Role-Playing in Analytical Chemistry: The Alumni Speak

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During the past decade numerous papers have addressed the organization and effectiveness of cooperative learning strategies. This discussion has forced the educational community, especially in higher education, to realize that the traditional lecture format fails to involve the multitude of students' learning styles. One cooperative learning format is role-playing. This paper reports the use of role-playing as a means to foster cooperative learning within the realm of science education, specifically analytical chemistry.

Role-playing is not a new construct. Its presence within society is well documented, and it is not our purpose to provide a comprehensive review. Role-playing has been used to train counselors, therapists, ministers, physicians, sociologists, and teachers (*1–5*). It has been used in Alcoholics Anonymous, chemical abuse rehabilitation, management training, teaching small-group dynamics, and teaching skill sets (*6–8*). It has served as a survey method and interview technique for issues related to education and equity (*9, 10*). Educators throughout multiple disciplines and educational levels have used role-playing activities to teach political science (*11, 12*), history (*13*), economics (*14*), psychology (*15, 16*), and the natural sciences (*17–24*).

However, few educators regularly incorporate role-playing into their base pedagogical structure; it is generally relegated to short activities. Resnick (*25*) and Aubusson (*26*) argue that role-playing activities can play a powerful role in math and science education, especially in the study of complex systems and in exploring viewpoints. This stands in stark contrast to a search of chemical higher education literature; in recent years reports of the use of role-playing as a teaching tool have been absent from publications in the chemical sciences.

Background

In a broad definition, pure role-playing is considered to be spontaneous and relatively unstructured, and to extend situations beyond reality. In contrast, pure simulations attempt to model some real-life phenomenon and are usually more structured in organization and objective. Simulation–role-play lies in the continuum between these two; it is not to say that some role-plays are not highly structured or that simulations always depict real-life scenarios. For a more comprehensive explanation of role-playing, simulation, and simulation–role-play see DeNeve (*15*) or Hood (*27*).

Role-playing is a different way to work in the lab and classroom. It stresses *interdependence* as the core part of mature *independence* and *division of responsibilities* rather than division of labor among those in the course. In general terms, role-playing is the activity of acting out, or mimicking. The role that is mimicked is a perspective or a personality defined to demonstrate some behavior pattern. The role is acted out, usually in a small group of fewer than 6 people, by adopting an exaggerated stereotype of the behavior pattern. The stereotyping and the exaggeration accent key functions of the role for teaching purposes. *Role-playing is the acting out of a deliberately exaggerated personality or cultural stereotype for the teaching of others and for experiential learning* (*17–19*).

Role-playing is a bridging educational model for the sciences. It spans the full scale from the *interdependence* that typifies industrial work and independent research (individuals in a group retain their individuality but agree to become mutually dependent in achieving a goal) to the *partners* approach that of necessity characterizes some of the beginning labs in the sciences. As a bridge, it allows students to explore management roles, specialist roles, and small-group communication dynamics, including how to reach a consensus without alienation. Students are encouraged to examine research or development work situations without the high risks that accompany the roles in the professional world. Students cannot be laid off from the course!

Active participation of students in their education represents a substantial paradigm shift in education over the past 50 years. In a recent communication in this *Journal*, Towns reported the results of an industrial round-table discussion on undergraduate chemistry education; the results lend credence to the above paradigm shift and the building of team problem-solving skills (*28*). A 1994 survey of 70 major chemical companies showed that the most desirable characteristics in chemistry and chemical engineering candidates are communication skills, computer skills, self-motivation, problem-solving skills, and being a team player (*29*). Each characteristic relates to the ability of a person to contribute to a group's mission and effectiveness. People no longer work in isolation. In an age of communication technology, *teams* tackle problems, and all people need to develop personal competencies that lead to improved productivity (*30*).

Course Structure

A key to understanding this report lies in the objectives and organization originally outlined in a three-part series on role-playing in the analytical chemistry laboratory as practiced at St. Olaf College (*17–19*). Even though the previous work emphasized the laboratory component, the role-playing structure is firmly rooted in all facets of the analytical curriculum. "Companies" (student groups) do homework assignments, present information and interpretations, break up into workshop sessions, create, innovate, and try to reach laboratory objectives together. The continuity of the company structure between the classroom and lab challenges students to begin to break down the artificial barrier between these regions that was constructed in their earlier chemical education. In the professional world chemistry is chemistry; there is no distinction between class and lab.

As outlined in ref *17*, grading for the course is different. It is based on a combination of group-based assignments, management interviews, and individual assignments and exams. Under the group rubric, each company member gets the same grade as the manager for a particular session or assignment. The individual grading is self-explanatory and traditional, although students are encouraged to consult with one another on individual assignments.

The goal of the role-playing experience is to develop technical expertise at an individual level while simultaneously stressing and developing the communication and collaborative skills essential to the profession. Moreover, the group construct allows students to examine larger, more complex questions mimicking real professional problems that are assessed only with difficulty on an individual basis. Instructors and students move toward these goals with the aid of technology and in a context of realism. Students are required to become active participants in their own education as well as in the education of their peers. Our assessment of the approach begins with this report on a survey of alumni that examines the long-term impact of the role-playing approach to teaching analytical chemistry.

Methods and Survey

The survey was motivated by several factors. First, educators at the elementary, secondary, and post-secondary levels have asked whether the method actually works and how it can be evaluated. The typical in-class evaluation process and personal reflections only ascertain the short-term impact of the method. A long-term assessment strategy provides additional feedback on the preparation given to the graduates and the overall impact of the program. Second, the results of the survey will be used to guide the future development of the teaching method within the chemistry department as the composition of the faculty changes and will provide a general forum for discussing pedagogical innovation. Third, collaborative constructs are encouraged and supported by the *NSF Workshop Report on Curricular Developments in the Analytical Sciences* (*31*), by examples from the chemical literature (*32–35*), and more specifically by those teaching within the analytical area (*36–41*). As scholars have suggested, a paradigm shift is occurring; education is moving toward a more interactive student-centered experience (*42*). Finally, the survey provides an opportunity to reconnect with alumni and possibly begin to reestablish relationships that will benefit alumni, students, and the college in the future. The use of alumni experiences in the classroom is a relatively untapped educational resource.

Cooperative learning constructs usually result in multiple learning outcomes (*42–46*), which fall into three broad categories: effort to achieve, positive interpersonal relationships, and psychological adjustment. Assuming an effective cooperative learning experience, we expect former students to provide feedback that fits into these categories. Students think more critically, gain interest in or change their attitude toward a subject area, value and develop interpersonal relationships with their peers and the faculty, increase their self-esteem, and perceive a shift in the locus of educational control (*42–46*). These are some examples of the thematic issues expected from the survey responses.

A copy of the survey is in the Appendix. The first five questions provide demographic information about the graduates. The remaining four speak directly to assessing the role-playing approach and providing future avenues for feedback. Since there was no clear benefit to the alumni for completing and returning the survey, it was kept short to encourage a reasonable return rate. The survey was mailed in early January and a follow-up postcard reminder was sent three weeks later. Surveys were collected through the Office of Institutional and Educational Research and responses were entered into a database to preserve the anonymity of the respondents. After half of the returns were read to establish categories and similarities in written responses, all responses were coded in the database.

Questions asking respondents to rank or recall specific experiences in the course were omitted because open-ended questions allow respondents to formulate their own reactions to the experience and to express those thoughts in their own words. The open-ended format preserves the possibility of discovering the unexpected and permits the study of *how* people think rather than just *what* they think (*47, 48*). Survey research indicates that open-ended questions are just as valid as closed-ended (*49*).

The challenge to using open-ended questions is in the analysis. The answers are not as easy to analyze as those using Likert and other scales (*48, 50*). The principal shortcoming of closed-ended questions is linked to the framing of responses. Krosnick pointed out that the closed-ended question can only be used effectively if its answer choices are comprehensive, and this is difficult to achieve (*49*). Bishop (*51*) and Presser (*52*) showed that respondents limit their answers to the choices given rather than expressing the best answer. Therefore, to achieve a candid, unlimited response, the questions were open-ended.

Results and Discussion

The survey was "blind" (investigators were unaware of the identity of the respondents). Course records cross-referenced with a database of college alumni identified 238 graduates during the years 1987–1997 who had completed the role-playing analytical class and laboratory as taught by John Walters, and surveys were mailed to these individuals. Alumni who lived outside the United States or were otherwise unavailable were not canvassed.

Ninety-four surveys were returned; one was undeliverable. This represents nearly a 40% return rate. Typical return rates for alumni surveys at St. Olaf run between 30 and 60%; recent surveys of alumni in the class of 1990 and of psychology majors between 1993 and 1997 yielded returns of 42% and 40%, respectively (*53*; personal communication with Huff, C., St. Olaf College, Psychology Department, 2 Aug 1999; Tallon, J., St. Olaf College, Department of Sociology and Anthropology, 29 Jul 1999; Johnson, J., St. Olaf College, Office of Institutional Research and Planning, 4 Aug 1999). These results are consistent with those from other private institutions across the United States (*53*; personal communication with Talon, J., and Johnson, J.).

The question of bias is critical when evaluating the quality of a survey. Table 1 shows the distribution of surveys mailed and responses received with respect to gender. The 60:40 split in gender that existed in course enrollment narrowed somewhat in the survey returns, but there was enough participation by both men and women that the survey is not gender biased. In addition to gender bias, graduation-year bias raised concern. One would expect heavy participation by fringe groups (recent graduates or long-

Table 1. Survey Gender Distribution

Gender	Number of Surveys	
	Mailed	Returned
Male	146	40
Female	92	36
Not specified	0	18
Total	*238*	*94*

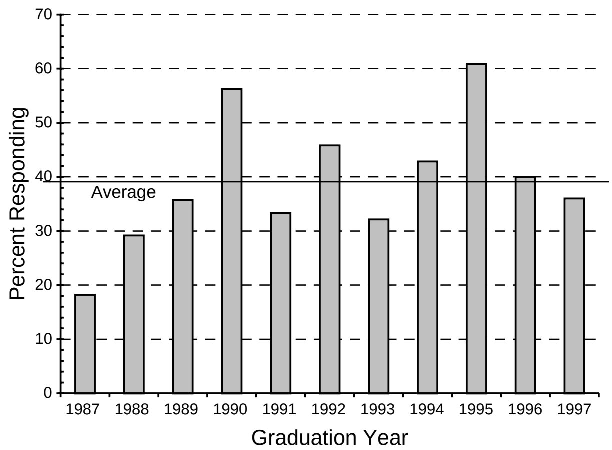

Figure 1. St. Olaf College Chemistry Department role-playing alumni survey: participation by graduation year. Horizontal line represents average response rate.

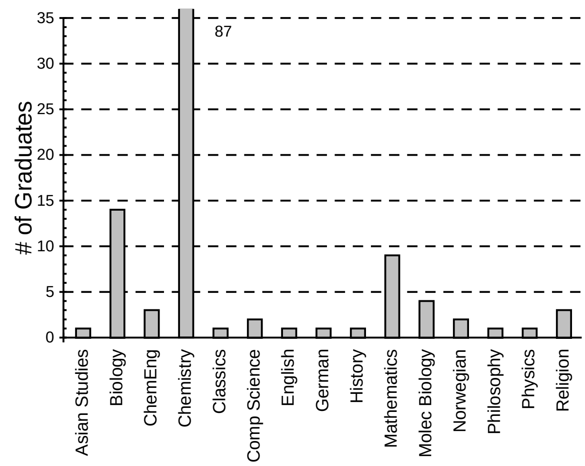

Figure 2. Undergraduate degrees awarded to role-playing survey participants. Some chemistry majors also had a second or third major in a different discipline.

term alumni) to bias the results owing to an individual's ability to recall the experience in question. Figure 1 illustrates the broad participation of the graduating classes. The average survey participation per class, computed from data spanning 11 years, 1987–1997, is approximately 41%, and the fairly consistent response rate across classes suggests little influence of graduation year on the responses.

It is appropriate to consider bias due to return of this questionnaire by people who fit a certain demographic pattern. This was a targeted survey of alumni who took the role-playing course. Whether the course structure induces self-selection is unknown, but considering informal first-day-of-class surveys and the average participation across the chemistry major, substantial self-selection is doubtful. During the period covered by the survey, approximately one-half of chemistry department graduates, either by choice or owing to scheduling needs, participated in the role-playing curriculum. (Heavy student participation in St. Olaf's off-campus study programs, 86% of every graduating class, probably dictates student course scheduling more than any self-selection phenomenon [Johnson, J., personal communication, 4 Aug 1999]). Self-selection based on general college enrollment is even more difficult to delineate. There is no basis on which to say that students who attend private colleges are more apt to function better in this type of teaching construct than students who attend public institutions; however, there may be some effect related to the fact that St. Olaf is a largely residential, rather than a commuter, institution. If there is evidence of substantial private/public differences, we accept this criticism. Potential bias along these lines is entirely coincidental; this must be fully appreciated both to adequately interpret these results and to acknowledge any deficiencies.

The role-playing experience not only impacts the chemistry curriculum but also provides inroads into other areas of study. For example, the course gives academic credit to the management studies concentration, and students wishing to augment their chemistry interests with formal management study make use of this option. Approximately 35% of chemistry department graduates also enroll in the college's premedicine program and many students with medical-profession aspirations participate in the role-playing course. Therefore, the survey was used to examine student demographics starting with the distribution of undergraduate majors within the course enrollment. Figure 2 shows the diversity of students' interests as reflected by their major. All but five of the survey respondents indicated a chemistry major; clearly the chemists define the course enrollments. A significant fraction of graduates, 35%, chose an additional major or concentration to complement their chemistry education. Thus many students do not have a single interest in chemistry, and role-playing is used to broaden the appeal of chemistry by stressing fundamental chemical concepts in a professional (human) context.

In addition to identifying student interests via the undergraduate major, the survey examined whether the pedagogical objectives outlined by the specific teaching approach were appropriate for the career paths the students took after graduation. Students were asked to share employment information and their pursuit of advanced degrees. Approximately two-thirds of the respondents indicated they were employed full-time; the rest were evenly divided between graduate and professional schools. The seven top occupations, in order of frequency, were chemical scientist, medical doctor, graduate student, medical student, teacher (primary, secondary, college), postdoctoral fellow, and manager. Combining the diverse positions shown in Figure 3 into general categories shows that chemically related work and health-care work each comprises 37% of the occupational descriptions. Teaching is third on the list. Thus on the basis of the survey returns, the chemistry department predominately prepares its students to engage in activities related to three areas: chemical work, health-care service, and teaching. This overlaps reasonably well with the course emphasis on communication, teamwork, and the role of a professional analytical chemist.

One-half of the respondents pursued advanced education. Of the degrees earned, 27% were Ph.D.'s, 27% were Masters, and 47% were in medical professions. The medical degrees were dominated by M.D.'s (67%); dental degrees comprise 8%. In the Ph.D. degree programs, analytical chemists were the largest group (42%) and biochemists were next (18%). The masters degree pool showed considerable diversity; teaching and public health had the largest response (18%). Again, the objectives of the role-playing course, with their emphasis on teamwork, communication, and collaboration, relate reasonably well to the areas of advanced study.

The remaining questions in the survey queried how the role-playing experience makes an impact. Almost three-quarters of the respondents indicated the role-playing class and laboratory experience had a positive influence on career choice (Table 2). It is interesting that individuals in the medical or health profession comprise the largest group in the "neither positive nor negative" category (ca. 70%). These graduates did not perceive a connection between the course and their current experiences, which is consistent with the course emphasis on the role of a professional analytical chemist.

Eighty-three percent of the respondents elaborated on their answers, frequently citing specific skills learned or appreciated as a result of the course. (These included people who said the course did not affect their career choice.) The specific skills or outcomes and the percentages of respondents citing them are reported in Table 3. The skill or concept most frequently cited as impacting the careers of the alumni arose from the group-based design of the experience. Forty-one percent of respondents stated that practice in planning and implementing a team-based problem-solving strategy or developing a working relationship within a group aided them in establishing their current career, and 46% answered that it affected their quality of life. Second to the team concept in frequency of mention was the real-world context provided by the course.

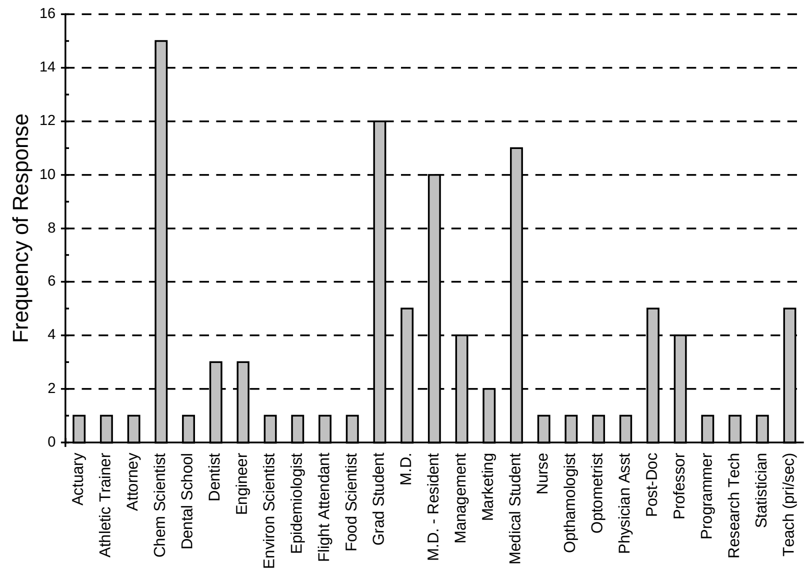

Figure 3. Current positions or occupational titles of role-playing survey participants.

Table 2. General Impact of Role-Playing Class and Laboratory Experience

Impact on	Responses (%)				
	Positive	Negative	Neither	Both	No reply
Career choice	72	0	24	0	4
Quality of life	66	0	23	4	7

Table 3. Specific Impact of Role-Playing Class and Laboratory Experience

Outcome Cited	Positive Impact on	
	Career Choice	Quality of Life
	% of Respondents	
Teamwork	41	46
Real / applicable context[a]	29	11
Gained self-confidence / self-interest	21	12
Problem solving	21	13
Made learning enjoyable	12	12
Hands-on exposure to technology	11	6
Personal responsibility	0	11
Communication	0	22

[a]Category emphasizing real-world experience or context directly applicable to professional activity.

The role-play construct, especially the laboratory component, was based largely on professional experiences of industrial and academic analytical chemists (*17*). This is where differences between role-playing and simulation bear reemphasis. The responses suggest that simulation–role-play rather than traditional role-play better defines the pedagogical approach. About one-fifth of the respondents indicated both gains in problem-solving ability and growth in self-confidence or interest in the subject. A few other notable comments were made regarding the pleasurable learning experience and the hands-on training in technology received in the course. It is somewhat surprising that no one singled out communication skills as influencing their career choice, although in order to achieve teamwork and problem-solve a considerable amount of communication had to occur and the necessary skills had to be learned. Overall, these responses are very consistent with the wealth of non-achievement-related outcomes associated with collaborative learning (*11, 15, 23, 25, 26, 44, 45*).

Alumni also addressed the impact the role-playing class and laboratory had on their quality of life. Numerous factors relate to one's subjective assessment of life quality, and the role-playing experience is only one of 36 course equivalents taken at St. Olaf. Consequently, a large response (especially a positive one) was not anticipated. Yet two-thirds of the respondents indicated the role-playing experience enhanced their quality of life! Team building in particular contributed to an improved quality of life. Somewhat surprising was the recognition of the benefits of improved communication skills and sense of personal responsibility in everyday life, but not in the career category (Table 3).

In addition to the open-ended questions, the survey contained a Likert-scale question designed to probe attitudes toward further association with the role-playing course through communications technology. This question could also indicate the general attitude toward the course. More than 70% of the respondents agreed (with a handful of caveats) that they would regularly participate in a Web page or other communications link. The distribution of the answers was "somewhat agree" (36%), "agree" (32%), and "strongly agree" (5%). These percentages mirror the open-ended responses extremely well and indicate that the coding in evaluating the responses to the questions was adequate.

Student response to role-playing as ascertained from our alumni is overwhelmingly favorable. It is interesting that even the one student who characterized the role-playing as "dumb and a waste of time" did not rate it a negative experience. More detail can be garnered by leafing through the responses to the last three questions, especially the question related to sharing an experience or personal anecdote. Those interested should download the tab-delimited file from the following Web site: *http://www.stolaf.edu/people/jackson/roleplay/*. A small sampling of comments follows verbatim.

> My first lab as manager was a complete disaster! Still, I learned more from that lab than any other, mostly due to the 15-minute "manager's review" in Doc's office. The short time spent reflecting on the whole experience that day taught me more than all the labs up to that point.
>
> *Quality Assurance Manager*

> Being the manager for the unknown acid scenario. We had to use the data to identify the unknown, but the data was not conclusive. I had to get input from team members to reach consensus. Although we made the wrong identification, I learned more about Acid/Base chemistry through the lab than I would have through a textbook, and I had my first taste of managing, which is my current position.
>
> *Analytical Scientist/Team Leader*

> I assume the bookshelf remains in the lab containing relevant management resources. At the time of the course I remember thinking that one of the books "The Giving Tree" [*54*] seemed out of place. I have since learned that this was the most important book of the bunch. It should be mandatory reading for any aspiring manager.
>
> *Senior Process Manager*

> I remember working all afternoon to identify a "secret chemical" and finally our team was the first to be correct—Doc was so excited and I won a computer book as first prize! It was great to be able to work closely with a professor—a wonderful way to learn that teaches a way of thinking which is adaptable to many situations.
>
> *M.D.*

> I just liked the way the class and lab were so obviously connected. I would like to say that the class was above average on a whole, but that perhaps a different instructor if his/her "heart" wasn't really into it—it wouldn't have been as effective.
>
> *Chemical Scientist*

> I remember having some problems with an experiment. Doc came over to the team and told us to simply talk it out and use each other's experience to solve the problem. We had the resources all along.
>
> *Analytical Scientist*

> Being "pushed" by Doc into a team of three smart men (so that I was the only female). That was a good experience, built my self-confidence—that these men respected me (and I them) and that we worked so well together.
>
> *Actuary*

> The entire experience is memorable. I loved the hands on work and even endured the computer work. The way the class teaching meshed with the lab work was great. And the introduction to the changing technology is something I will never forget.
>
> *Medical Student*

Summary and Conclusions

During the last 15 years St. Olaf College has offered analytical chemistry via a formal cooperative-group structure predicated on role-playing. The classroom and laboratory experiences involve the same formal groups to create a learning environment that presents the professional aspects of analytical chemistry in a comprehensive fashion. The course teaches not only technical skills, but also communication and collaboration.

The results of the alumni survey indicate that role-playing in the analytical chemistry curriculum has a profound impact on St. Olaf graduates. Not only have students achieved under this construct, but alumni reported receiving additional benefits through participation in the course. These skills and experiences have served them well professionally and personally. Furthermore, these skills reflect the wealth of non-achievement-based outcomes associated with cooperative learning. The results show that this teaching approach has passed the proof-of-concept phase and establish a basis for continued evolutionary effort.

With such an enthusiastic alumni response, this teaching strategy seems broadly applicable to other courses and subjects. However, a carefully thought out approach that serves the multiple learning styles of the students is always a priority. As paraphrased from one alumnus, cooperative learning strategies such as role-playing must be judiciously used by faculty members who thoroughly support the endeavor and "own" the implied responsibilities. That effort is not without risk for tenure-track faculty.

Acknowledgments

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[W]Supplemental Material

Supplemental material for this article is available in this issue of *JCE Online*.

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Appendix A: Role-Playing Class and Laboratory Survey—January 1999

1. In what year did you graduate from St. Olaf College?

2. What were your major(s) at St. Olaf College?

3. Circle the responses below which best describe your current situation:

	Primary	Secondary
Employed full-time	1	2
Employed part-time	1	2
Unemployed, by choice	1	2
Unemployed, seeking employment	1	2
Raising a family	1	2
Volunteer	1	2
Full-time graduate student	1	2
Part-time graduate student	1	2
Professional school	1	2
Undergraduate course work	1	2
Other: please specify	1	2

4. If currently employed, what is your current career field, employer, and current position (including title)? Note: please consider graduate/professional school employment and include the institution and program in your response.

5. Have you completed any other degrees since graduating from St. Olaf College (please list degree, field, and year of completion)? If not, are you planning to work on any future degrees?

6. Do you feel that your experience in the role-playing analytical chemistry class and laboratories at St. Olaf made a positive or negative impact on your career choice? Please explain in a short narrative.

7. Do you feel that your experience in the role-playing analytical chemistry class and laboratories at St. Olaf made a positive or negative impact on the quality of your life? Please explain in a short narrative.

8. Please share any memorable experiences or personal anecdotes from the role-playing class or laboratories.

9. Rate your reaction to the following statement, “I would regularly use a Web page or other communications link to reconnect with course alumni and to share my role-playing/life experiences with others.”

1 Strongly Disagree	4 Agree Somewhat
2 Disagree	5 Agree
3 Disagree Somewhat	6 Strongly Agree