Using Scale Models to Promote Technological Literacy

Dr. William R Loendorf, Eastern Washington University

William R. Loendorf is a Full Professor Emeritus of Engineering & Design at Eastern Washington University. He obtained his B.Sc. in Engineering Science at the University of Wisconsin - Parkside, M.S. in Electrical Engineering at Colorado State University, M.B.A. at the Lake Forest Graduate School of Management, and Ph.D. in Engineering Management at Walden University. He holds a Professional Engineer license and has 30 years of industrial experience as an Engineer or Engineering Manager at General Motors, Cadnetix, and Motorola. His interests include engineering management, technological literacy, improving the competitiveness of American companies, and real-time embedded systems.

Prof. Terence L Geyer, Eastern Washington University

Terence Geyer is the Director of Distance Education in the Department of Engineering & Design at Eastern Washington University. He obtained his B.S. in Manufacturing Technology and M.Ed. in Adult Education in a specially combined program of Technology and Education at Eastern Washington University. His interests include collecting and re-manufacturing older technologies.

Dr. Donald C. Richter, Eastern Washington University

DONALD C. RICHTER obtained his B. Sc. in Aeronautical and Astronautical Engineering from The Ohio State University, M.S. and Ph.D. in Engineering from the University of Arkansas. He holds a Professional Engineer certification and worked as an Engineer and Engineering Manger in industry for 20 years before teaching. His interests include project management, robotics /automation and air pollution dispersion modeling.

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Abstract

The use of technologies by humans is nothing new. In actuality, humans have utilized technologies of many types since the beginning of time. They extended the capabilities of humans allowing them to accomplish more, do things better, and to some extent make life easier. These technologies were simple and crude by today's standards, but absolutely essential for life in their point in time. However, modern humans are so wrapped up with today's gadgets that they have lost touch with and forgotten the early technologies that made it all possible. Since most of them were made of leather, animal tendons, wood, and other items, they have decomposed and been lost over time. Thus leaving only the stone and bone artifacts remaining to be discovered and convey their story. One solution to this unfortunate dilemma is to rebuild them. Recreating the small relics using the original tools and methods is relatively easy but larger items make the task far more difficult. The sheer size of many of these items makes the job extremely challenging, problematic, and undoable. That is where the use of scale models comes in. Exact replicas of large objects can be fabricated at a scaled down size to demonstrate how they were originally constructed and used. Two years ago a project was undertaken to do exactly that. Beginning with one scale model, the project was so successful and well received that it was quickly expanded to include other technologies and machines. These scale models average about three feet in length making them suitable for use in classroom demonstrations. They are extremely mobile and transported on specially designed Educational Delivery Vehicles (EDVs). They bring the past back to life and give today's students a realistic look at ancient technologies in a way that is superior to pictures and textual descriptions. The objective is to enhance the student's understanding of how and why past technologies were developed and used. This paper reviews the scale model project discussing what artifact was first reconstructed, how it was made, and looks into the future to relics that can also be built as scale models to promote technological literacy.

Introduction

Humans have created and utilized tools and technologies since the beginning of civilization. In fact, without them it is highly unlikely that humans would have even survived. All of these early tools and technologies were simple by today's standards, but absolutely essential nevertheless. They were used to sew clothes, build shelters, provide protection, make food more accessible, and in general make life a bit safer, easier, and tolerable. As time progressed so did the development of tools and technologies as humans sought solutions to more and more problems that plagued them. It was a progression as one tool or technology led to another, which evolved into yet another. It created an endless cycle of advancement that is still with us today.

Many of these tools and technologies were incorporated into all types of devices and machines. The capabilities of these contrivances were not only wide-ranging and very diverse, but the size of these contraptions or apparatuses also varied greatly. Some were quite small able to be held in your hands while others were extremely large. A lot of these gadgets, mechanisms, and machinery have disappeared over time. Unless they were made from stone or bone, they likely decayed and decomposed leaving little or no trace of their existence. However, that does not mean they were unimportant and should no longer be studied.

In order to rectify this situation an interdisciplinary course, TECH 393: Technology in World Civilization was created ten years ago. "This junior level course explores a historical perspective of the development of technology in a global context by tracing the interconnected events and cultures in which technology developed (Loendorf[8], 2010)." The course investigates how technologies are inter-related and how cultural factors affect the acceptance or rejection of technology. One of the main objectives of the course was to enhance the student's understanding of how technologies developed and why.

Due to the interdisciplinary nature of this course, it satisfies the University's International Studies graduation requirement. A major outcome from this categorization is the large diversity of students from all disciplines, offered by the University, which regularly take the course. This assortment of backgrounds and specialties leads to discussions with a wide range of perspectives on how and why technologies evolved. Even though the course is facilitated by engineering professors and all engineering and technology majors are required to take it, the course's content is targeted at all students regardless of their major.

Just like technology, the course makeup and content is always evolving and changing. Initially the teaching methods included lectures, discussions, videos, exams, and written projects (Loendorf[7], 2004). Over time the teaching methods have been expanded to include recreated artifacts (Loendorf & Geyer[11], 2008), demonstrations (Loendorf & Geyer[12], 2009), other collections of technologies (Loendorf & Geyer[13], 2010), innovative visual content (Loendorf[9], 2011), and always the use of stories (Loendorf[10], 2012).

A wide variety of historical artifacts have been recreated for this course as demonstration exhibits. They were reconstructed using the same materials, tools, and techniques that were originally utilized centuries ago. However, typically these objects were small, no bigger than a foot or so. The challenges that would be encountered to recreate the much larger artifacts, due to their size, were almost insurmountable. Nevertheless, that did not detract from their importance. In order to rectify this situation, a project was started over two years ago to build scale models of these very large relics for demonstrations. Now they are part of the many collections of ancient artifacts routinely utilized in the classroom.

Theoretical or Conceptual Support

Dramatic change has always occurred and affected civilization in countless ways both good and bad. Every century has seen extraordinary change. However, the rate of this change has also accelerated with each passing century leading to a pace that is more rapid today than in any time in the past. The driving force behind this change is technology. This can be clearly seen by simply reviewing the technologies in use just one hundred years ago and comparing them to what we use today. The differences are striking.

Few people a century ago or even fifty years ago could ever have imagined the technologies we take for granted today. Civilization is totally dependent upon technology for countless aspects of our modern day life. As a result, technological literacy is absolutely essential in order to allow people to function and be productive in our competitive society today.

Martin[14] (2002) stated that "In a democratic society, technological literacy has individual, societal, and environmental implications…. As individuals, people need (a) to develop technological abilities so they will better know how to use products; (b) to assess the impacts of technological actions; and (c) to develop better decision-making abilities in order to determine which technological system or process to use or not use (p.52)." According to the International Technology Education Association, ITEA[3], (1996) "The technologically literate person recognizes the possibilities advances in technology create and the choices society makes in adopting them."

Ernest Boyer[1] (1983) "advocated the study of technology by all students. To insure that people do not confuse technological literacy with computer literacy. The great urgency is not 'computer literacy' but 'technological literacy,' the need for students to see how society is being reshaped by our inventions, just as tools of earlier eras changed the course of history. The challenge is not learning how to use the latest piece of hardware, but asking when and why it should be used" (p.304).

Technological literacy education enables students to understand, utilize, and manage technology. Teich[18] (2000) related how knowing the development of technology, its impact on society, and the environment builds a foundation from which future decisions can be made. These concepts, systems, processes, and procedures can then be applied to challenging new problems that today are not even being considered. Israel[4] (1995) stated that "a student who has completed a technology education program should be able to participate as an active citizen by expressing their positions on technological issues, making wise consumer choices such as selecting, using, and disposing of technical artifacts, and making informed career choices." Technological literacy, according to Wiens[21] (1995), "is essential to the political and economic empowerment of the citizen."

"Artifacts are probably our most obvious everyday encounter with technology. Therefore, a good understanding of the nature of technical artifacts is a relevant part of technological literacy" (Frederik, Sonneveld, & Vries[2], 2011). Students can learn a great deal from studying artifacts whether they are from the recent or ancient past. However, ancient artifacts are difficult to find and are usually very expensive. One affordable way to utilize ancient artifacts is to recreate them using the original tools and methods as was done by Loendorf and Geyer[11, 12] (2008, 2009). Another way is to form collections of artifacts (Loendorf & Geyer[13], 2010) from the past that can be displayed and examined (Loendorf[9], 2011).

An additional problem is size. Many ancient machines and devices were very large making recreating them expensive, time consuming, and difficult. Even if these large artifacts were recreated it would be impossible to bring them into the classroom for demonstration purposes. The solution is to build scale models that are transportable for use in the classroom.

“A scale model is a version of an item that is either smaller or larger than the original size of the object. In most cases, the scale model is much smaller than the original (Otto & Wood[15], 2000). “A scale model is a three-dimensional depiction that accurately represents a solid object” (Voland[19], 2003). “The dimensions of the item are in direct proportion to the actual dimensions of the original object. The scale relates how the models dimensions and the actual dimensions are associated” (Lindbeck[6], 1994). For example, the scale 1 in : 3 ft means that 1 inch in the model represents 3 feet of actual distance.

Many professions routinely use scale models. Engineers and technologists use scale models to test the performance of designs early in the development stage without having to build prototypes. Architects use scale models to evaluate the design and look of new buildings prior to their construction. Sales people utilize scale models to represent large products to potential customers. Television and movie producers use scale models in their shows in order to speed up production and cut costs. In addition, of course, there are many more applications as well.

The use of scale models is nothing new. In fact, humans likely used them since the beginning of time to model ships, castles, weapons, and other devices. “Architects and map makers were increasingly making drawings to scale and soon shipwrights such as the Englishman Matthew Baker were doing the same” (Pacey[16], 2001). “Models were an important method of showing the concepts and capabilities of an inventor’s idea without utilizing a lot of resources and expenditures (Volti[20], 2009). “Another technique used in ship design was the construction of scale models, and Galileo, the great Italian mathematician, wrote about the comparative strengths of models and full size structures” (Pacey[16], 2001).

The building of scale models continues to be extremely useful method of constructing smaller sized artifacts that replicate the large original relics. Even extremely small objects are enlarged as scale models. Today scale models are routinely used by engineers and scientists to model everything from large objects like airplanes and ships to small items like molecules and atomic structures. Bringing scale models of ancient artifacts into the classroom adds a three-dimensional visual aspect that will be remembered long after typical lectures are forgotten.

Creating Scale Models of Historical Artifacts

A series of preliminary or alpha scale model prototypes were initially built to test the feasibility of the project. The methods and materials utilized to construct these examples were similar in every way to the original items used. Even the same types of ancient tools, though recreated as well, were utilized. Three of these alpha prototype scale models are shown in Figures 1, 2, and 3. Figure 1 depicts and ancient battering ram as it attempts to breach the walls of a castle. Figure 2 shows a mobile battering ram with a shield that can protect the soldiers, to some extent, from arrows and other objects thrown off castle walls. A working scale model of a trebuchet is presented in Figure 3 in the relaxed or unloaded position. Each of these scale models represents the beginning of the learning process during which every attempt was made to accurately replicate in size and function the original ancient machine. Much of what was accomplished can be attributed to the trial and error method of discovery. In fact, that was perhaps the most interesting aspect of the initial alpha scale model reconstruction phase.

Figure 1. Scale Model of an Ancient Battering Ram.

Figure 2. Scale Model of a Battering Ram with Protective Cover.

Figure 3. Scale Model of a Trebuchet.

The first authentically accurate scale model project was to reconstruct an Egyptian light chariot. The project began by analyzing the process of how a chariot might have been constructed in ancient times. Starting with one of the earliest designs, the mysteries of the old technology versus new technology started to unravel. Throughout this project, the same question kept surfacing. How did they do it with their technology compared to modern day technology? After reviewing numerous pictures and old drawings of chariots, it was revealed that most of the wood used for construction was bent into shape. How did they do this? What led the ancient crafters to experiment with this type of procedure of bending wood to form it into shapes? Did they use green wood, shape it, and then dry it? Or did they shape small trees as they grew in order to obtain the bends and shapes for the parts they required?

Since time did not allow for the growing and shaping of trees to obtain the required parts, an alternate method to accelerate the process was sought. After evaluating a number of suitable methods, it was determined that the most appropriate way to bend the wood would be to use steam. Ancient crafters (Kidder[5], 2001) would bend branches by first soaking the wood in water for a long period of time, then applying heat, and then shaping the wood into the desired form. The time required for this process was likely shortened by using a device known as a steam box.

It was decided to discover how ancient craft workers used steam to bend wood in the same manner they did and that was by trial and error. Prior to building the steam box, there were many attempts made at soaking the wood for hours, days, and even weeks. Then heat would be applied and attempts were made to bend the wood. The results were disappointing with the failures greatly outnumbering the successes. Eventually it was determined that the steam box was the method to use. Although the bending process seemed long in modern times, just imagine how long it took ancient craft workers around 3000 - 2500 B.C. to accomplish this task.

With the steam box, using a home steamer for clothes as a source of steam, the first few attempts utilized both steam and pressure. After a few attempts, the results were negative. The wood would break under the stress. To help resolve this problem, the process was extended to two cycles in the steam box and a vent was installed to lower the pressure. After the first cycle, which was about 45 minutes, a minor bend was placed in the wood, and then placed back in the box for another 45 minute cycle, which turned out to have more positive results. Now that the basic bending was achieved, it was time to start making the wood form to the desired shape required for the chariot. Forms and jigs were needed and designing them was straightforward. However, making the steamed wood cooperate was another matter. With the hot steamed wood, the time to work was minimal. As the wood quickly cooled, it would end up breaking. The solution for overcoming this obstacle was to use a second set of hands to speed up the process and it worked.

The carriage became the foundation and the ideal place to start. After making a jig of the desired shape, the wood was steamed through two cycles, then wrapped around the jig, and held into place. After letting the material stay in this shape for 24 hours, the results were outstanding. The wood retained the shape (refer to Figure 4) and was firm, and still had some "give" to it.

Figure 4. Chariots Carriage Foundation

The next challenge involved forming the wheels out of a single piece of wood. Although it did come close, there just was not enough flexibility there and the material cooled too quickly. The next best thing was to make the wheel rim out of two pieces. This was a much easier process, but once again, because of how fast the wood would cool; you could only do one-half at a time**.** Please refer to Figure 5.

Figure 5. One-half of the wheel being shaped.

While the second piece was being steamed, it gave the shaped wood piece time to conform to its new shape. Eventually both pieces would end up being clamped to the same jig and left there for 24 hours prior to assembly of the entire wheel. The dried and formed pieces of the wheel were very close to the desired shape, they just needed to be spliced together to complete the shape. Refer to Figure 6.

Figure 6. Formed and Dried Wheel Frame.

The splicing of the two halves was another challenge. Even with the glue and setting up over night, the pieces sprung apart after being released from the confines of the clamps. Brass sleeves were cut and placed over the splice to help retain integrity.

The guard on the chariot also proved to be another challenge, not only for its shape, but once again, the cooling factor played a part. After setting one side into the jig, with the right shape, by the time it was to shape the other side, the wood had cooled. An alternative was needed to get the wood to shape, without having to take the whole piece out and re-steam it. Instead of placing the wood back in the steam box, the hose from the steamer was removed and the side that had cooled was inserted directly in the hose to be steamed for another 20 minutes. This change worked and was valuable to the process. The complete carriage assembly is shown in Figure 7.

Figure 7. Chariot Carriage Assembly

Once all the main parts to the carriage were in place, they were wrapped in twine at the main joints. It was very surprising how rigid this simple structure was turning out to be. How did the ancient craft workers know? Again, it was likely due to trial and error just as this project proved.

While waiting on the wheels to dry, the webbing was added to the carriage, and more joints wrapped in twine. This work in process is displayed in Figure 8.

Figure 8. Main Body of the Chariot with Floorboard Webbing

For the wheels, a simple four-spoke design was used as is shown in Figure 9.

Figure 9. Completed Chariot Wheel Design

The axel was also of simple design, with the wheel hubs being pinned into place on both sides. The details are shown in Figure 10.

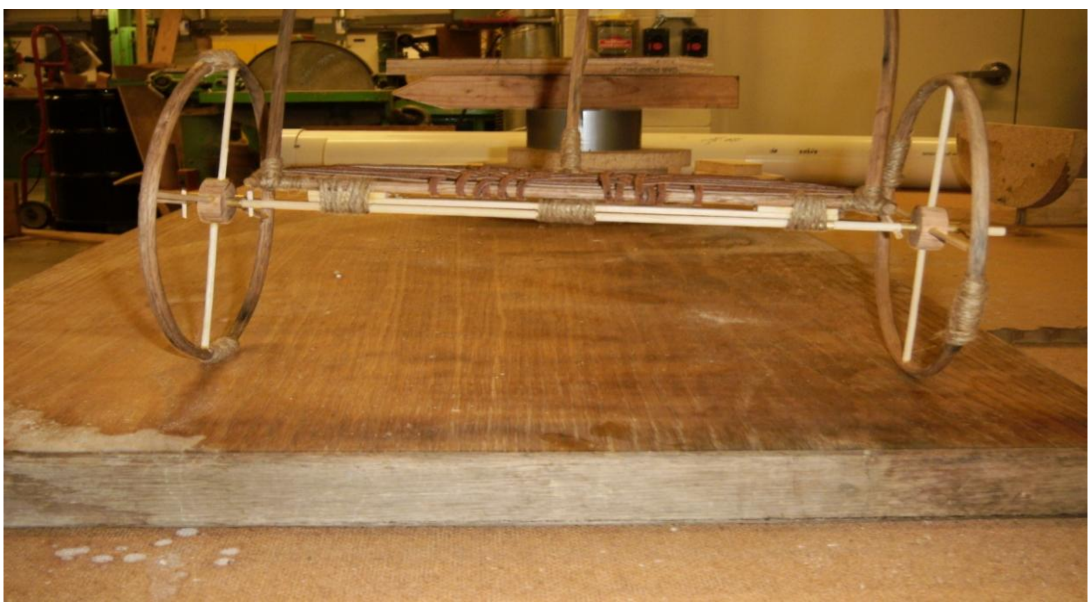

Figure 10. The Chariot’s Axel Design

Finally, all of the various components were assembled together. The completed chariot revealed something that was not even thought about through the whole process. By putting some pressure on the webbing of the carriage, there was no visible sign of it flexing to the weight. However, the most fascinating thing was seeing how the stress would be transferred out to the horses. Once again, how did the ancient craft workers know? It can only be assumed by trial and error methods. The completed scale model chariot is shown in Figure 11 below.

Figure 11. The Completed Scale Model Egyptian Light Chariot

After completing this project, it is no wonder why it was developed, and used as one of the first mobile war machines. It was lightweight, maneuverable, very stout, and easy to repair. The ancient crafter workers were very creative with their knowledge and concepts, much like modern manufacturer's are today. Nevertheless, how did they know? In our modern world, computers are routinely utilized to assist in the design and development of new products. However, in contrast ancient craft workers had simple tools and still produced amazing things that still confound modern man. This leads to the question. Were the ancient workers more advanced with their ability to do more with less?

The success of this project has led to the decision to continue building scale models of other ancient artifacts for classroom demonstration purposes. Among the ancient relics under consideration are the Hittite heavy chariot, catapult, trebuchet, siege tower, Hoplite shield, animal skin boat, ship with the planks sewn together, and other sailing vessels. All of these projects would require student assistance to design and build, just as this first project did. However, a number of students have already shown an interest in being involved with these projects and the facility has a complete wood shop, metals lab, and non-metallic lab for them to use during the construction process.

Classroom Experience

As it is with all of the ancient artifacts that have either been collected or reconstructed they must be transportable into the classroom. With this in mind the use of old surplus audio-visual (AV) carts continues. After refurbishing, they are transformed into “Educational Delivery Vehicles” or “EDVs” (Loendorf & Geyer[12], 2009). All of the scale models are designed to fit onto the EDVs. As a result, the dimensions or scale varies with the item reconstructed. In other words, they are designed to fit on the Educational Delivery Vehicle for transportation purposes.

The use of scale models has enhanced the classroom experience in many ways. Among them, is the capability to see and touch these three-dimensional artifacts rather that just looking at pictures or listening to descriptions. Students have the opportunity to examine the materials and construction methods actually used by the ancient craft workers. They can also see exactly how the ancient device functioned using technologies that might not have been totally understood at the time, but nevertheless worked.

The students participating in the design, development, and production process also experienced the highs and lows of trail by error. Since many of the building techniques were never documented or lost over time, they must once again be rediscovered. This adds greatly to the student’s educational experience. In many ways, the students are tracing the development of technologies just as the ancient craft workers did. All of this is shared in the classroom during the presentation and discussion of the recreated scale model artifacts.

Lessons Learned

By using scale models to recreate ancient artifacts using the original methods and technologies to improve technological literacy, several lessons have been learned. In one way or another, each of these lessons learned have been incorporated into the classroom experience. As a result, the ability to transfer knowledge while enhancing the student’s Technological Literacy experience has been greatly improved.

The use of scale models made it easier for students to experience visually exactly how very large retro and ancient technologies were built and utilized. Just how these ancient and old technologies worked is no longer left solely to their imagination. Instead, they can see them in action. The technologies are brought to life in ways that words and pictures alone could never accomplish. The scale models also added variety to the traditional lectures that can become routine and boring even to the most interested student.

As more and more interactive and creative displays, collections, and recreated artifacts have been incorporated directly into the class sessions, the students have become more involved in their learning process. This proactive approach to learning has had a very positive impact on their level of enthusiasm and interest in past technologies and Technological Literacy. Students began to participate in the process by bringing to class journal articles, pictures, and other examples of ancient technologies.

Once again, it became apparent that some form of laboratory project or exercise would be appropriate for this course. However, not all of the students have the time, training, and skills required to recreate ancient artifacts. In addition, it is extremely difficult to incorporate a laboratory project or exercise into a lecture only course. That is why it is so important to continue to discover and implement new and interesting ways to bring ancient artifacts into the classroom. This has been accomplished with great success in the past and will likely continue well into the future.

Corroboration, Substantiation, and Validation

The methods, materials, and techniques utilized in this project to build the scale model Egyptian chariot was authenticated and confirmed by a team of experts that was well funded working essentially at the same time on a similar project. This team of archaeologists, engineers, woodworkers, and horse trainers joined forces to build and test two highly accurate replicas of Egyptian royal chariots. Traveling to Egypt, they also discovered the use of advanced engineering features including wheels with spokes, springs, and shock absorbers.

This team of experts consisted of Robert Hurford (highly skilled carriage maker), Mike Loades (military historian), and Kathryn Hansen (horse and chariot expert). In addition their support team included Mohamed Abd Elsalam (steam shop owner), Steven Harvey (Egyptologist), and Dr. Bela Sandor (University of Wisconsin). The entire process they utilized along with the results of their efforts were recorded and aired as an episode of NOVA[17] on the PBS Television Network on February 6, 2013.

It is remarkably interesting to note that their process of discovery utilized trial and error, multiple failures, and disappointments while they worked to build their chariots. Essentially they made the same journey, but at a much greater expense, as our scale model project team did. The work that the team of experts conducted supports and proves that the use of scale models can exactly replicate the efforts required to build full sized antique artifacts.

The knowledge gained from this project, whether it utilized scale models or full sized replicas, was for all intents and purposes the same. The major difference was cost. For universities with limited budgets, the research and development of scale models makes perfect sense. This discovery, by itself, made the project worthwhile for both the students and faculty involved.

Conclusions, Reflections, and the Future

The use of scale models recreating ancient technologies has been added to the Technology in World Civilization course. The use of scale models has impacted the students learning process in three ways. First, students take an active part in the construction process requiring trial and error attempts to recreate ancient building methods. Second, the completed scale models become an integral part of classroom demonstrations providing three-dimensional evidence depicting how the technology was built and utilized. Third, the design, development, and fabrication process is described in detail as part of the class presentation and discussion. With the addition of recreated scale models, the study of past technologies utilizing recreated artifacts, collected objects, graphic images, pictures, and videos has enhanced the student's understanding of technological literacy.

The intent of this course was to create interest in technological literacy by reintroducing past technologies in a variety of interesting and informative ways. This included focusing on the problem solving ability of previous generations of humans along with their desire to invent and develop new tools, techniques, and processes. The objective was to enhance the student's understanding of past technological issues in order to better prepare them to solve the technological challenges they will encounter in the future. This goal has not only been easily met, but actually exceeded. It has achieved its objectives of increasing the awareness and understanding of past technologies and their social, political, economic and cultural impact on society.

Reflecting back, 10 years ago this course began with one instructor and only one section with 20 students. At the time, it was quite a gamble to offer a course related to Technological Literacy. Gradually over the years, as new creative ways to present the material were implemented, the popularity of the course rapidly increased resulting in expansion of the number of sections offered and instructors participating. Each of the courses facilitators follows a common syllabus that incorporates all of the presentation methods developed during the past 10 years. Every quarter four or more sections containing over 40 students each are run with an additional two sections run during the two summer sessions. In total, over 14 sections are offered each academic year with over 600 students taking part in the learning process. What seemed to be a gamble has paid off in more ways than were ever expected or anticipated.

Looking into the future reveals that the Technological Literacy course will continue to expand and grow. Each time the course is offered it is different incorporating new material, ideas, innovative approaches, and additional exhibits. This trend will continue because the project is a long way from completion. There are still many new creative ways to promote Technological Literacy that can be used.

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