Hands-On-Workshop Based Learning of Rapid Prototyping

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Abstract

Although the manufacturing industry has recently declined considerably, several new manufacturing methods are growing in the 21st century. One of these methods is Rapid Prototyping (RP). Through the past decade, RP technology has increasingly been implemented in many places, (i.e. dentistry, biology, casting, tooling, and robotics). Although this technology has been advancing swiftly in teaching, training, and learning, it is still in its infancy. Since this vital technology is very important for the progression of the manufacturing industry, an NSF grant has been awarded for the RP Education (DUE Award Number 0302314: Technician Education in RP and Virtual Manufacturing Technologies). Project team members organized a workshop on Training the RP trainers at San Diego City College from July 27 to August 1, 2003. Tennessee Tech University (TTU) faculty and assistants attended this workshop because TTU was in the process of building a RP Lab and organizing workshops for high school students/instructors. This paper intends to report learning practices, adaptations, and implementations accomplished via this workshop.

The State of the Art

The mission for all instructors is to educate their students the best way possible. Their teaching techniques should challenge, educate, and promote the students' innovative thinking¹. The lecture-based format of teaching, which predominates in engineering education, may not be best to achieve these technical learning goals². Through the lecture method, an instructor introduces students to course work by producing notes on a chalkboard or overhead projector. The instructor then hopes that students can regurgitate this collected information on their homework or exams. Some classes, if students are lucky, have accompanied laboratory practices where they can gain hands-on experience. There have been several attempts to revise engineering curriculum to improve understanding and foster creative thinking³. RP laboratories and practices may bridge lecture based education and laboratory execution in design and manufacturing courses, and then increase students' comprehension.

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In July 1999, TTU's Technology Access Fund provided a computer laboratory to support many of the software needs for CAD, CAM and CNC practices. Fifteen DELL OptiPlex GX1, Pentium III computers currently run programs such as: AutoCAD, Mechanical Desktop, I-DEAS, Pro/E, MasterCAM, and CNCez. In December 2002, this computer lab was upgraded to include 22 Pentium IV computers and multimedia teaching capabilities. Although students gain excellent experience with industrial-level CAD/CAM/CNC software tools, compatible advanced manufacturing hardware is limited for producing parts in a real environment. Since the hands-on labs are very important to concrete the CAD/CAM/CNC concepts, lack of adequate CAM and CAD application hardware was the "weak link" in the current enhancement effort. TTU students' lab practices were limited to conventional and some CNC turning and milling projects. There was no high technology equipment beyond a token handful of CNC machines.

Therefore, implementing RP was planned to fill the gap between CAD/CAM and provide TTU students with the opportunity to practice high tech prototyping practices. Finally, TTU received a NSF DUE CCLI A&I Grant, 0311586 to establish the state's first educational RP Laboratory funded by NSF in Summer 2003⁴.

A Generic Overview of RP

RP consists of various manufacturing processes by which a solid physical model of a part is made directly from 3D model data, without any special tooling. CAD data may be generated by 3D CAD modelers or model data created by 3D digitizing systems⁵. Charles Hull is given credit with bringing the first commercial RP machine to market in 1987 with SLA-1^{6,7}. His machine, like all RP machines, requires 3D CAD data for its operation.

To begin the RP process, the 3D CAD data is sliced into its thin (~.005 in.) cross-sectional planes by a computer. The cross-sections are sent from the computer to the RP machine, which builds the part layer-by-layer. The first layer's geometry is defined by the shape of the first cross-sectional plane generated by the computer. It is bonded to a platform or starting base and additional layers are bonded on top of the first, shaped according to their respective cross-sectional planes. This process is repeated until the prototype part is complete.

The advantages of RP are clear: development of physical models can be accomplished in significantly less time as compared to the traditional machining process. Some other applications of these technologies include development of molds, patterns for casting, and tooling. The prototype built by RP machines can be put to a number of uses as given in Table 1.

Three-dimensional prototypes put students and designers on equal footing in evaluating designs. All the interested parties can see, touch, and handle the design, just as the ultimate customers will.

Most students can't see the design changes or final designs in product form until tooling is produced. New concept-stage RP technologies can provide dozens of snapshot views of the final product at a fraction of the time and cost of RP systems. This lets students watch as the product evolves and lets them take more chances and be more creative as less time, effort, and ego are invested in each model.

Table 1: The Advantages of Rapid Prototyping Systems

Check the feasibility of new design concepts	Visualization
Function/fit test and verification	Conduct market tests/evaluation
Promote concurrent product development	Make Rapid tooling
Make many exact copies simultaneously	Use as a master for metal mold conversion
Manufacturing producibility and supplier quoting	Reverse Engineering using RP

The various existing RP methods can be categorized by the material they use: photopolymer, thermoplastic, and adhesives. Photopolymer systems start with a liquid resin, which is then solidified by discriminating exposure to a specific wavelength of light. Thermoplastic systems begin with a solid material, which is then melted and fuses upon cooling. The adhesive systems use a binder to connect the primary construction material. The typical processes are Stereolithography, Laminated Object Manufacturing, Selective Laser Sintering, Fused Deposition Modeling, 3D Printing, and Multi Jet Modeling⁵.

Rapid Prototyping Technology at TTU

Although neither the current TTU curriculum nor any other school in the state of Tennessee had an RP laboratory in which to practice⁸, Middle Tennessee State University, Murfreesboro, TN has recently purchased some rapid prototyping machines for their machine tool technology lab. These machines were planned to be used in industrial projects and senior level capstone courses⁹.

At TTU, all the CAD design labs are currently done with AutoCAD2002 in the computer lab, and the CNC production labs cover only Milling and Turning Processes practicing CNCez and MasterCAM. Establishing the RP laboratory and enhancing the current courses with RP help the course instructor to convey the cutting edge technology to current students in CAD, CNC, and CAM courses.

Since the initial introduction of the RP process in 1987, several machines have entered the market, which are now affordable by universities. Project team has searched many sources in order to decide which RP machine will be selected. A low cost per prototyped part is important because of the need to prototype a large number of concepts, and to have many student teams use the machine. Speed is important as well. With a class size ranging from 15-20 students and plans to increase the class size to 40 students, a machine that takes one-to-two days to produce a part would limit student access. The use of benign printing materials also would make it safer to let students work with the system.

Because of the short time allowed in the course schedules for the projects, and large number of student teams, cost and speed are the two main determinants in the

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decision to purchase the Z406 machine¹⁰. The speed of the system allows an entire class of students to print color parts for their projects within a week. Additionally, it is easier to modify parts after they have been printed, just as traditional foam models are reshaped.

Safety concerns are negligible with the Z406 machine. After a communal build is completed, students receive the final parts they designed and built. There is also no need to add additional support structure on the CAD part design. This extra work is totally eliminated with the Z406 system.

Rapid Prototyping Technologist “Train the Trainer” Workshop

The objective the NSF grant, 0302314 is to develop rapid prototyping and time-compression techniques in a “design for manufacturing” program for technicians¹¹. Tasks include developing and expanding nine course modules, offering workshops for faculty, providing technical and research experiences for students, and developing laboratory and computer-aided design tools. A strong information technology component includes the sharing of design code and files over the Internet between the laboratories at the institutions. The project also serves community college, university, and high school vocational technical students.

- @ Only 25 openings available*
- @ \$50 refundable deposit
- @ \$600 stipend for each attendee**
- @ Free hotel room for the week
- @ Copy of curriculum available to attendees
- @ Stipends for curriculum evaluation also available

The opening session, including dinner, is on Sunday, July 27 at 4:30 PM.
Closing session ends on Friday, August 1, at 4:30 PM.

RSVP to kpatton@saddleback.edu, as the 25 openings will fill up quickly.
Also, contact Ken Patton with any questions.

Please refer to the following page for the entire week's schedule.

*NCATC members have priority

**Attendees should have basic familiarity with CAD and/or CAM

DUE 0302314

Figure 1: RP Technologist “Train the Trainer” workshop announcement

As part of this grant, RP Technologist “Train the Trainer” Workshop was held in San Diego City College from July 27 to August 1, 2003. One TTU faculty member and two lab assistants attended this workshop since Tennessee Tech was about the build

State's first educational RP Lab funded by NSF. Figure 1 shows the workshop announcement.

As can be seen in Figure 2, workshop took one week and covered the fundamental RP techniques and its hands-on practices. Vendors presented their up-to-date equipment, and gave a chance the attendees to practice. Lectures were supported with the lab practices so that no gaps are left in the attendees' learning. Table 2 presents the list of participants' institutions.

Rapid Prototyping Technologist Workshop July 27 - August 1, 2003

	7/27 Sunday	7/28 Monday	7/29 Tuesday	7/30 Wednesday	7/31 Thursday	8/1 Friday
8:30 - 10:00 AM	Arrival	Keynote Speech	RP Technician Skill Standards	Vendor Showcase	Finish & Fill Technician Skill Standards	Effective Teaching of RP Curriculum
10:00 - 10:30 AM		Break	Break	Break	Break	Break
10:30 - 12:00 PM		Introduction To Rapid Prototyping	RP Technician Build Preparation	Vendor Showcase	Finish & Fill Technician Post Processing	Integration RP into Existing Curriculum
12:00 - 1:00 PM		Lunch	Lunch	Lunch	Lunch	Lunch
1:00 - 2:30 PM		Technologist Skill Standards Shop Management Data Manipulation Procedures	RP Technician* Building RP Models	Open Lab/ Plant Tour	Finish & Fill* Technician Basic Post Processing	NSF Funding Presentation Q & A Lab Session**
2:30 - 3:00 PM		Break	Break	Break	Break	Break
3:00 - 4:30 PM		Technologist* Application Of Procedures	RP Technician* Part Removal & Maintenance	Open Lab/ Plant Tour	Finish & Fill* Technician Advanced Post Processing	Closing Session (Evaluation)
4:30 - 6:00 PM	Opening Session	Break	Break	Dinner Cruise Sponsored by: 3D Systems, Paton & Assoc. Z-Corp.	Break	Departure
6:00 - 9:00 PM	Dinner					

* Learning LAB

** Split Session attendee decides which one to attend

SAN DIEGO
HARBOR EXCURSIONS

Figure 2: Scheduled events of the workshop

RP Technician

The Rapid Prototyping Education Resource

...: Site Navigation ...:

- [Home](#)
- [Forum](#)
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2003 Technician Training Workshop Photos

All of the photos from the Rapid Prototyping Technician Education Workshop in San Diego, California are now online. To view them, visit the [Photo Gallery](#). A zip file containing full resolution versions of all images may be downloaded [here](#).

Dec 17 2003, 04:53 PM

Site Launched

Welcome to RPtechnician.com: The Rapid Prototyping Educational Resource. We are in the process of bringing everything online and implementing planned features. If you [sign up](#) for a forum account we will send you an e-mail when this site is completely online.

In the mean time, take a look around to see a few of the things this site will offer. Thank you for visiting.

Oct 1 2003, 12:00 PM

...: Poll ...:

Which type of RP machine do you have?

☐ 3DP (Z Corp)

☐ FDM (Stratasys)

☐ SLA (3D Systems)

☐ SLS (DTM)

☐ MJM (3D Systems Thermojet)

☐ Other/Do Not Own One

[Vote!](#) [Results](#)

Figure 3: Workshop materials were collected in a website, <http://www.rptechnician.com/>

Table 2: Institutions of the workshop participants

LONG BEACH CITY COLLEGE	CA	MT SAN ANTONIO COLLEGE	CA
CENTRAL MAINE COMMUNITY COLLEGE	ME	RIVERSIDE COMMUNITY COLLEGE	CA
LONG BEACH CITY COLLEGE	CA	TRIUMPH COMPONENTS	CA
TENNESSEE TECH UNIVERSITY	TN	MIDDLE TENNESSEE STATE UNIVERSITY	TN
DANNVILLE COMMUNITY COLLEGE	VA	CUYAHOGA COMMUNITY COLLEGE	OH
MT SAN ANTONIO COLLEGE	CA	SAN DIEGO CITY COLLEGE	CA
EL CAMINO COLLEGE	CA	GLENDALE COMMUNITY COLLEGE	CA
CENTRAL PIEDMONT COMMUNITY COLLEGE	NC	GLENDALE COMMUNITY COLLEGE	CA
KETTERING UNIVERSITY	MI	GLENDALE COMMUNITY COLLEGE	CA
CENTRAL MAINE COMMUNITY COLLEGE	ME	CALIFORNIA STATE UNIVERSITY LA	CA
CENTRAL MAINE COMMUNITY COLLEGE	ME	SADDLEBACK COLLEGE	CA
ST LOUIS COMMUNITY COLLEGE	MO	SAN DIEGO CITY COLLEGE	CA
TENNESSEE TECH UNIVERSITY	TN	SAN DIEGO CITY COLLEGE	CA
TENNESSEE TECH UNIVERSITY	TN	SADDLEBACK COLLEGE	CA
MT SAN ANTONIO COLLEGE	CA	SAN DIEGO CITY COLLEGE	CA
CHEMEKETA COMMUNITY COLLEGE	OR	SAN DIEGO CITY COLLEGE	CA
SAN DIEGO CITY COLLEGE	CA		

More details about the workshop are given in an Internet site, <http://www.rptechnician.com/> as can be seen in Figure 3. Some of the training Figures are given in Figures 4-6.

Figure 4: One of the course instructors in discussion with one of the workshop attendees

Figure 5: One of the workshop attendees practicing a post processing operation

Figure 6: One of the lecturing sessions held in the RP lab

Conclusion

After the training held at the “train the trainer” workshop more challenging student RP laboratory assignments and industrial projects were developed in the areas of CAD, CAM, CNC practices at Tennessee Tech. Special assignments have been established to specifically introduce RP, allowing students to create a solid model of their design and use the Z406 to create a physical model as part of the concept and sketch

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model refinement process. Some new projects include introducing the student to both layer additive and layer subtractive process; hands-on team exercises including set-up of Z406 machine operations, construction of models, and use of a prototype to critique the current design from design, manufacture, and assembly standpoints. It is also important to give access to other universities and community colleges to give them exposure. The lab and course development was made available for others through Tennessee Tech University's Instructional Web Server, http://iweb.tntech.edu/ifidan/RP_Lab.htm. RP Technologist "Train the Trainer" Workshop was a great success since it helped all attendees have solid hand-on RP experience. Some of the adaptations and implementations accomplished by the TTU team have presented in this paper.

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Biographical Information

ISMAIL FIDAN

Dr. Ismail Fidan is an Associate Professor in the MIT department, College of Engineering, Tennessee Tech University, Cookeville, TN. He has been at TTU since August 2000. Dr. Fidan received his PhD in Mechanical Engineering from Rensselaer Polytechnic Institute in 1996. He is a senior member of IEEE and SME, life member of TAS, and member of ASEE, NAIT, and ASME. Dr. Fidan also serves as an associate editor for the IEEE Transactions on Electronics Packaging Manufacturing and International Journal of Computer Applications in Technology. He has been ABET and NAIT manufacturing program evaluator since 2003. Dr. Fidan is the recipient of 2004 TTU Leighton E. Sissom Innovation and Creativity Award, 2003 SME Jiri Tlustý Outstanding Young Manufacturing Engineer Award, 2002 Provost "Utilization of Technology in Instruction" Award, 2002 Technology Award by The Institute for Technological Scholarship, 2001 NAIT Outstanding Professor Award. His teaching and research interests are computer-integrated design and manufacturing, electronics manufacturing, rapid prototyping, and manufacturing processes.

CORAL NOCTON

Miss Coral Nocton is the president of the Tennessee Tech University's Society of Manufacturing Engineers student chapter. Keeping her plate full, she is also the Chair of National Engineer's Week for the College of Engineering at TTU. During the 2000-2001 year she was the secretary of the SME student chapter and President of the Society of Women Engineers. Currently a Senior in the Manufacturing and Industrial Technology department, Coral has been awarded many scholarships due to her highly involved educational nature. Miss Nocton completed a manufacturing cooperative education program in high school, then continued on to complete a summer co-op program in her freshman year and is currently finishing up her college career with a one and one-half year process engineering co-op at a local automotive supplier. Planning to graduate in May of 2004, Miss Nocton hopes to obtain a manufacturing engineering or management position in a progressive company.

ADAM MCGOUGH

Mr. Adam McGough has been a research and laboratory assistant at the TTU Rapid Prototyping Laboratory. He has a BS degree in Industrial Technology and Minor in Business. He has been a member of SME, AFS, and the vice president of the TTU FSAE Team while also acting as the CAD and CNC applications manager/designer for the team. He has been in the CAD, CAM and CNC industry for the last 10 years.

KEN PATTON

Dean Ken W. Patton is currently in his second year at Saddleback College in Mission Viejo, California. He has over 30 years experience in higher education, with almost 20 years at the Dean level. He has extensive experience in workforce and economic development, with a national reputation for being innovative in developing technology transfer programs for students and industry. He is a member of SME, ASEE, California Association of Local Economic Developers (CALED), Orange County Joint Chamber of Commerce, Orange County Business Council, and California Community College Association of Occupational Educators (a former board member). He has served on the board of the Economic Alliance of the San Fernando Valley and is currently on the Board for the National Association of Advanced Technology Centers (NCATC).