Paper Planes: Developing Teamwork Awareness with a Manufacturing Simulation

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Abstract

We find that many students who enter UVa have not been involved in activities which require larger teams to function, to adjust their structure for improved efficiency and success, and to assess individual roles in the context of goal-oriented teamwork. This may be common in other universities as well. Yet, this experience is most important for engineering graduates to have worked and achieved in for contemporary and future technical and business careers. Our goal has been to provide an introduction to such perspectives in typical interdisciplinary first-semester classes of engineering design and/or communications.

For several years, we have been using a modification to classroom use of commercial simulations of manufacturing. The activity is usually done in the evening accompanied by pizza and soft drinks. The materials used are paper templates that require student teams to perform many steps of cutting, folding, adorning, inspecting for quality, and launching for accuracy on a target. The format is a competition allowing redesign and improvement from the first (usually quite ineffective) and second (somewhat better) member assignments and team construction strategies to a third (reasonably satisfactory) run that "counts".

We have monitored individual student assessments during and after the activity. They show much greater appreciation of the need for team members to look beyond themselves to assist others, to analyze and adapt their roles to improve productivity, and to focus on what they can do, both individually and collectively, toward achieving the whole team's objective, rather than merely reaching their individual goals.

This paper describes the format of the simulation, gives analyzed and anecdotal assessment by students, and provides information about how other teachers might use our materials and experience in their own programs.

1. Introduction

Teamwork is essential for accomplishing engineering projects and solving contemporary and future engineering problems. The complexity of modern technology and the sophistication of current knowledge and procedures makes it impossible for any single individual to know and do everything; assistance from others is essential in virtually every engineering endeavor.

It is vital that engineering graduates both understand the nature of, and be able to function in, team situations. As a result, engineering education must include a significant number of experiences that impact students in ways that build awareness and skills in teaming. There are many formats in which this can be done. Teams can be made up of two to twenty people, be focused in one or several disciplines, the period of time can vary from one class or activity to multiple years.

It is our view that our students should encounter a breadth of team learning situations. The literature describes many opportunities for teachers to organize team building[1-3] and we have used a number of them ourselves[4-6]. This paper describes an alternative 2+ hour activity that we have used for several years. The students report it is especially valuable for their appreciation of the importance of teamwork and for building some of their skills in adapting for greater effectiveness. It also seems to provide them major insight into the importance of details in producing quality products.

The exercise is a modification of commercial simulations of manufacturing for engineering education purposes. The objective is for teams of 10-15 students to use paper templates of planes or "spaceships" requiring each of them to perform one of many steps of cutting, folding, adorning, inspecting for quality, and launching for accuracy on a target within a short period of time. The role of the teacher is to organize the activity, tabulate the results and guide the analysis and feedback aspects. The format is a competition that allows 1-2 practice runs followed by redesign and improvement of the assembly until member assignments and team construction strategies can accomplish a successful run that "counts" in the competition. We have used this mainly at the freshman-level engineering design and communications courses, principally about 2/3 through the first semester at the University.

2. Our Adaptation and Use of Manufacturing Simulations

In the fall semester of 1996, three of the authors (RJ, MAS, JPO'C), became interested in using classroom simulations as one experience in the UVa Professional Development Program[4] for beginning students in Engineering Design. We approached Aviat, a subsidiary of ORION International in Ann Arbor, MI, about trying their manufacturing simulation, Paper Planes, Inc., which was created by W.C. Musselwhite for business use. We were attracted to it because it could involve as many as 30 participants simultaneously (about the size of our classes), required the production of a device that had to perform as well as meet visual criteria, provided opportunities for system reengineering and process improvement based on self- and group-evaluations, and appeared to provide considerable enjoyment along with intense involvement. Aviat subsidized our purchase of the participant supplies, facilitators guide and tools. They also gave us permission to make modifications that would better suit students. The activity proved extremely popular and successful with only a minimum of procedural adjustment, teacher training, and rewrites of the handout materials.

The initial exercise consisted of the participants acting as employees of airplane companies engaged in a competition to manufacture the most paper planes of explicit quality standards set by an "international consortium". The standards included precise cuts and folds, application of decals and launching to a target at 15 feet away. Two teams of about 17 students each were formed; one team did the first production run while the other served as observers. Each participant of the production team played a role in the production process, *i.e.*, cutter, folder, inspector, tester, supervisor, etc. Table 1 shows the roles we currently use for a different device.

Table 1. Roles for Workers in Manufacturing Simulation

ASSEMBLY WORKERS
FOLDER 1: Makes first fold of template after obtaining it from Inventory Clerk. Passes to Cutter 1.
CUTTER 1: Responsible for making first cuts in template; follow lines exactly. Passes to Cutter 2A.
CUTTER 2A: Responsible for finishing certain crucial cuts. Passes to Folder 3 and Cutter 2B.
CUTTER 2B: Makes very important cuts. Passes to Cutter 3.
CUTTER 3: Responsible for finishing cutting. Passes to Folder 2.
FOLDER 2: Makes folds in 4 places. Passes to Assembler.
FOLDER 3: Responsible for folds to allow proper assembly. Passes to Assembler.
ASSEMBLER: Responsible for assembling all pieces. Improper placement results in weakness of unit And unacceptable visual quality. Passes to Shield Applicator.
SHIELD APPLICATOR: Places 8 shields in right spots for protection. Passes to Hatch Applicator.
HATCH APPLICATOR: Places Fuel Bay Hatch cover (FBH) over Fuel Bay. Passes to Inspector.
LAUNCHER: Test-flies the ships from Inspector, records results of flight testing. Theship must fly for at least 15 feet and hit poster. Try each ship only 3 times; if unsuccessful, attach green tag to ship.
ADMINISTRATIVE PERSONNEL
INVENTORY CLERK: Distributes materials to workers, keeps track of quantity of materials used. Once materials are checked out, they are considered used and can not be returned to the inventory. Does an accounting of the materials and costs at end of run.
INSPECTOR: Inspect each ship, determine if could be acceptable to Consortium Representative. Reasons for rejection include: Cuts not even or not along lines; folds not smooth or not along lines; triangular stabilizers not folded to 45^o; meteor reflective strips not in proper locations; IAC's not fully covering fire emission openings; FBH not in proper orientation; wrinkles.
ASSISTANT SUPERVISOR: Assists Supervisor in the completion of overseeing entire production.
SUPERVISOR: Oversees entire production process. Problem-solves & troubleshoots, responsible for Smooth work flows through steps, ultimately responsible for completion of quality products.

The simulation began with the assembly sequence prescribed as a traditional division of labor with the steps done in sequence. It produced no planes in fifteen minutes. At the end of the simulation run, individuals of both the producers and observers had five minutes to silently wrote down their answers to a series of questions designed to evoke their attitudes and assessment of individual and team accomplishment, or lack thereof, and ideas for improvements for the next run. Then separated team discussions were held for ten minutes to establish a reorganized assembly process done by the first-run observers while the first-run producers observed. There was considerable improvement in total production, as well as higher quality in the manufactured planes. After another individual and group assessment period, both of the teams did the simulated production in separate rooms with the testing being done in a common hallway. The production was the best and the results were very close for both teams. The winner had to be chosen not on the basis of total number of satisfactory planes produced – which was the same for both teams - but from quality points accounting for minimized waste and best use of supplies.

At the end of each run, there is a quiet period of about five minutes when every individual writes answers to a series of questions. Table 2 shows the questions we currently use during the simulation; Table 3 shows the final debriefing assignment to be done by the beginning of the next class. There is great value in this format because contemporary students may not search for their own thoughts and responses to learning situations; they often prefer to reflect those of others. Further, emotions build during the practice sessions, and it is valuable to let them die down for the more rational process of reengineering. We find their written comments, even after the first practice, demonstrate considerable honesty and growing awareness of the values we are trying to promote.

Table 2. Individual Questions for Reflection and Discussion

#	After Run 1	After Run 2	After Final Competition
1	Are you satisfied with the results of your personal efforts?	What improvements did you implement compared to the first run?	Do you feel successful? Y___ N___ To what do you attribute your success or its lack?
2	Are you satisfied with the results of your team's efforts?	Was your teamwork more effective? Y___ N____ How?	How has your view of teamwork changed?
3	What most affected your effectiveness?	How was the communication different?	How has your concept of quality changed?
4	Specifically, how did the other participants affect your performance	Was the quality improved? Y __ N___ Give an example	What was the impact of redesign on your team's effectiveness?
5	Did you work together as a team? Y___ N___ Give an example	What still needs to be improved for the next run?	Were you empowered in the system that was adopted? Y ___ N ___ How?
6	How might the team's effectiveness be improved?	Will this be an incremental or a radical change?	General reflections
7	General reflections	General reflections	
8	Ideas for redesign of the setup & personnel use	Ideas for redesign of the setup and personnel use	

Table 3. Survey about the Manufacturing Simulation

1.	Based on your experience with this simulation, please write no more than 15 words that come to your mind when you read each of the following words/phrases: Quality; Customer; Communication; Division of Labor; Performance; Individual Responsibility; Team Responsibility; Productivity; Pay for Performance
2.	Write a 2-page reflection paper on your experience from the simulation exercise. If you discuss ideas that are already covered in a previous section of this follow-up exercise, cover them briefly unless you plan on using these ideas as a means to discussing a deeper level of reflection. Turn this in to your professor at the beginning of next class.

It was particularly interesting to see how the level of voices and individual motion went from the initial run's quiet, interrupted by occasional outbursts, to the final run's loud and animated cheering for the testers. As discussed below, debriefing of the students at the next class period showed that they had realized their contribution to the team needed to be more than merely "doing their own job" and that reorganization based on participant information and decision-making had great positive impact.

Evolution of UVa simulations 1997-2000

The simulation was run again in the same courses in 1997 using the Paper Airplane Simulation from International Learning Works, Durango, CO. The change to this provider was done because the materials were easier to adapt and considerably less expensive. In general, the setup, execution and results were the same; the students achieved the same levels of productivity and reported similar growth about the importance of engagement, quality, adaptiveness and whole team responsibility.

The simulations were run in 1998, 1999, and 2000 with some evolution of the materials and format. In particular, all assembly and testing was done in the same room, though the reengineering sessions were still done separately. The “airplane” materials became no longer available, being replaced by a “spaceship” designed to ward off invading aliens. In our last version, the premise was not a threat, it was a competition for the first civilian space flight service called Spaceflights.com. This also allowed safety to be invoked as a criterion to encourage greater quality.

The simulations have been run with 3 teams simultaneously; the first three practice runs are rotations of pairs of production teams and an observation team, followed by a final competition run of the three teams in production. Although we have used two or three class successive periods to complete the exercise, the most successful format has been an evening which begins with pizza or other dinner food followed by the activity, which takes about 2-3 hours depending upon the number of teams.

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3. The Essential Ingredients for Success

The most important ingredient to accomplish the goals of the simulation is to get the students to “show up”. They have great skepticism about doing such a “game”; as much, if not more than in business[7]. We find that the proper “hook” is free food and, occasionally, extra credit toward the course grade. In fact, we say very little about the details of the simulation in advance because students severely prejudge what should happen and will conclude that being there would be a waste of time. Evidence of this is in some quotes from final debriefing surveys (Student initials). “I must admit that when I first read over the description of the . . . simulation, I thought it was a joke.” (CL) “I must admit that I entered the room with some skepticism, but I left thinking how useful that experience had been.” (RB) “I figured it would be an exercise that I would not enjoy. . . . I found my impression was wrong.” (JM) “It didn’t sound like much fun . . . and I was scared of working in big groups with people I didn’t know.” (MG) “I had come into the room not at all wanting to be there and looking most forward to the pizza. . . . It had been a long day and all I wanted to do was go home and relax.” (SR)

We also find that this simulation to have important value because it requires the <u>construction of a real device</u>. Unlike team building activities which focus on collaborative learning[1-3], or those based on computer simulation[8-10], Paper Planes provides experience in making a product that must pass both human and Nature’s standards. While people can miss subtle errors, and computer programs not be programmed for all possibilities, Nature is absolutely unforgiving. Thus, in the first run, it is very rare for any ships to be successfully launched, which had significant impact on the teams. This lesson is vital for technical students to understand, especially in our current world filled with virtual images and effects that may not fully reflect the realities that engineers, more than anyone else, confront in their professional work. This lesson is usually not obvious in schooling, even when failures are described[11-12], so it must be "lived" and then formulated clearly as a part of the debriefing. It should be noted that this simulation is not intended to stimulate creativity or innovative product design. There is an element of new thinking required for the reengineering steps, but originality is not a major goal. Rather it is to develop new insights about human interactions, productivity and quality.

In addition, unlike small group teambuilding, when there are ten to fifteen members, we learn from the comments that there are much different dynamics. "In my previous team environments, the task was one to be completed by the entire group or split into individual tasks. This simulation combined both where the group had to unite to perform individual tasks." (KC) The need for leadership is more obvious, but there is a concomitant tendency for individuals who are not in such position to ignore their responsibility to the whole process. "I realized that the purpose of my role was not to show how well I was putting on stickers, but I had to work with the entire team and coordinate my role so that productivity would be maximized." (WL) "I thought that being Folder 3 would mean nothing, but I began to realize . . . there was an importance to each one of the duties performed." (TM) In the case of a serial manufacturing assembly process, if the person does not have something to do at that moment, he or she tends to think about something else or become impatient with the situation, without actually attempting to see if a contribution could be made. ". . . even if people don't have a genuine interest in the project, in most cases something will get the person to do the best job possible." (SR) We have found that after reengineering, students realize that they can do other tasks besides those assigned, even if it is just to be cheerleaders urging on those doing the work at that point. The consequent comradeship that arises enhances both the effectiveness of the production and its enjoyment. "I noticed that the individuals in the group I was observing would help each other out just as if they had been friends for years." (CL) "I learned not to have tunnel vision when performing a task. Once we began helping others and expanding our jobs, [production] and quality increased." (NK)

For students, even more than professionals, it is essential that there be a <u>competition</u> in order to establish engagement. "I think that it does help that the activity is competitive because most first-year college students want to win at all costs." (DA) Productivity, quality and teamwork are abstract concepts that many students will not connect to. They do appreciate the need for practice, though it too will not lead to involvement unless there is a more innate driver at work. There is also the aspect of rapid, and obvious, skill development that happens. In a very short period, they realize that growth and success enhanced performance and commitment. The period leading up to the final competitive run provides a suitable time of concentration on the process. We have tried games of the order of ½ hour, and while certain specific lessons can be accomplished, but it takes longer than that to build the sense of personal responsibility and connection to others. Apparently 2 hours can be quite effective.

It is also essential that students do <u>observing as well as assembling</u>. Lessons are not as well learned in the heat of the moment. "Teamwork was evident through observation.' (RP) "We saw many things go wrong. . . . . lack of communication . . . sitting around not helping . . . suggestions to improve met with hostility." (BS)

Teacher responsibilities

Certain <u>preparations</u> must be made by the teacher to insure maximum success. All of the materials must be provided and distributed smoothly and completely. There are "participant packages" that are given to each individual describing the overall premise and activity format as well as the particulars for the role he or she plays in the assembly process. The leaders must be selected in advance, though the communication of position is made only at the start of the exercise. The key positions are those of supervisor, inspector, launcher, and inventory clerk. The supervisor directs all processes including making decisions during the runs, chairing the reengineering, and enforcing the regulations. The inspector judges each plane's quality of appearance and makes the tough calls to reject unacceptable work. Both of these positions require character and respectability. With some of the device designs, especially the "spaceships", successful launching requires athletic ability and willingness to persevere until the most effective technique is found. Finally, the demands made on the inventory clerk to provide supplies, often in response to chaotic demands, to log them out, and then ultimately compute their cost, takes an individual who is unflappable and organized. While we have had no major failures of the simulation with people who were not as effective, when we have made good choices, the whole experience is better.

Sometimes, we have chosen individuals on a "hunch" that he or she has leadership qualities that have not yet been demonstrated; when we were right, that person was also affected in a particularly positive way. "I didn't want to be supervisor and couldn't handle being in charge of 10-12 people all at one time. . . . . [Then] I knew I wasn't the only leader of this group. We all were. We just had different levels of leadership and different tasks at hand." (AP) "I was worried when I found out I was the supervisor . . . . I learned a great deal about the importance of listening to all the team members and keeping an open mind about their suggestions. I learned I must trust everyone and let them be responsible for their own job." (DA)

It is also useful to <u>involve three facilitators</u> in the exercise. Commonly they have been up to three teachers in the course sections doing the activity, but we have also used colleagues, mature teaching assistants, and industrial friends. There needs to be someone, usually the lead teacher, to introduce the exercise, be the timekeeper, and the enforcer of policy and procedure. It is helpful for this person to have an assistant for distributing materials, to note developing issues, and be a conduit for communication to the chief facilitator. Finally, there has to be the "customer", who represents the consortium seeking the best manufacturing company and who has the final say in whether a particular device is acceptable. The best person for this position is someone whom the students do not know, but whose position commands respect. He/she should also have a healthy sense of humor and is genuinely supportive of the simulation.

In addition to preparation, there are several <u>post-simulation requirements</u> of the teacher. The contemporaneous reflection forms and all other materials must be collected, especially completed planes. The surveys should be examined immediately to determine what understandings were accomplished and which were missed so that the next class period can be devoted to the most useful discussions. This class session is typically introduced with brief questions about winners and losers such as "If you were on the losing team, what made the others better than you?" This inevitably stimulates student involvement in discussion which than can be guided toward the importance of quality, the value of teamwork, the acceptance of roles, and the avoidance of pejorative judgment of others. Usually, individuals will start by complaining about someone else or some regulation. Often, the teacher does not have to respond, other students will jump in to comment on both sides of appropriateness. Sometimes, the complainer can be asked about what he or she was doing at the time, and whether he or she should actually have acted. Typically, the class comes to understand that failures occur from three sources: lack of a broader commitment by individuals, lack of effective communication, and the Natural limitations associated with a multistep process in a limited time. They also then realize that they are the ones that can control the first two problems, and that they are constrained to operate under the third. We also try to reinforce the messages quoted above; students often phrase them better than we do. The one that they do not consider, but usually is appreciated after the simulation is "if you want to be world-class, you have to do world-class work, regardless of what the task is". Finally, a teacher's oral summary of what was learned is useful; it often triggers additional insights for individual students.

4. Outcomes

Tabulations of the survey results for Fall 2000 have been made. At the end of the first run, student expressions of satisfaction were high (78 %) for themselves and less (63%) for their teams. However, every single student said that the second run had more effective teamwork. At the end of the first run, 90% of the students had ideas for redesign of their team's process; at the end of the second run, 70% still had ideas. But in the end, 88% felt "successful" at the end of Run 3. At that point, over 89% said that their view of teamwork had changed, especially that it was very important (26%) and that agreement and organization were needed (20%). After the exercise, the concept of quality changed for 75% of the students and 75% felt "empowered" in the system that was used in the final run; the common feeling of those who were not (40%) was that they were still "just a cutter, etc.". While 52% of the observers noted that conflicts arose, they also noted that 64% of the team members were working or helping others. We have not done any pre-assessment benchmark of student attitudes.

In addition to these quantitative results, we feel the student commentary was extremely gratifying. CL who thought it was a joke said, "I realized that something as simple as cutting impacts everyone else on my team. I enjoyed the time and met new people, which is what it will be like out in the real world." RB who entered the room with some skepticism "left thinking how useful that experience had been." JM who figured it would be an exercise not to be enjoyed said, "I found my impression was wrong." MG who was scared of working in big groups with people he didn't know, "learned that big groups aren't as bad as I thought they would be. I thought I wouldn't have much to say in a groups with so many people, but that turned out not to be true." SR who did not at all want to be there except for the pizza admitted that it "helps people to learn to work in groups so that in their daily jobs they work better together and form a more cohesive whole. This is somewhat like the real engineering world."

The year 2000 version was also run in 2002 by one of the authors with a class of 36 junior Chemical Engineering students at the beginning of their first unit operations laboratory, which requires extensive work by teams of three. None of these students had done the simulation before. Though the ultimate rate of successful ships was greater, this was mainly due to more effective reengineering of the process by the more mature students. However, these students commented about learning in essentially the same ways as the freshmen; they emphasized the value of teamwork, the importance of every member contributing with quality, and the need for adapting. During the semester, as these students have encountered inevitable difficulties in teaming as well as in getting the experiments to work as well as they thought they should, the teacher referred back to the simulation to develop student insight. The impression is that more effective and efficient guidance has occurred by this technique.

An interesting development occurred in 1999. It was a 3-team event with a lot of action and organization was challenging to the facilitators. The difference in satisfactory planes was a single one between two teams, much to the disappointment of the losing team. However, the feedback indicated that the usual lessons had been learned. But then, on the second day after, one of the teachers received a note from a student on the winning team who admitted that they had not won fairly. Apparently they retrieved successful planes discarded after a practice run and submitted them in the final run, giving them the victory. The teacher decided to inquire of the class at its next meeting if they knew of any irregularities that might have occurred. After some oblique, and then some honest, conversation, it was revealed that members of both of the top two teams had cheated! This was particularly remarkable, in that UVa has a strict Honor Code for which there is extensive orientation of all students. The discussion was then able to center on the goals of the exercise, not just the mechanics. The students justified their behavior because the objective was to "win". They showed their immaturity in not realizing their role in school is to learn. The teacher felt that this unusual situation provided great insight to all involved. However, we have taken precautions to insure such cheating would not occur again.

We have not yet followed up for long-term impact on the students, but we are developing a brief survey to send via e-mail to the students during the last semester before graduation. This will contain items about their recollection of the experience, whether it helped them deal with effectiveness in teamwork situations during their college work, and if they expect that they will be able to use it in their careers. These results will be reported in the future.

5. Conclusions

We conclude that our manufacturing simulation is an exercise that is complementary to other teambuilding activities and is effective in building student awareness of how teams should function and the value of adapting for greater accomplishment. The students indicate an unexpected level of growth, a realization that learning can come in many different guises, and that quality and teamwork do not just "happen". The value of communication, commitment, and care seems to come through uniformly and strongly.

6. Bibliography

1. Woods, D.R. Problem-based learning: How to gain the most from PBL, Waterdown, ON.
2. Felder, R.M. and Brent, R. Effective strategies for cooperative learning. J. Cooperation & Collaboration in College Teaching, 10(2), 69-75 (2001).
3. Johnson, D.W., Johnson, R.T., & Smith, K.A. (1998). Active learning: Cooperation in the college classroom (2nd ed.). Edina, MN: Interaction Book Co.
4. O'Connell, J.P., Shields, M.A., Seeloff, E.R. Scott, T.C., and Pfaffenberger, B. Professional development at the University of Virginia: Attributes, experiences, ABET 2000 and an implementation. ASEE Annual Meeting, 1997 Session #2653.
5. Shields, M.A., and O'Connell, J.P. Professional development and collaborative teaching in an undergraduate curriculum. ASEE Annual Meeting 1997, Session #3253.
6. Shields, M.A., O'Connell, J.P. Technological capability: A multidisciplinary focus for undergraduate engineering education. ASEE Annual Meeting 1998, Session #1261.

7. Musselwhite, W.C. Flying High; Exploring whole systems and quality. Proc. 1992 Int. Creativity and Innovation Networking Conf., Stanley S. Gryskiewicz (Editor), Center for Creative Leadership, Greensboro, NC, 1993.
8. Dörner, Dietrich. The logic of failure: Why things go wrong and what we can do to make them right. Translated by R. & R. Kimber. New York: Metropolitan Books, 1996.
9. Elgood, C. What can simulations contribute to training programmes? The Training Journal, January 2000.
10. Internet sites which list simulation games, including those for education, include: http://www.simulations.com, http://compsimgames.about.com, and http://www.maxis.com.
11. Petrowski, H. To engineer is human: The role of failure in successful design. New York: Vintage Books, 1992.
12. Schlager, N. (Ed.). When technology fails: Significant technological disasters, accidents, and failures of the twentieth century. Detroit: Gale Research, 1994.

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Faculty interesting in trying the simulation may obtain the basic materials in electronic form from JPO'C. Under certain circumstances, the authors may be engaged to facilitate these simulations. Contact jpo2x@virginia.edu.