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Linking Cultures: An Industrial Project-Based Design 
Course for U.S. and Chinese Students in China 

Background

Globalization of the engineering enterprise has not only impacted its practice but also the 
education of its practitioners in ways previously unimagined. Virtually every engineering 
program in the country has implemented new activities and programmatic changes to assist 
graduates develop the skills, knowledge and experience to function effectively in a world of 
diverse culture, language and aspirations. Examples include a variety of variable duration 
international study, design, research and exchange programs as well as curriculum revisions that 
provide greater cultural, language and international practice exposure.

In 2007 North Carolina State University conducted a Study Abroad program with 
Zhejiang University in Hangzhou, China. Its purpose was to begin the development of a 
relationship to promote student exchange and faculty interaction. The plan for this six-week 
program was to have NCSU students (1) enroll in six hours of credit that would be taught by 
accompanying faculty and (2) engage in tours, cultural events, industry visits and social activities 
with Chinese students for cultural enrichment. The College of Engineering participated by 
offering an introductory course in mechanics, MAE 206 Statics. The schedule coincided with 
the first summer session on the NCSU campus.

Participants included three faculty from management, political science and mechanical 
engineering and seventeen students. The academic program consisted of two business courses, 
an introduction to international relations and the first course in engineering mechanics. All 
courses were taught by NCSU faculty and only NCSU students were enrolled. Classes met for 
one and a half hours every day for five weeks.

The basis of the cultural experience was housing all participants on a university campus 
with Chinese counterparts. Additional cultural exposure was a series of tours, cultural lectures 
and industry visits. Guided tours included visit to Shanghai, Wuzhen and Shaoxing. Three 
Cultural lectures were provided by Zhejiang faculty on Chinese history, minority ethnics groups 
and Chinese calligraphy. Several Hangzhou business enterprises were also visited.

Among the lessons learned was the need for a program assistant fluent in Chinese to 
accompany future programs. Also more direct interaction between NCSU and Chinese students 
needed to be organized and scheduled. An introductory course in Chinese language taught by 
Zhejiang faculty should be added.

In year two the original course offerings were expanded to include Chinese religion, earth 
science and Chinese language. A four day optional tour of Beijing was offered as an add-on to 
the regular program. Several social events with Chinese students were scheduled and held. 
Excursions relevant to the religion, business and engineering courses were included and 
conducted. Some preliminary interaction with Zhejiang faculty was begun but no plans evolved 
for NCSU and Chinese students to take classes together.
It was not until year three that the issue of combined class enrollment became a real possibility. An ME doctoral student at NCSU and graduate of Zhejiang provided the author with an introduction to Professor Gu Daqiang in the Mechanical Engineering Department. This resulted in an invitation to lecture to Professor Gu’s design classes and to serve as a judge in a design project competition. We agreed on the value of teaching design skills through project activity and having NCSU and Zhejiang students experience this together. This led to the decision to create a design offering for the summer of 2010 involving both NCSU and Zhejiang students in design teams working on a real industry design need.

Program Planning

The proposed program was to consist of a three credit hour course in design taught by North Carolina State University and a three credit hour course in introductory Chinese taught by Zhejiang. With only one NCSU faculty involved program costs were reduced requiring fewer students to meet the program budget.

An NCSU course, MAE 495 (Mechanical Design Engineering), was chosen for the program design offering. This special topics course is normally taken by juniors and seniors to satisfy a technical elective requirement for the Mechanical Engineering BS degree. The course could be structured to include a design project together with normal class room sessions. To satisfy contact hour requirements for three credits, in each of the five weeks of the program there would be three 90 minute class sessions and two 2 hour design labs. This was an agreeable arrangement with both institutions.

The class session material content was selected from related courses taught regularly on the NCSU campus. The following topics were included:

1. Introduction to Design Engineering –
   An Engineering Problem Solving and Design Process
2. Personality Traits and Preferences –
   Myers-Briggs Type Indicators, Right/Left Brain and Learning Styles
3. Creativity –
   Innovation, Inventiveness, Formal Techniques
4. Operational Analysis Solution Process –
   Process Guidelines and Example Applications
5. Design for Power Transmission –
   Principles, Constant and Variable Speed Devices
6. Design for Dynamic Response –
   Vibration, Impact and Isolation
7. Design for Deflection –
   Energy Method Applications
8. Design of Special Elements –
   Non-symmetrical Beams, Non-circular Shafts, Columns and Composites
9. Design for Strength and Endurance
   Static and Dynamic Failure Analysis
10. Design for Assembly
   Product and Part Design Guidelines and Applications

A special set of notes was generated for distribution to all students to use as a text for the course.

The five week course with the design labs meeting four hours weekly provided each team with 80 scheduled man hours for project effort. Within this limited period the project needs had to be understood, the design problem defined, a practical solution created and the results reported. It was decided that to insure maximum potential for success and a sense of accomplishment for the students within this time constraint a realistic redesign experience would be more appropriate than an effort to create some new device.

Recruitment and selection of students and establishing the schedule for the program posed some interesting problems. A class size of twenty with equal numbers of NCSU and Zhejiang students was considered to be about right; large enough for good competition among design teams, not too large to manage for a first time effort and sufficient to meet the budgetary needs. Students would be divided into five 4 person teams with two NCSU and two Zhejiang students on each team. Recruitment for summer study abroad programs at NCSU begins in mid-September after the start of the fall term and the final commitment of students to participate is not required until early March. The program was promoted in upper level fall ME classes and ten student applications to participate were received by mid February. This response was somewhat disappointing as early expressions of interest were high. As the commitment deadline approached, with its requirement of a non refundable registration fee, four students withdrew their applications. One of them was unable to raise the funds to cover the cost while the other three decided to accept summer engineering internships locally that provided both industrial experience and compensation. The remaining six students were all males.

Having only six participants created a severe budget problem for the program as proposed. Three mechanisms were used to resolve this issue. By this time a second summer study abroad program to Zhejiang had been organized with an emphasis on business, management and international relations. Scheduling the two programs at the same time led to efficiencies in cost with common tours, industry visits, social events and local transportation. A second cost reduction was achieved by a voluntary reduction of the director and instructor’s compensation as well as that of the Chinese graduate student program assistant. Finally, both the NCSU Study Abroad Office and the Zhejiang Mechanical Engineering Department agreed to cover some of the expenses from discretionary sources. Both universities were committed to conducting this experiment so the program proceeded.

Recruitment of Chinese students was carried out by Professor Gu in his junior design classes. Since the design course would be taught in English a high priority for selection was fluency in English. To establish this capability interested students were required to submit written applications in English listing their academic qualifications and background together with a personal statement of why they wanted to participate and what they could contribute. Thirteen students applied to the program, all of whom had comparable academic qualifications. Preference in the final selection was based on the quality of the English in the written personal
statement with additional preference given to students who indicated plans for graduate study in 
the United States. Of the six students selected two were females.

Scheduling the class and lab sessions was the next issue dealt with. The 5 week 
academic program would take place from May 25th through June 26th. Since the Chinese spring 
semester begins in early March the program would take place in the second half of their term. 
To keep the design course from interfering with the Chinese participant’s regular classes the 
lecture sessions were scheduled for Monday, Wednesday and Friday late in the afternoon and the 
two design labs had to meet Thursday and Friday morning. A greater separation of the design 
labs was desirable but could not be achieved.

The next concern was to identify an industry partner that could provide an appropriate 
real design problem. Since these kinds of relationships between industry and universities are 
only just beginning in China initial contacts were begun in the US. After several unsuccessful 
attempts a contact was made through a Caterpillar facility in North Carolina that provided an 
introduction to the manager of a Caterpillar large equipment assembly plant in Suzhou three 
hours from Hangzhou by car. The manager, Paul Watts, who was from the UK, was not only 
sympathetic to our need but strongly supportive of the plan to combine NCSU and Zhejiang 
engineering students together in the design teams.

Because there was some earlier question of the program going forward when NCSU 
student participation decreased detailed discussion of the design problem did not proceed in 
earnest until early April. Several iterations resulted in a detailed Project Charter provided by 
Caterpillar Suzhou in early May. The project was to redesign the operator access ladders on 
Caterpillar’s Medium Wheel Loader (MWL) model 950 GH to reduce their manufacturing cost. 
(The original Project Charter appears in Appendix 1.) With the group’s departure date for China 
set for May 17th there was insufficient time for Caterpillar to assemble and transmit the relevant 
existing design and manufacturing information on the current access ladders. The only 
documentation received prior to the start of the program was the industrial standards that applied 
to these components.

The logistic aspects of the program which included arrangements for housing, group air 
and land transport, tour and industry visits, cultural lecture arrangements, social gathering 
schedules, visa applications and program orientation were completed through local and Chinese 
contacts previously developed for the earlier programs to Hangzhou. This was all done by the 
program director concurrently with the planning for the academic components of the program.

Program Implementation

The group left Raleigh, NC the morning of Monday May 17th and arrived in Shanghai 
early Tuesday afternoon. There we joined the other NCSU Hangzhou program group that had 
arrived the day before. Both groups toured sites in Shanghai for the next day and a half. 
Thursday afternoon we all traveled to Hangzhou by bus. The following day was spent on 
orientation to Zhejiang University and the local environs. Saturday was another orientation and 
tour of the city of Hangzhou accompanied by Chinese students who would be coming to NCSU 
in the fall. Sunday was a free day followed by a scheduled kick-off dinner with Prof. Gu and the
Chinese program students. Monday the academic program got underway with all classes meeting.

The class room provided by the University the Formal Lectures and the design labs was ideal. It was a large room that could easily seat eighty for a formal class meeting and provided adequate space for separation and privacy for the design teams during the lab activity. It came with a full complement of audio visual equipment and an elevated podium that made for effective presentation of the prepared class notes. The room contained movable tables and chairs that could easily be arranged in lecture room style or moved around to permit face to face team work. Full daily access to the room made it a convenient location for the design teams to meet outside the scheduled class and lab sessions.

Three design teams of four students each were organized prior to the first design lab. Each team consisted of two NCSU and two Zhejiang students. The two female Chinese students were divided between two of the teams. The students were not given any choice of team selection. This arrangement provided maximum diversity for interaction and at the same time avoided cultural isolation.

Lack of full documentation of the access ladder design specifications was initially thought to be a significant hindrance to getting the project underway the first week. In reality, the lack turned out to be fortuitous. With only the Project Charter and Industry Standards in hand the first task undertaken was to completely understand the content of these documents. This created a real need for immediate interaction across the two cultures since one of the standards was written in Chinese. As the interpretation of the requirements of the standards progressed it became apparent that a number of questions concerning both the current and proposed design needed to be answered. This led to the collective generation of a list of specific questions to be put to Caterpillar before proceeding further.

Arrangements were made for a day visit to the Caterpillar facility for Tuesday of the second week of classes. The students along with Prof. Gu, I and our two assistants made the three-hour trip to Suzhou in a mini bus provided by Zhejiang. We were warmly received by Paul Watts, plant manager, and Mike Wang, a Caterpillar engineer, assigned to us for project liaison. The students were given a tour of the assembly facility and then provided with the opportunity to fully examine the model 950H MWL with the access ladders to be redesigned. Although Caterpillar provided the group with CAD representations of the ladders the students wanted to photograph them in detail. This created a problem with a company policy that restricted camera use in the plant by visitors. The plant manager resolved this issue by directing Mike Wang to take the pictures with a student camera under the direction of the students. The students also requested samples of the ladders to take back to the Hangzhou for further study. Since the plant is located inside a special export zone providing the ladders would normally require extensive paperwork. Again, Paul Watts stepped in and simply directed Mike to have two of the ladders loaded into the bus and to forget the paperwork.

Many of the questions the students raised were answered by their physical examination of the loader. In addition Mike Wang accepted the entire list of questions and later provided written responses. It was also agreed that Caterpillar would provide all the CAD drawings of the
ladder components and the manufacturing design specification electronically to the group prior to their next lab session. All of this represented a level of industry participation and cooperation that had not been anticipated.

The day following the visit a request was received from Mike Wang for Prof. Gu and me to sign non disclosure agreements with Caterpillar before receiving the CAD and drawing information. On executing these documents and returning them we were informed by the site legal staff that these releases had to be signed by the university presidents, which would lead to considerable delays. The issue was presented to Paul Watts, whose response was simply, “Forget about the NDAs. --- I’ll take care of it.” The electronic project information arrived the following day.

A second issue dealing with design software also required resolution. Caterpillar uses Pro-E as their CAD system which is not licensed by Zhejiang. This problem was solved by Caterpillar converting the most important graphic and drawing files into pdf format for electronic transmission. Solid Works licensed by NCSU was used by the student teams for their design activity.

Before the second week was completed a set of common project constraints was proposed and accepted by Caterpillar and a project schedule was outlined for the remaining three week of the program. The summarized project constraints and project chronology are presented in Appendix 2. The design effort proceeded smoothly over the next two weeks and arrangements were made for Caterpillar personnel to come to the campus for a final project report presentation during the last Friday lab session of the program.

A last minute Caterpillar scheduling conflict required the presentation to be moved up to Thursday afternoon. This created some final report preparation pressure for the teams but also a valuable lesson in revising plans to meet the client’s needs. The Caterpillar group drove to Hangzhou in the morning, were hosted by the Zhejiang Mechanical Engineering Department at a formal luncheon and presented with the final report delivered in the early afternoon permitting the visitors to return to Suzhou by that evening.

The final report presentation consisted of a brief overview of the program and project charter followed by the proposed redesign concept results developed by each team. A common format was agreed to for each team’s report along with a standard template for the PowerPoint slides used for illustration. All students were required to participate in their team’s report that was not to exceed fifteen minutes. Questions and comment were withheld until the team completed its report. An example of the slides used by Team 1 is presented in Appendix 3. Both electronic and hard copies of the presentation slides were provided to the Caterpillar visitors.

Assessment

Evaluation and assessment of student performance, success and satisfaction together with educational goal achievement in engineering design courses has resulted in a variety of practices, methodologies and instruments that deal largely with capstone design project activity. In
this abbreviated industry based design project a limited set of desired educational outcomes appropriate to the student makeup, structure of the program and desired work product were defined to evaluate overall success. The vision for this educational experiment was to have a culturally diverse group of students undergo the following experiences.

Collaborating in a multicultural engineering project team  
Addressing a realistic industry need  
Working within prescribed constraints  
Defining realistic goals and expectations  
Establishing a realistic project time table  
Generating well-engineered practical solutions  
Delivering a report of professional quality

The level of achievement of these outcomes was assessed using the course instructor’s observations and the student’s responses to a post program survey. Five of the NCSU and four Zhejiang students responded to the survey. Two Zhejiang participants could not be contacted following completion of the program. Summarized results of the formal survey are presented in Table 1.

Team member collaboration was observed from the very first lab session. As indicated earlier this was essentially required with one of the industry standards written in Chinese. Team members also sat together in the regular class sections and often ate lunch together. Interaction and friendship development continued through other non program events. On one occasion the NCSU students invited their Zhejiang counterparts to an American style dinner they prepared themselves. During the national Dragon Boat Festival the Zhejiang students hosted the NCSU students to a day’s activity associated with the festival’s observance.

Results from the survey further support team member collaboration. All students strongly agreed that the mixed-culture teams promoted interaction (survey statement 1). On the question of similar technical backgrounds making communication easier (statement 2) there was a high level of agreement among most of the students. All students were strongly in agreement with social activities being helpful with team bonding (statement 3). Relative to cultural differences hindering team effectiveness (statement 4) there is a high level of disagreement among the NCSU students while the Zhejiang student were a little more neutral. On the question of one or more team members not communicating well (statement 9) the NCSU students were somewhat more strongly in disagreement than were the Zhejiang students. In contrast the Zhejiang students were somewhat more strongly in agreement than were the NCSU students on the question of team members making useful contributions to the project solution (statement 10). All respondents strongly agreed with their having learned about working with people from other countries (statement 17). All students were also strongly in agreement that they enjoyed the China Caterpillar design team experience (statement 14). The following comment from one of the Zhejiang respondents addresses the cross cultural collaborative team experience quite nicely.

“When communicating . . . we have a different thinking mind from each other so that each of us will deal with a problem with different ways. . . ."
American friends with a quick response to a problem will be confident and handle it with their first mind, while we Chinese always are deliberate and think about advantages and disadvantages of all possible methods to that problem before handle it. But this difference often helps us cooperate effectively. American friends can give many innovative ideas and we Chinese can combine them perfectly after evaluating them, then a great scheme will come out.”

In response to whether the project was too challenging (statement 5) the NCSU students basically disagreed. On the other hand the NSCU students were somewhat more neutral on the project not being challenging enough (statement 6). On the project being too challenging the Zhejiang students were basically neutral. The Zhejiang students were again neutral relative to the project not being challenging enough. The balance of the distribution of these responses would seem to indicate that the project was just about right and it certainly represented a real industry need achievement the second outcome. These results also justify the planning decision to have the project be limited to the redesign of an existing product.

Achievement of outcomes 3, 4, and 5, working within prescribed constraints, defining realistic goals and expectations and establishing a realistic project time table is best discussed in relation to one another. As in all real design problems there are always a set of constraints within which solutions must be generated. Without project boundary conditions defined it is difficult to focus effort on achieving realistic goals and expectations. The design teams experienced this lack of focus and direction until a common set of constraints was recognized, articulated and agreed upon. This was then followed by the establishment of specific goals and expectations. Another consequence of the common set of constraints was the creation of a project time table with specific milestones to insure project completion and satisfactory goal achievement. Hence, the experience of defining and working within prescribed constraints led to providing an experience with establishing realistic goals and creating a realistic project time table. The value of defining a common set of constraints together with its consequences was recognized by all students (statement 8) with the NCSU students in somewhat stronger agreement than the Zhejiang students.

The goal of each team was to generate a practical redesign that was feasible, well engineered and had the potential to reduce manufacturing costs. Identifying the positive features and weaknesses of the existing designs became the basis for the design strategies employed by each team. Although there are similarities in the appearance of the final proposed redesigns, as can be observed in Appendix 4, the approach used by each team was quite different. Team 1 emphasized simplifying part fabrication and introduced manual assembly, Team 2 worked at reducing material usage and making parts interchangeable and Team 3 concentrated on reducing part count and assembly activities. All Zhejiang students strongly agreed that they had achieved sense of personal accomplishment with the course (statement 13) while the NCSU students were evenly split between agreement and strong agreement with the same conclusion.

Even the best design that is poorly communicated is hardly better than a poor solution to the problem. To insure the preparation and delivery of a final report of professional quality a common content format was developed, a standard template for Power Point slides was created...
and the teams had a practice round of presentation and critique. The value of these actions was evident in the satisfaction voiced by Caterpillar personnel with both the student presentations and the final results. Paul Watts remarked, “I am surprised at what they accomplished. There are some good ideas here we can use”. The students recognized the value of these pre-report activities, 90% of them strongly agreed that it was helpful to have a common format (statement 12) and all students strongly agreed with the benefit of practicing the final presentation (statement 11).

Conclusions

The anticipated course outcomes were achieved, the students derived personal satisfaction from their project work with a unique cultural experience and usable recommendations were generated for the industrial sponsor. It seems reasonable to conclude that this experiment of using integrated design teams with US and Chinese students can again be successfully conducted, providing benefit and value to all participants and partners. Ninety percent of all the students strongly agreed that the overall experience had been worth the time and effort (statement 16) and that they learned about engineering from the experience (statement 17). Following are some direct student comments on what they liked best about the program.

“The design project was an incredible experience. I learned much about design work in engineering.”
“The best part of the design was the discussion on the project . . . every team member was inspired and contributed a new idea.”
“My favorite part was my team members. We did a lot of things together to improve the relationships between the team members.”
“Working with people from another culture in their native Land.”
“The foreign friends I made in the program”

All the NCSU students were in strong agreement with recommending the Caterpillar Design Team experience to friends in engineering (statement 18) with the Zhejiang students split between agreeing and strongly agreeing with this recommendation. The satisfaction of Caterpillar with their participation and the project results is expressed in the following quote from Paul Watts in an email exchange following the program.

“. . . I am equally as glad the project was a success. We are actually building on one of the design ideas to implement as a cost reduction and I will keep you posted on developments.”

Near the end of last year Paul informed me that design and manufacturing specifications had been completed for the Team 1 redesign concept and production has resulted in a cost reduction of 28%.

This program structure and implementation plan represents a model that can be adopted by others to provide greater numbers of US and Chinese students the opportunity to better prepare themselves for their future in the arena of global technical interaction. It must be recognized, however, that the cost is not insignificant and scale up represents a challenging problem. Small class sizes are easier to manage and permit more individual attention but limit the number that can engage at one time in the experience. The current practice of placing the
financial cost for such programs almost solely on the students will continue to keep participant numbers small. The time and effort required of a program director to recruit participants, plan the program, arrange for housing, tours, etc., interact with a host institution, identify an industrial sponsor and spend six weeks away from home is more than most faculty in the midst of their academic careers are likely to undertake. If global interaction experience with other cultures is an opportunity to be provided to US engineering students greater levels of tangible support must be made available through university, government and industry leadership. In addition there must be greater recognition and reward for faculty to take on the sizeable responsibility required to conduct such programs. It then becomes a matter of priorities as to where resources will be or should be allocated in educating our future engineers for US industry to be competitive and successful in what has become a global marketplace for technological goods and services.

References


Appendix 1

Caterpillar Suzhou China (Ltd) Project Charter

May 14, 2009

Project Title: Optimize Motor Grader and Medium Wheel Loader Front Access Steps in the focus to reduce cost.

Business Case:
As part of the LRC (Lesser-Regulated Countries) machine strategy the Medium Wheel Loader (MWL) and Motor Grader (MG) product groups are investigating into different methods to reduce the material cost of the 950H and 140K machines. The 950H is the smallest and most cost competitive machine in the MWL family and over the past 5 years this model has lost some market share to the ever-increasing pool of competitors. In an effort to increase market share and grow the profitability of Caterpillar Suzhou China (Ltd) (CSCL) the team will look to redesign some features on the machine. Historically, the 950H has been designed and developed in Higher-Regulated Countries (HRC) and there is common belief that some sub-systems are over designed for LRC markets.

Opportunity Statement:
Over the past 18 months, the majority of the Light Fabrication Subsystem (LFS) has been localized or resourced to local China suppliers. The only remaining opportunity to reduce the cost would be through redesign. In particular the Access Steps are thought to be a little overdesigned when compared to competitors machines. It is also useful to note that current material cost is only 40% of the total cost where the process cost is almost the same at 35%. If the team could redesign this component to reduce the process time/cost and improve the material utilization then it would significantly help the product group design team in Wuxi to meet their cost reduction goals.

Goal Statement:
Y1 = Reduce the total cost of the MWL Front Fender by 20%

X1 = Design Requirements
X2 = Design Validation
X3 = “Should Cost” Modeling for Light Fabrications

Tools or Skills Required:
The team will need to understand and learn the following to enable the project to be successful:
- FEA Analysis
- Fluent in Pro-e or other 3D modeling package
- A good understanding of the MWL & MG Light Fabrication System
- An understanding of different sheet metal manufacturing processes
- An understanding of the different cost elements to “Total Cost”
- An understanding of the “Pugh Matrix”

Project Timeline and Team:
The project team should submit a list of activities and planned completion dates.
Appendix 2

Common Project Constraints

1. Redesign is subject to provisions of ISO 2867
2. Original functionality must be retained
3. Changes restricted to ladders on MWL Model 950H
4. Interface mounting points must be kept the same
5. Redesign will incorporate existing step units
6. Retain Caterpillar product quality
7. Proposed redesign concepts due by program end

Project Chronology

- Week 1
  Held Kick off Dinner Event
  Made team assignments
  Presented Project Charter
  Reviewed industry standards
  Prepared clarifying questions

- Week 2
  Visited Caterpillar facility
  Dismantled and studied ladders
  Revisited clarifying questions
  Defined common project constraints
  Resolved software issues
  Received design documentation

- Week 3
  Evaluated Caterpillar response
  Reviewed and evaluated drawings
  Defined common system parameters
  Began redesign concept development

- Week 4
  Evaluated proposed concepts
  Proceeded with selected final design
  Completed geometric design
  Began presentation development

- Week 5
  Made final revisions to design concept
  Completed report presentation
  Practiced delivery of report
  Delivered final report to sponsor
Appendix 3
Example Presentation Slides

North Carolina State University
& Zhejiang University

Team 1

MWL Access Ladder Simplification

Project Sponsor
Paul Watts
Caterpillar Suzhou

Proposed Solution

- Cost reduction
  - Sheet steel more cost effective
  - Removes 8 tubing bends
  - Easier to stamp & bend
  - No welds required
  - Fewer parts
- Handgrips retained
- Simpler to repair/replace
- Complies to ISO standards
Appendix 4
Proposed Redesign Concepts

Proposed Solution
- Cost reduction
  - Sheet steel more cost effective
  - Removes 8 tubing bends
  - Easier to stamp & bend
  - No welds required
  - Fewer parts
- Handgrips retained
- Simpler to repair/replace
- Complies to ISO standards

Proposed Solution
- Cost reduction
  - Sheet steel less costly than tubing
  - Single stamped part
  - No welds or tubing bends
  - Simpler assembly (mounting plates/support bars)
- Handgrip kept at top even though rarely used
- No addition mud flap required

Design Change 1: Repeat Tubing Parts on Right and Left Sides

Design Change 2: Eliminate Tubing
- Replace tubing with steel plates and weld steps to plates

Primary Ladder Redesign

Secondary Ladder Redesign
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<tr>
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<th>Post Program Survey Response</th>
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<tr>
<td>1</td>
<td>A mixed cultural team promoted my interaction with Chinese (US) students</td>
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<tr>
<td></td>
<td>Strongly Agree: 100 % *</td>
</tr>
<tr>
<td></td>
<td>Agree: 100 % **</td>
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<td>2</td>
<td>Similar educational backgrounds made communications with my teammates easier</td>
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<td>Strongly Agree: 80 %</td>
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<td>Social activities helped me bond with my team</td>
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<td></td>
<td>Agree: 100 %</td>
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<tr>
<td>4</td>
<td>Cultural differences hindered my team’s effectiveness</td>
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<td></td>
<td>Strongly Agree: 20 %</td>
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<td></td>
<td>Agree: 50 %</td>
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<td>Neutral: 40 %</td>
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<td>The design project was too challenging</td>
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<td>Disagree: 50 %</td>
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<td>7</td>
<td>The review of design standards was a good starting point</td>
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<td>Agree: 75 %</td>
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<td></td>
<td>Neutral: 25 %</td>
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<td>Defining common problem constraints was useful</td>
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</tr>
<tr>
<td></td>
<td>Neutral: 33 %</td>
</tr>
<tr>
<td></td>
<td>Disagree: 75 %</td>
</tr>
<tr>
<td>9</td>
<td>One or more of my team members did not communicate well with others</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 25 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 40 %</td>
</tr>
<tr>
<td></td>
<td>Neutral: 40 %</td>
</tr>
<tr>
<td></td>
<td>Disagree: 20 %</td>
</tr>
<tr>
<td>10</td>
<td>All of my team members made useful contributions to the design solution</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 60 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 75 %</td>
</tr>
<tr>
<td></td>
<td>Neutral: 25 %</td>
</tr>
<tr>
<td>11</td>
<td>It was beneficial to practice our report presentation</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 100 %</td>
</tr>
<tr>
<td>12</td>
<td>It was helpful to have a common report format</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 50 %</td>
</tr>
<tr>
<td></td>
<td>Neutral: 50 %</td>
</tr>
<tr>
<td>13</td>
<td>I ended the course with a sense of personal accomplishment</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 50 %</td>
</tr>
<tr>
<td></td>
<td>Neutral: 50 %</td>
</tr>
<tr>
<td>14</td>
<td>I enjoyed the China Caterpillar Design Team Experience</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 100 %</td>
</tr>
<tr>
<td>15</td>
<td>The overall experience was worth my time and effort</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 75 %</td>
</tr>
<tr>
<td></td>
<td>Neutral: 25 %</td>
</tr>
<tr>
<td>16</td>
<td>I learned about engineering during the experience</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 75 %</td>
</tr>
<tr>
<td></td>
<td>Neutral: 25 %</td>
</tr>
<tr>
<td>17</td>
<td>I learned about working with people from other cultures during the experience</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 100 %</td>
</tr>
<tr>
<td>18</td>
<td>I would recommend the China Caterpillar Design Team experience to my friends in engineering</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree: 100 %</td>
</tr>
<tr>
<td></td>
<td>Agree: 100 %</td>
</tr>
</tbody>
</table>

Notes: all percentages have been rounded to whole numbers
* upper column percentages represent NCSU responses
** lower column percentages represent Zhejiang response