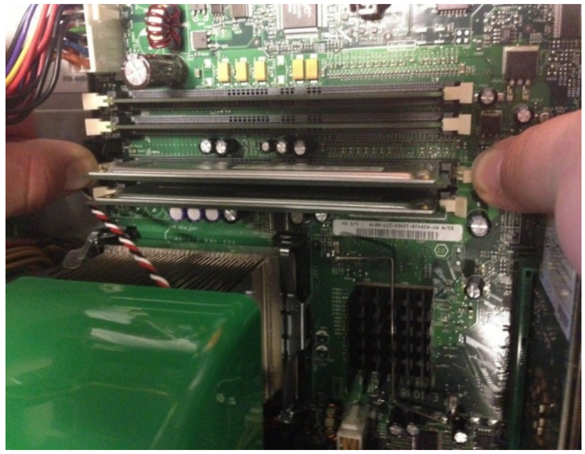

Figure 4

12 The students remove the RAM module and document the type, speed, and capacity of the RAM module on the Activity Sheet. The type of RAM will be DDR, DDR2, or DDR3. The speed of the RAM module will be list in MHz or by a name. The name would begin with the letters "PC" followed by a 4-6 digit number. The number indicates the speed of the RAM module. For example, PC5300 RAM modules operate at 667 MHz. The capacity is typically presented in GB. This information is typically printed on the RAM module as seen in Figure 5.


Figure 5

13 The student should then place the RAM module in an anti-static bag (See Figure 6). This is done to ensure that static electricity does not cause damage to the RAM module.

Figure 6

14 The student should turn the computer on. If the beep pattern still occurs, the non-functioning RAM module is still installed in the computer and the one in the bag is a functional RAM module.
15 The student should turn off the computer.
16 The student should reinstall RAM module from the anti-static bag. It should be noted to the student that when installing RAM, the notch in the RAM module should line up with the corresponding spot in the RAM slot. If there is resistance when trying to install the RAM module into the slot, the module probably needs to be turned around. Excessive force when trying to install any computer component can result in damage to the device.
17 The student should place the RAM module in the RAM slot and press down firmly and evenly on both sides of the module until the holding tabs lock.
18 The student should repeat the process of removing the remaining RAM modules individually and documenting them on the Activity Sheet. The student will have found the non-functioning RAM module when the computer boots into the operating system without any beeps.

**Conclusion**

While the CPU dictates what can be done on a computer, it has been shown that RAM allows the CPU to do its job. RAM provides the workspace from which the CPU draws its instructions and data. It was shown how increasing RAM provides a larger workspace for the CPU, resulting in faster processing. This manuscript discussed some of the history and evolution of RAM. From DIP chips to DRAM, RAM has performed the same function. The continued micronization of RAM components will allow manufacturers to produce RAM modules with increasing storage capacities. Due to its vital role to the computer, problems that can arise from RAM failures or errors were discussed. In response to these problems, an activity was presented that provides students with hands-on experiences with troubleshooting and replacing RAM modules in a computer.

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ISSN 2327-0160 (Online)
*Volume 1. Number 1.*

**Name: ________________________________________**
**Score: __________**

**Activity Sheet**

| RAM Module # | Type of RAM | Speed of RAM | Capacity of RAM | Did it function properly? |
|---|---|---|---|---|
| #1 | | | | |
| #2 | | | | |
| #3 (if applicable) | | | | |
| #4 (if applicable) | | | | |