

Service-Learning in CHE Senior Design

Lisa G. Bullard, Patti H. Clayton, and Steven W. Peretti
North Carolina State University

ABET 2000 Criterion 3 explicitly states that engineering graduates must have “an understanding of professional and ethical responsibility,” “an ability to communicate effectively,” and “the broad education necessary to understand the impact of engineering solutions in a global and societal context.” Service-learning is the approach we chose to enhance our students’ capacities in these areas. For the past two years, senior projects containing a significant service-learning component have been offered in the capstone chemical engineering senior design course at NC State University. Students have worked with an economically disadvantaged community facing pollutant emissions resulting from a high concentration of local industries. Students characterized the pollutant problem and its sources and provided the community with process-related information useful in their discussions with regulatory bodies. This paper will review the conceptual foundations of service-learning, discuss potential applications of service-learning in engineering curricula, and summarize the strategies used and the challenges faced in the design and implementation of a service-learning component in chemical engineering senior design.

Principles of Service-Learning

Service-learning is a form of experiential education that connects academic material to service through guided reflection. Instructors partner with members of the community to craft student experiences that help to fulfill the learning objectives of the course through a process of service that meets important needs for individuals and/or organizations in the community. Students bring their own experience and skills, as well as what they are learning in the classroom, into the community; and they bring those community-based experiences back into the classroom, engaging in systematic reflection that is intended to improve both their learning and the quality of their service.

It is this emphasis on reflection in the context of academic material that distinguishes service-learning from community service or volunteerism and that facilitates the integration of service with learning. Service-learning students do not receive credit for service itself but rather for demonstrating learning attained through the process of reflection on service. The learning objectives of service-learning include not only a deeper understanding of academic content but also personal growth and civic engagement. Reflection—individual and/or collaborative, written and/or oral—is carefully designed to help the students analyze their experiences in the community from academic, personal, and civic perspectives. Reflection supports students in considering the similarities and differences between theories as presented in the classroom and as applied in the community, in examining their own personal characteristics (strengths,

weaknesses, skills, assumptions, beliefs, etc.) as they emerge in the service-learning process, and in evaluating the objectives and approaches to change they and/or their community partners adopt. At NC State reflection occurs through structured journaling and through trained peer and/or instructor facilitated discussion, in and out of the classroom as well as online.

Service-learning thus challenges students to apply their learning, to evaluate their own effectiveness and that of the individuals and organizations with whom they work, and to set personal development goals. It requires that they interact with a diverse range of people other than their instructors and fellow students and that they take on often unfamiliar and high-responsibility level roles. It gives them opportunities to work in teams, to write, to present to public as well as academic audiences, to make connections between their studies and the rest of their lives, and to develop their critical thinking abilities. It exposes them directly to issues of concern in the community and helps them develop a sense of their own ability to affect those issues as citizens and as professionals.

Service-Learning in Engineering

Many applied disciplines have a long history of sending students into the community as part of their professional preparation. Within engineering, we have well-established practices of engaging students in “real-world” projects, often based in the corporate community. At recent ASEE Annual Conferences, as many as twelve papers (in 2002) explicitly focused on the application of service-learning, primarily focused in freshman engineering courses⁷ and capstone design courses^{2,3,9,10}, with a few vertically integrated service-learning programs based in Colleges of Engineering⁸. Among the engineering disciplines, service-learning applications are most frequently implemented in biomedical engineering, mechanical engineering, environmental engineering, and civil engineering. As formalized in ABET 2000, many engineering educators are committed to cultivating among our students a sense of professional responsibility and sensitivity to the complex social and ethical dimensions of engineering practice. We are thus looking for opportunities to more explicitly connect our students’ learning with the important community issues that engineers help to address and with the people whose lives are affected by our profession.

As with any discipline, service-learning presents unique challenges and opportunities to engineering students and faculty. Many of the students who enter our discipline are less familiar—and less comfortable—than their humanities and social science peers with reflective processes that require introspection and that often increase rather than resolve ambiguity and uncertainty. The highly technical nature of much engineering content also makes the process of establishing community partnerships and projects that are closely linked to academic material more difficult than in some disciplines. The task, therefore, is three-fold: 1) to identify community issues—such as environmental issues—that pose technical challenges and require technical and technological expertise, 2) to support students, instructors, and community partners alike in the process of applying the knowledge and skills of the discipline in the complex and turbulent context of personal, organizational, and community agendas and constraints, and 3) to maximize the learning that can result to all parties through systematic reflection.

The process-orientation of service-learning, combined with the difficulties of linking technical content to the service needs of many community organizations, seems to render this pedagogy especially well-suited to introductory and capstone engineering courses, where there is an emphasis on teamwork, communication, problem-definition, project design, and project

management. The College of Engineering at NC State is experimenting with the integration of service-learning especially at the freshman and senior year. The remainder of this paper will present our experience with a two-year service-learning project in a senior design Chemical Engineering course.

Description of Service-learning Projects in CHE Capstone Design Course

Spring 2002

In planning for the Spring 2002 offering of senior design, both instructors (Bullard and Peretti) had recently completed an on-campus Service-learning Faculty Associate training program and were eager to apply service-learning to their upcoming senior design course. The instructors initially corresponded with NC WARN (Waste Awareness Reduction Network), but after talking with this community action group, it seemed that the group had a strong political agenda and might not be receptive to the results of the students' work if they were not favorable to their organization. Furthermore, the students were asked to be advocates rather than analysts, a position the instructors deemed incompatible with the nature of the technical content of the course. NCWARN did refer the group to the Southeast Chatham Citizens Advisory Council (SCCAC), a group of citizens who meet monthly to discuss environmental, political, and economic issues affecting their county. This group was eager to have student support in investigating concerns about air quality in Chatham County. In particular, SCCAC was concerned about Moncure, NC, a small town with a large concentration of chemical industries. Many citizens had complained about strong odors, particularly near the manufacturing plants in the area. The project description that emerged from the preliminary discussions between the instructors and the SCCAC is in Appendix A.

The project team included seven chemical engineering students. The students met with an upperclass student reflection leader every other week to discuss the project status, analyze their experiences reflectively, and develop "articulated learning" statements. Discussions with the potential community partners delayed the project kick-off, so the students were rather late getting started. Most of the students had a hard time adjusting to the differences in their project versus the more traditional design projects. They resisted the reflection sessions and saw the articulated learning as busy work that detracted from the project. However, after the team met with the community group, several members became extremely invested in the project and went to Moncure on an almost weekly basis to meet with the community partners. Of the seven students involved, two were African American females and one was an African American male. Given the high minority population in Moncure, the presence of these students was a positive element in the interaction of the student team with the diverse community.

The essential technical element of the team's work was to review publicly available environmental databases in order to characterize and rank local air emissions on a national level. Using the EPA database from 1999 -- the most recent year for which data were available -- the student group found that⁵:

- Chatham County is ranked No. 1 among the 3,219 U.S. counties for emissions of formaldehyde, a colorless, flammable gas that can cause irritation of eyes, nose, throat and skin.

- Chatham County is ranked 10th in North Carolina for sulfur dioxide emissions, logged at 13,996 tons in 1999.
- Chatham County is in the top 10 percent of sulfur dioxide emissions in the United States.
- About 97 percent of sulfur dioxide emissions in Moncure were found to come from CP&L's Cape Fear utility plant, owned by Progress Energy. About 99 percent of formaldehyde emissions came from SierraPine Ltd., a plant that manufactures particleboard.

The students took their community involvement a step further, believing that empowering the community of Moncure with the knowledge necessary to combat air pollution involved educating the community's children. By informing the community's youth about the environmental as well as health impacts of polluted air, the group completed a cycle in educating both ends of the community's generational gamut. Toward that end they developed a lesson plan for Earth Day, targeted at a sixth grade level and designed to teach students about the problem of pollution, its effects on our environment and health, and the latest methods designed to combat air pollution. The middle school students also participated in hands-on experimentation in order to see the effects of pollution.

Spring 2003

After the project's conclusion, the SCCAC was enthusiastic about the team's findings and wanted to have another student group continue the project in Spring 2003. After evaluating the content of the Spring 2002 project, the instructors wanted to redirect the focus of the project to increase the technical content. Based on the previous team's results, the instructors decided to focus on two top air pollutants – ethylene glycol and formaldehyde – that were identified as being much higher in Moncure, NC than in similar plants nationwide. The student teams would then focus on how these emissions might be reduced. The project description for the second year is provided in Appendix B.

Six students selected the project in Spring 2003. These students had a very technical focus and did not particularly enjoy the community partnership aspect. During this semester, the instructors again had the team work with an upperclass reflection leader. One difference in the second service-learning project is that the reflection leader, in addition to leading discussions and helping the team develop articulated learnings, also presented or coordinated the presentation of non-technical content (such as ethics, sustainable development, diversity, and civic responsibility) that was more closely related to the service-learning process and that served as much of the academic material against which the students analyzed their experiences in reflection sessions. The service-learning module, which met during the students' regularly scheduled problem session, had a separate syllabus (see Appendix C). The student team tried to make contact with the local industries in question to better understand their processes, but the industry would not allow them to visit the plant and would not provide process-related information. As a result, all of the students' work was based on literature and patent information.

The team made the following recommendation to reduce emissions at the plants in question¹:

SierraPine (formaldehyde)

Use destructive treatment to burn hazardous emissions before they are released to the atmosphere

Install a Regenerative Thermal Oxidizer to accomplish destructive treatment

Total cost = \$4-5M

Honeywell (ethylene glycol)

Apply recycle technology so chemicals are reused instead of emitted

Install a Glycol Recovery Unit to recycle EG

Total cost = \$3-4M; payback period = 2-3 years

Impact of Service-learning Projects

Spring 2002

Although the group's work in Spring 2002 was not particularly technical in nature, their findings were news to the community. The student group from Spring 2002 presented their findings at the SCCAC meeting in May 2002. As a result of the meeting, there was a front page article in the local newspaper, the *News and Observer*⁴ (see Appendix D). This generated a great deal of positive and negative attention for both the student team and the faculty involved.

In general, the students were enthusiastic about the project and its results. They enjoyed interacting with the community at all levels. The students' perspective on their service to the community is indicated by the following passage taken from their final report⁵:

Some of the older residents had a misconception that young people do not care about the environment....After the presentation, residents approached members of the group with hugs and lots of "thank you." It seems that people in rural communities that have little interaction with government officials and local, state, and national agencies forget that there are people "on their side." The Students A.W.A.R.E. group showed the audience members that there are "outsiders" that take interest in their community.

The students were equally excited about their interactions with the elementary school children, as indicated by this passage in the report⁵:

Upon departure from the classroom, Mrs. McCombs-Porter expressed her tremendous gratitude and also mentioned that her students were very fortunate to have a first hand experience with individuals that had post-high school education to further their knowledge. As a result, the Students AWARE team not only felt a great sense of pride and self-worth from presenting the 6th grade class with useful information, but also took great honor in the fact that they may have intrigued a young person to look to the future to see the benefit of higher education.

Clearly, these students identified with and internalized the problems of the community and realized that their expertise had value to society as a whole.

Spring 2003

The student group from Spring 2003 presented its findings at the April 2004 SCCAC meeting. After that meeting, local citizens were more proactive and informed about the options

that industry might have to reduce emissions. For example, below is an excerpt of a letter from a Chatham County citizen to Mike Brandon, N.C. Division of Air Quality⁶:

In the spring of this year a group of N.C. State University Chemical Engineering Seniors gave the community of Moncure a report on this Honeywell facility. Honeywell is 5th in the nation for its ethylene glycol emissions, surely cause for concern. Interestingly, for the amount of PET (polyethylene terephthalate-a plastic material used in seat-belt manufacturing) produced, there is a very large amount of emitted ethylene glycol...Other facilities in North and South Carolina, as well as in other parts of the country, producing PET material have much less pollution in relation to their capacity than Honeywell, Moncure, does. A Kosa plant in Salisbury, N.C., for instance, has a much higher rate of production in relationship to its pollution than Moncure's Honeywell plant does, and a Nan Ya plant in Salt Lake City is even more impressive in its productivity to pollution ratio. Even Honeywell's other plant, in Hopewell, does pollute at nearly the level that Honeywell does. According to the student report, if Honeywell used the most advanced MACT technology and the glycol recovery unit in particular, they could use the less expensive recycled ethylene glycol and save the cost of buying it new. The students estimated, based on what they could learn (Honeywell refused to allow them to visit the plant), that if Honeywell installed the new equipment, they would pay for it in 2-3 years in saved costs.

The students also recognized significant benefits accruing from their involvement in the project, as stated in their final report, "This project has allowed [us] to obtain a better perspective on [our] technical knowledge, in that we must use our abilities to mesh together productivity and community-friendly solutions to engineering design and problems."¹ This is indicative of their understanding of the societal impact of their profession and would have been difficult to convey in other than a service-learning setting.

Recommendations and Conclusions

Without a doubt, the community of Moncure, NC is better off because of its interaction with chemical engineering students from NC State. Citizens are more aware of the emissions in their local area, as well as how local companies compare with their counterparts in other parts of the country. As a result of this information, citizens have become more proactive in working with industry and state regulatory agencies to ask for increased monitoring.

There are some stumbling blocks to implementation of service-learning in Chemical Engineering. The most significant of those include:

- Including sufficient technical considerations to make it meet CHE design criteria
- Identifying a partner who doesn't have preconceived notions of the desired outcomes
- Conveying to students the nature of the experience in advance so they can knowledgeably choose to participate
- Linking content to service in a meaningful manner
- Helping technical students learn to reflect carefully and to value doing so

In our experience, the environmental arena is a good fit for chemical engineering vis-à-vis senior design projects. Problems of this nature require knowledge of environmental regulations, emission calculations, economics, and process changes in the spirit of green engineering. While the line between service and advocacy can often be blurred to the detriment of the prudent exercise of technical judgment, it is possible to strike the balance and incorporate both the technical and service components into an appropriate, engaging project.

In addition, a subset of students is highly motivated to work on senior projects that they perceive to have societal benefits, either directly in terms of service or indirectly through the utility of the products generated by the facilities they are designing. Service-learning projects offer these students the opportunity to bridge the academic-community gap in a meaningful and productive way.

BIBLIOGRAPHY

1. Ambrosini, G., K. Caudle, S. Freeman, J. Mangum, B. Price, and M. Rice, "Benchmarking Ethylene Glycol and Formaldehyde Emissions," final project report, CHE 451, May 2003.
2. Brackin, Patricia and J. Darrell Gibson, "Capstone Design Projects: Enabling the Disabled," *Proceedings of the 2002 ASEE Annual Conference & Exposition*, Quebec, Canada, June 2002.
3. Green, Matthew, Alan Dutson, and Kristin Wood, "Integrating Service-Oriented Design Projects into the Engineering Curriculum," *Proceedings of the 2002 ASEE Annual Conference & Exposition*, Quebec, Canada, June 2002.
4. Harris, Stephaan, "Bad Air in Chatham County," *The News & Observer*, May 4, 2002.
5. Deans, V., T.J. Eatmon, D. King, J. Lynn, N. Purnell, K. Redden, and M. White, Students A.W.A.R.E.: *ADVOCATING WORK AND ACTION TO REDUCE EMISSIONS*, final project report, May 2002.
6. Hogan, Judy, email to the author, November 3, 2003.
7. Nagchaudhuri, Abhijit and Anthony J. Stockus, "Freshman Engineering Majors Get Pumped Up To Design Human Powered Water Pump at University of Maryland Eastern Shore," *Proceedings of the 2002 ASEE Annual Conference & Exposition*, Quebec, Canada, June 2002.
8. Oakes, William C., Edward J. Coyle, and Leah H. Jamieson, "EPICS: A Model of Service-Learning in an Engineering Curriculum," *Proceedings of the 2000 ASEE Annual Conference & Exposition*, St. Louis, MO, June 2000.
9. Somerton, Craig W. and Brian S. Thompson, "Community Outreach for Capstone Design: The Cycle Projects," *Proceedings of the 2002 ASEE Annual Conference & Exposition*, Quebec, Canada, June 2002.
10. Swan, Christopher W., Paul Kirshen, and John Durant, "Environmental Engineering Education and Community Service: A Synergistic Partnership," *Proceedings of the 2002 ASEE Annual Conference & Exposition*, Quebec, Canada, June 2002.

BIOGRAPHICAL INFORMATION

LISA G. BULLARD

Lisa G. Bullard received her BS in ChE from NC State and her Ph.D. in ChE from Carnegie Mellon. She served in engineering and management positions within Eastman Chemical Co. from 1991-2000. At N.C. State, she is currently the Director of Undergraduate Studies in Chemical Engineering.

PATTI CLAYTON

Patti Clayton is Coordinator of the NC State Service-Learning Program. She has an M.S. (1992) and Ph.D. (1995) from UNC – Chapel Hill. Co-developer of the Program's reflection framework, assessment strategy, and student leadership roles, she trains and supports faculty in implementing service-learning and consults with other universities on service-learning capacity-building.

STEVEN W. PERETTI

Steven W. Peretti is an Associate Professor of Chemical Engineering at North Carolina State University. A recipient of the NSF Presidential Young Investigator Award in 1991, he has directed research in bacterial protein synthesis, bioremediation, gene transfer in biofilms, and green chemistry applications of bioconversion processes. Recently, he has become active in the areas of cross-disciplinary education and service-learning.

Appendix A

Abstract for Spring 2002 Service-learning Design Problem

Students A.W.A.R.E. (Advocating Work and Action to Reduce Emissions)

The air quality in Moncure, North Carolina is a problem that has been of concern for local residents for some time. Moncure, North Carolina is a small town in Chatham County, approximately 23 miles from Durham, NC, which lies on U.S. Highway 1. The Moncure population is approximately 630. The closest city nearby is Pittsboro, NC. Moncure Elementary is the only public school in the area, with a 1998 enrollment of 250 students in grades PK-8. As a low-income, rural community close to a major urban center, Moncure provides an amenable site for industry, and has become the site for plants from several area industries. Moncure is also located on the banks of the Haw River, which provides cooling water and a convenient outlet for waste for these industries

While federal and state regulations govern emissions and other pollution from individual factories, this oversight neglects the cumulative effect of chemical emissions from several companies to a particular area. The Moncure Community is an apt example. The industries above cumulatively release 4,066,630 pounds of emissions each year into the Moncure community and create approximately 43,203,962 pounds of total waste each year. If the community feels that these levels are hazardous and would appreciate further study, the Students A.W.A.R.E. group is prepared to determine the cumulative effect of the air emissions and if these amounts are harmful. To do so, it may also be beneficial to include an analysis of what kind of pollution control equipment is being used by these industries and what the Industry Best Practices are for these processes. This data collected will be compared to other similar communities in other parts of the United States, as well as to Best Available Controls Technology (BACT) databases. The outcome of this project would be to assist and educate the residents of the community as well as the industries on what types of pollutants that they are being exposed to and what they can do to better the situation.

Appendix B

Abstract for Spring 2003 Service-learning Design Project

Benchmarking Ethylene Glycol and Formaldehyde Emissions

One of last year's design groups studying air emissions in Moncure, NC concluded that the emissions for this NC county are among the highest on the East Coast. Two of the large emission sources are the AlliedSignal PET plant and the SierraPine particleboard plant located in Moncure, NC. Because of their process configuration choices, both plants' emissions are higher than other PET or particleboard producers. This project will involve analysis of the PET and particleboard processes across the chemical industry to understand the sources of emissions and potential process configurations to reduce emissions. Students will benchmark various PET and particleboard processes by leading market producers and will contact equipment vendors to understand the impact of equipment design on emissions. The process design requirements and economics of reducing ethylene glycol and formaldehyde emissions will be addressed. Students will interact with community leaders in the Moncure area to understand concerns about emissions and provide input on benchmarking results.

Appendix C

Syllabus for Service-learning Module

DEPARTMENT OF CHEMICAL ENGINEERING
NORTH CAROLINA STATE UNIVERSITY
Draft Syllabus
CHE 451P, Chemical Engineering Design II – Spring 2003
M 1:30-3:20, Riddick 242

Instructor: Dr. Steven Peretti (peretti@eos.ncsu.edu) 221 Riddick Labs, 515-6397
Dr. Lisa Bullard (lisa_bullard@ncsu.edu) 206 Riddick Labs, 515-7455

Contact: Jennifer King (jiking2@unity.ncsu.edu) 835-4368

Objectives:

- To assist in providing an understanding of engineering in a broader, community-based context
- To discuss issues of diversity and the implications upon the career of engineers
- To define and assist in understanding the concept of Service-Learning (S-L)
- To provide course content to support the Service-Learning project

Potential Speakers:

- Dr. Sarah Rajala, Engineering Administration
- Dr. Joe Herkert, Engineering Ethics
- Dr. Erin Malloy-Hanley, Environmental Ethics
- William R Mosher, PE. Chairman of PENC Community Leadership Steering Committee
- Dr. Leon Danielson, Ag and Resource Economics
- David Knight, Lobbyist for Sierra Club NC
- Dr. Rupert Nacoste, Vice Provost for Diversity and African-American Affairs

Readings:

- Schinzinger and Martin. Excerpts from Introduction to Engineering Ethics. McGraw-Hill Higher Education: New York, 2000.
- Hawken, Paul. "Natural Capitalism." *Mother Jones*, March/April 1997, 40-53, 59-62.
- Boyle-Baise. Marilynne. "Chapter 2, Making Distinctions: Charity, Civic Education, or Community Building." Multicultural Service-Learning. Teachers College Press: New York, 2002.

Electronic Info:

World Federation of Engineering Organisations – ComTech
Sustainable technology in the engineering profession
<http://www.wfeo-comtech.org/>

Accreditation Board for Engineering and Technology, Inc. (ABET)

<http://www.abet.org/images/Criteria/2002-03EACCcriteria.pdf>

*"Proceedings of the 2004 American Society for Engineering
Education Annual Conference & Exposition
Copyright © 2004, American Society for Engineering"*

National Academy of Engineers-Committee on Engineering Education. “The Engineer in 2020, Project Summary.”

[http://www.nae.edu/nae/naeceedcom.nsf/af1bc775c209ab9a85256ad80070861f/59922a2be5f66e7785256c010071c4e4/\\$FILE/2020%20Prospectus.pdf](http://www.nae.edu/nae/naeceedcom.nsf/af1bc775c209ab9a85256ad80070861f/59922a2be5f66e7785256c010071c4e4/$FILE/2020%20Prospectus.pdf)

NC State Diversity Initiative. <http://www.ncsu.edu/provost/diversity/initiative.html>

Class Schedule: subject to change

Date	Topic
1/13	Intro to S-L/Engineering Education
1/20	No school
1/27	Reflection Session (RS) Group 1
2/3	Social and Civic Responsibility/RS Group 2
2/10	
2/17	Cultural Diversity/RS Group 1
2/24	RS Group 2
3/3	Global: Engineering Ethics + Bhopal
3/10	No school
3/17	RS Group 1
3/24	Local: Environmental Ethics and Justice/RS Group 2
3/31	
4/7	Appropriate Sustainable Technology/ RS Group 1
4/14	RS Group 2
4/21	Wrap-Up
4/28	

Content will be delivered every other week of class. Each group will have four reflection sessions to last 2 hours. If a Reflection Session (RS) is scheduled when course content is to be delivered, the time will be from 2:30 to 4:30. If there is no content, the RS will be from 1:30 to 3:30. Assume all classes will last at least one hour, *except January 13th, which will be the entire block of time, 1:30-3:20.*

Grading and Attendance:

There will be occasional reading responses as well as related reflection session activities. Attendance is *mandatory* for the course and reflection sessions unless the instructors approve your absence in advance. As it will be a small group, every person is integral to the success of our conversation and, ultimately, the service-learning design project. Participation in this section of your senior design project will be reflected in your final grade.

Appendix D

Newspaper Article based on Spring 2002 Service-learning Project

Harris, Stephaan, "Bad Air in Chatham County," The News & Observer, May 4, 2002.

An environmental report done by a group of N.C. State University engineering students finds that the industrial center of Chatham County produces some of the country's highest chemical emissions, sparking residents and officials to call for cleaner air. The report, completed Friday, studied the release of chemicals ranging from sulfur dioxide to formaldehyde emitted from the eight manufacturing and chemical plants in the rural Moncure area, where some residents have bristled at the proximity of manufacturing companies to homes.

Using information from the database of the Environmental Protection Agency from 1999 -- the most recent year for which data were available -- the group of seven undergraduate students did an analysis of air quality and found that:

- Chatham County is ranked No. 1 among the 3,219 U.S. counties for emissions of formaldehyde, a colorless, flammable gas that can cause irritation of eyes, nose, throat and skin.
- Chatham County is ranked 10th in the state for sulfur dioxide emissions, logged at 13,996 tons in 1999.
- Chatham County is in the top 10 percent of sulfur dioxide emissions in the United States.
- About 97 percent of sulfur dioxide emissions in Moncure were found to come from CP&L's Cape Fear utility plant, owned by Progress Energy. About 99 percent of formaldehyde emissions came from SierraPine Ltd., a plant that manufactures particleboard.

"Personally, I was surprised any county in North Carolina would be the No. 1 emitter of anything, but the numbers suggest that's so," said Steve Peretti, an associate professor of chemical engineering at NCSU. Peretti oversaw the student community project that investigated air pollution through state and federal emissions data, interviews with residents and a tour of SierraPine.

A SierraPine spokesman was unavailable for comment Friday. But Progress Energy spokesman Keith Poston said the company plans to install scrubbers at its Cape Fear plant to cut down on sulfur dioxide emissions. He also said that nitrogen oxide -- another plant byproduct -- has been reduced by 57 percent. "We share the goal of cleaner air," Poston said. "We're working hard to reduce emission from all our existing plants."

The report is scheduled to be discussed at a Chatham County commissioners' meeting Monday, and one group troubled by the findings -- the Southeast Chatham County Advisory Council -- is figuring out what step to take. "We're not out to lambaste anybody," said advisory member Winifred Smith, who lives in the community of Corinth. "We want [plants] to work with us as we work with them."

Although the report paints a damning picture of air pollution, the plants have not violated permitted emission levels since the mid-1990s, according to the N.C. Division of Air Quality.

But that area still needs to be studied, said Charles McEachern, a division environmental engineer. Although individual plants may not violate state standards, the cumulative effect of so many plants in one cluster can produce harmful results, he added. A study that was supposed to look at that question never got off the ground because of lack of funding. "The problem is that [plants] don't look at the emissions of their neighbors who are emitting the same chemical," McEachern said. "Their neighbor may be fine, but the combination of both of them may not be OK. This study would have addressed that."