

Student Engineers as Agents of Change: Combining Social Inclusion in the Professional Development of Electrical and Computer Engineering Students

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Abstract Community-based action research helps students link subject matter to everyday life and developing sense of responsibility to their community. While combining research and a development into teaching engineering software which has been vastly conducted in engineering disciplines such as Electrical and Computer Engineering (ECE) and Computer Science (CS), including inclusive participatory research is yet to be fully developed. We participated in the NGO by providing information technology (IT) and/or assistive technology (AT). This paper examines the practice of action research in service-learning projects that aim to introduce more socially responsible studies in the context of engineering education. It begins by exploring different forms of action research that may benefit engineering disciplines with a focus on action engagement to improve students' involvement in marginalized communities. The article provides field-based reflections of the action research project and suggests ways in which practice of action research may increase socially responsive value in the professional development of student engineers.

Keywords Action research · Social inclusion · Service-learning · Engineering ethics

Introduction

It was pointed out that, to make academic research relevant, researchers should try out their theories with practitioners in real situations and real organizations (Avison et al. 1999a, b;

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Artail 2008; Alzamil 2005). Many different universities have incorporated service-learning into their curricula to address the contextual, motivational, and multi-disciplinary team needs (Malerius and Odermatt 2005; Bushell et al. 2006; Santas 2009; Hood 2009). Brenner et al. (2007) at the University of Notre Dame helped out non-governmental organizations (NGOs) in their community and examined the application of Kolb's Learning Cycle, the Action Research cycle, and correlations with Community Based Research (CBR). As humans interact with technologies alone or as they make technology-mediated human-to-human interactions, social structures are formed. Multidisciplinary research has been devoted to understanding these structures and interaction patterns, and to understanding the ethical and social impacts they bring. This meta-discipline has come to be known as social informatics (Kling 1999). In the work of McIver Jr. and Rachell in Dominican Republic (2002), social informatics was used a research framework to make academic research more relevant. Kim (2009) applied action research in a project to deliver Information Technology (IT) to the underserved regions in Latin America where there was minimal access to technology. Inexpensive cellular phones were experimentally used as a learning tool for young children in geographically remote areas where computers were rare and the school system was nearly non-existent. The findings revealed some of the contextual phenomena that created both challenges and opportunities for a learning model for children who could not gain access to a formal education system. Purdue University created the Engineering Projects in Community Service (EPICS) program in 1995 (Olssen 1996). Under this program, freshman to senior undergraduate engineering students form multi-disciplinary teams to meet community needs. Penn State University has created a certificate program entitled 'Humanitarian Engineering' (Colledge 2009). This enables outreach programs at the Penn State University to reach into local communities and creates awareness of civic engagement.

Rehabilitation institutes that work with individuals with mental impairments to support them in learning new jobs and maintaining paid employment may support that for several weeks helping a person learn *how* to travel to and from their work. Even so, the person with a disability may at times still require assistance of one form or the other. While en route to their work, the person may need to be reminded via a phone call from the supporting group. As a result the majority of otherwise-employable persons with cognitive impairments remain unemployed, rarely access appropriate community services, and are socially isolated (Bond et al. 1997, 2008; Crowther et al. 2001). The growing recognition that assistive technology can be developed for cognitive as well as physical impairments has led several research groups to designing systems in real life. Researchers at the University of Colorado have designed a system to assist bus users with getting on and off at the right stop (Carmien et al. 2005). The Assisted Cognition Project at the University of Washington has developed models that learn a user behavior to assist users who need task instructions in activities of daily living. Later they designed a navigation system to give directions to cognitively impaired persons (Liu et al. 2006).

The contribution of this paper combines social inclusion as a curriculum design emphasizing action research methods of teaching, learning and conducting research that transform academic classroom curricula into meaningful services in community-based settings (Chou et al. 2008; Chang et al. 2010). In a service-learning curriculum at the senior level in Electrical and Computer Engineering (ECE), we practice the action research methodology to improve students' involvement in the social context. The curriculum encourages students to apply what they learn in the classroom to enabling NGOs to achieve more. Thus participatory research and service-learning are integrated so that opportunities for students to participate in communities can be more

meaningfully created (Sigmon 1979, 1994; Furco 1996). In the light of action research (Agyris et al. 1985; Baskerville 1999; Friere 1970; DeLuca et al. 2008; Friedman 2001), the framework of participatory research has been adopted that includes problem identification, intervention, and interpretation of results. This gives us an in-depth perspective when we take actions to implement changes at the community and greater society level.

Students as trainee programmers participated in identifying the issues with an NGO, generating workable solutions to implement changes, and making constant reflections in the continuous spiral process of inquiry, analysis, and actions. In our study, initial definition of problems paved the way for subsequent action plans and interventions which informed the next iteration of problem discovery. One assumption is that iterations of the action research cycle improve the quality of professional development due to the four following reasons: (1) Action engagement enhances the students' knowledge of the local work practice through personal involvement (Rolfesen et al. 2007); (2) personal involvement by the students enhances their emotional understanding of the insiders' real problems that need to be solved; (3) through emotional understanding, the students become self-motivated to accomplish the project to their best; the prototype they develop becomes their tool in the interventions to solve real problems. Feeling valued in the process of intervention could be a powerful incentive, and (4) action engagement builds mutual trust between the two worlds and creates a shared sense of good intentions which could be critical for both parties' commitment to overcoming difficulties and challenges hand in hand when the project encounters obstacles on the way.

Theoretical Foundations

Action research is a discipline that emphasizes creating communities of inquiry within communities of practice (Friedman 2001). This means that both researchers and practitioners must redefine their roles and develop a set of common values, norms, terminology and procedures. One of the objectives of action research is to make the tacit knowledge of practitioners explicit so that it can be critically examined and possibly changed in order to understand the problems under scrutiny and implement interventions to solve the problem. Action research in essence integrates practical problem solving with theory building. Action researchers explore the experiences and difficulties the insiders had in their problems and confirm what researchers saw in their field work. It helps raise the real issues behind the scene and shed light on the possible solutions.

When starting a new action research project, researchers as outsiders use their facilitating skills to create arenas for collective learning and creating common ground instead of defining the problem issue without involving insiders. However, insiders and outsiders live in two worlds (Chang et al. 2010). Action researchers orientate themselves to a new situation, learn about it and prepare to deal with it. For outsiders to take proper actions for interventions, action engagement (Rolfesen et al. 2007) suggests that researchers could use some time to involve themselves in the everyday activities in the relevant part of the organization to their advantage. It suggests a willingness to understand the insider's culture and systemic parts of the insider's problem. Action engagement provides the researchers with stronger relational ties to the insiders and insights to local organizational practice (Rolfesen et al. 2007).

Methodology Combining Social Inclusion Through Action Research

Setting

The participating NGO is the Foundation for the Rights of the Mentally Ill (FRMI), Taipei, Taiwan. It is one of the organizations that participate in government-funded supported employment programs. Supported employment programs are staffed by employment specialists who have frequent meetings with treatment providers to integrate employment with mental health services. The crux of supported employment is having people with disabilities in real jobs for real pay. Before individuals are placed in a competitive workplace, they are often enrolled in pre-service training programs at supported employment institutes and organizations. The participating NGO has been providing pre-service training for individuals with cognitive impairments through community-based programs for the past ten years. These programs help people with mental disabilities counter inadequate social participation, exclusion from mainstream activities, lack of social acceptance and lack of power. There were ten job coaches, one occupational therapist, one psychiatric doctor, and 35 trainees with mental disabilities.

Starting from 2006, senior-level ECE undergraduate students and graduate students with qualified prerequisites were offered a service-learning course. The prerequisites included proficiency in one programming language and basic knowledge of programming. The course lasted for two semesters, resulting in a total of four credit units. At the outset, the students enrolled in the course understood that they were required to co-work with an NGO as trainee programmers in order to improve civic engagement. Students enrolled in this course were assigned into groups, each with three to five members as a project team to conduct action research at the NGO.

The course consisted of topic modules and field practices. Topic modules included canonical action research methods such as problem exploration, needs analysis, planning, interventions, evaluation, and reflections. These modules were designed to guide students to conduct ethnographic observations, approach and talk to individuals with mental impairments, and set goals of a long-term intervention through engineering and technology. Topic modules were delivered 1 day a week for 2 h per meeting. The class met once a month in the format of group discussions in which students shared the progress of the projects, challenges they had met, solutions that they had worked out, and so on. Outside class workload was substantial in the format of field practices led by on-site supervisors of the NGO. Depending on individual motivation levels, a student was likely to spend 2–8 h a week in addition to inside class workload.

Identification of the Problem

It was found that the participating NGO had minimal use of information technology (IT) in their daily practice. Insufficient human resource often put job coaches in extreme work burden, which forced them to diminish the use of IT as it was often interpreted as extra efforts. Job coaches had distrust in IT because their job report system set up by the funding government agency was very difficult to use. They had experiences that job reports they prepared for hours were suddenly gone because the system crashed without warning. However, they still had to use the job report system in order to receive government funding continuously. Furthermore, students became aware of low job retention of mentally

impaired trainees in workplaces. These phenomena created emotional burden job coaches had to live with.

Initial Intervention

Field observations were arranged for the students to gain understanding of supported employment. Students had five-one-day trips to supported employment programs at a pizza shop, a recycling station, a hospital parking lot, a rehabilitation center and a school for children with special needs. To further improve students' involvement in the action research project, the students of each team were placed on the pizza shop floor for days, working with employees with disabilities under the supervision of job coaches. Action engagement enabled students as outsiders to get to know the job coaches face-to-face, understand what they did, learn their languages, and build friendship and trust. In return three teams of students decided to offer to teach Internet skills in an on-site computer workshop. The offers were well received because of the growing friendship between students and job coaches. It turned out that three workshops were scheduled in one semester, one in making the most of Skype, another in using Google email, and the other in creating and editing documents, spreadsheets, and presentations. Thus the computer skills job coaches spent their off-office hours learning. Because there were not enough personal computers in the NGO, for every workshop they brought their personal laptop computers and set up Internet links, turning a meeting room into a computer classroom in 20 min. Further, in April of 2007, a student team decided to set up an online discussion board to facilitate support mechanisms for emotional support among job coaches. For each future user of the system, a mentor from other student teams was assigned to assist a job coach in learning and discovering new features of the system.

Findings

The technology should prove relevant to their job functions and meet the objectives of the NGO to change their attitudes towards IT. We had findings that support the use of technology but the gap may be in people's perception of it, or even about change, or learning new systems. Job coaches recalled numerous previous experiences with academic research projects that resulted in little action or results. As opposed to their previous experiences, the collaboration within this project not only produced local knowledge but also actionable results. Students were impressed by the enthusiasm job coaches showed in computer workshops. With assistance and technical support from the students, job coaches overcame their distrust in IT that has been accumulating in their career. The discussion board quickly became a place of their own, an accepted tool for communication and was used widely in peer conversations.

To so many people at the NGO, cognitive impairments are an everyday lived experience the students are not even aware of. Students experienced the effects of being a cognitively impaired individual that can permeate every aspect of that individual's life. The experience created opportunities for participation and stirred the feeling of being included and valued for the individuals with cognitive impairments. Being exposed to such an unfamiliar way of life not only played into a tipping point for the course itself but also built the momentum for change in their professional development and their ability to span different worlds as a function of curiosity, self-confidence, and sociability.

We encouraged students to use feedback that we considered an important aspect contributing to rigor of the study and which can mitigate against inappropriate assumptions or interpretations outsiders can easily step into (Rolfson et al. 2007). Feedback happened on an as needed basis and helped ensure that we had not been misunderstood. For example, when a pre-service trainee with mental disabilities didn't dress herself up as usual, the student volunteers interpreted it as unimportant. However, a job coach would say that it could mean a sign of emotional stress or interruption of medication. Without this feedback, erroneous interpretations would have been taken for granted.

The findings from this iteration have provided insight into social dimensions that are an intrinsic part of professional development, including shared values, assumptions and beliefs. Students achieved increased credibility and trust through action engagement in ways that enabled students to bring in new aspects into the NGO. The trust and credibility between the NGO and students enrolled earlier in the course helped new students communicate their ideas and thoughts to job coaches.

Identification of New Problems

After a year of action research as a bridge between two worlds, a previously unknown world of people with mental disabilities and people who care them, and a world of college students themselves, students found the job coaches had increasingly used the IT. In the next stage, job coaches considered whether technology could be directly used by people with disabilities in their process of social integration, i.e. community-based living, recreation and leisure pursuits, use of community services, or independent movement in and around the community. Coupled with this increased independence and integration is risk.

With repeated training continued with daily practice, the individuals usually had no problems of getting lost or disoriented. However, there were occasions that individuals forgot how to travel to and from work. For example, part-timers with fewer shifts had more chances of running into transportation problems because they forgot the routes. For places with many distractions, few landmarks that could help remain oriented, or surroundings that looked similar, the situations could become complicated. Therefore, the problem was redefined as how to use technology to decrease the risk for victimization of individuals with disabilities as they increasingly participated in their communities, sought social inclusion, and increased autonomous functioning.

Follow-up Interventions

A team of students implemented software for a handheld device that was carried by individuals with cognitive impairments. The device enabled individuals to respond to unexpected situations such as getting lost by effectively using the handheld device to obtain environmental information, or call for assistance from the support network. The system was used in community-based settings in 2008. A small user study involving six participants with cognitive impairments investigated its performance in exploratory, control, and longitudinal examination. The results were consistent with the findings of Chang et al. (2009b). The project has lasted for 2 years. In fact, projects may last several years, so tasks of significant size and impact can be tackled. New students can work on existing projects over a multi-year span and carry on.

In 2009, a team designed a task prompting system for individuals with cognitive impairments to remain engaged in workplaces, recall task routines, and transition autonomously across tasks in a way relying on limited cognitive capacity. The prompting system provided antecedent cue regulation procedures that facilitated a shift in stimulus control from an individual to the system itself allowing the user more autonomous functioning. Picture prompts were used to facilitate user performance sequentially by introducing visual depictions of task steps. Recorded audio cues were also used as auditory prompts that facilitated user performance in completing targeted tasks. The system was implemented and tested in a community-based coffee shop involving eight individuals with cognitive impairments. Results showed that the handheld device increased 10–50% in task correctness for participants (Chang et al. 2009a).

Evaluation

To study the efficacy of the technologies, students conducted analysis across the participant groups in 2009. They adopted Hart and Staveland's NASA Task Load Index (TLX) (2006) method to evaluate the task load subjects might have experienced during the use of device. NASA TLX includes six indices: mental demand, physical demand, temporal demand, performance, effort, and frustration. It is used to assess work load on seven-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales. Considering the reading and verbal limitations with some of our participants, TLX assessment was conducted in the form of oral interview. In the meantime, 21 gradations were simplified and reduced to only five, i.e. one to five representing very low, somewhat low, neutral, somewhat high, and very high, respectively.

The participants unanimously found mental and physical demands and efforts to operate the device low or very low, i.e. one or two on the scale of one to five. In addition, individuals did not feel rushed to accomplish the expected level of performance. The task was completed at the participant's pace. No significant frustration was experienced by the participating users. The performance of the system was considered high or very high, i.e. four or five on the scale of one to five. During the interviews, all the participants felt comfortable recommending the system to their friends with disabilities (Chang et al. 2009a).

These results significantly impacted on students' learning. Using action research allowed students more of an insider viewpoint and resulted in students standing in one's shoes and feeling more confident in their understanding of the problems. We found that students became increasingly self-motivated and committed to the project because of empathy. In particular, action engagement in the volunteer programs gave students working insights into job coaches' daily tasks and helped make sense of seemingly minor yet important details in providing services. Action engagement not only helped identify the common grounds of assistive technology requirements but also exposed creative conflicts in implementation priorities. Therefore, action engagement fostered an esprit-de-corps as well as an opportunity for creativity. Students learned that active participation of the NGO and the inclusion of their local knowledge had accounted for more relevant results and usable products and services.

By making individual's embedded thoughts explicit through group discussions, students enhanced their communication and critical thinking skills even in an environment where there was an assumption that they would be iteratively changed. Students, as trainee programmers, were no longer solely associated with the responsibility for identifying the

problems to be solved; it was the responsibility of the NGO and students to identify, define, clarify, and thus prioritize the problems that existed. Working closely with job coaches enabled the students to avoid some of the potential pitfalls in earlier thoughts and rework the design without waiting until the end of a project. Therefore, the project was not a linear process of requirement analysis, design, implementation and assessment but rather a continuous, boundary-blurred spiral process.

Conclusions

With the practice of action research methods and action engagement in particular, the course transcended into part of a social process and students' community involvement. Students worked with insiders in the organization thus facilitating a learning situation in which the students were encouraged to create new meanings based on their participation in the organizational routines. Through long-term interventions, students went through the process of changing the world around themselves, no matter how small the changes were, and most importantly they changed themselves profoundly. The findings from the study have provided insight into the social dimensions that are an intrinsic part of professional development such as shared values, assumptions, beliefs and the influence of participating individuals. Furthermore, students achieved increased credibility and trust through action engagement in ways that enabled them to bring in new aspects into the professional development for engineers. We found that students through action research, not technology per se, became increasingly self-motivated and committed to the project. Field experience at the NGO was an important part of learning that enabled students to integrate their academic studies with periods of civic engagement related to their career goals.

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