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Integrating Service Learning in Engineering Clinics

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***Abstract* - Rowan University College of Engineering's innovative curriculum with the Engineering Clinic sequence provides a unique opportunity to integrate service learning activities that increase student awareness of social equity, global issues, and stakeholder concerns as they pertain to engineering practice. In many curricula, case studies are presented in specialized courses, or as segments of a design course, but identification of stakeholder needs and views are not effectively included in the design process itself; hence, societal or environmental effects are reported at the end of the project rather than integrated as part of design considerations. Service learning projects, such as Hurricane Katrina Relief project, and EWB-USA projects present an ideal framework for incorporating social, cultural, and environmental considerations into the design process in a meaningful way. These activities help all students realize the contribution that non-technical disciplines and points of view can have in implementing more socially equitable and environmentally benign engineering designs. They also prepare students to participate intelligently in public debates on technical policy issues. In addition, engineering students also have the opportunity to work on research projects with emphasis on social entrepreneurships. The junior/senior clinics provide students with valuable experiences that give them advantages when applying for internships, scholarships, graduate school, and jobs after graduation. Often, Rowan undergraduate students can point to conference or journal publications, engineering reports, design and fabrication experience or field work as evidence of their exceptional preparation for the real world. This is supported by anecdotal evidence and internship surveys from employers. The engineering clinic sequence is an excellent platform for integrating service learning into the engineering curriculum. The purpose of this paper is to present the mechanism that was developed to provide service learning opportunities that include a larger student body that have varied levels of interest. In addition, this paper, curriculum features, such as engineering clinics at Rowan University's College of Engineering is presented. In addition, a detailed description of the service learning projects conducted in these clinics and their impact on Rowan and the host community is explained.**

Index Terms - clinics, engineering, service, and learning

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INTRODUCTION

The innovative curriculum at Rowan University's College of Engineering provides a unique opportunity to integrate service learning activities that increase student awareness of social equity, global issues, and stakeholder concerns as they pertain to engineering practice. The purpose of this paper is to present the mechanism that was developed to provide service learning opportunities that include a larger student body that have varied levels of interest. In addition, the paper presents the impact of these service-learning activities on student learning and how faculty has to adapt to incorporate the flexibility needed to execute the project successfully. In many curricula, case studies are presented in specialized courses, or as segments of a design course, but identification of stakeholder needs and views are not effectively included in the design process itself; hence, societal or environmental effects are *reported* at the end of the project rather than *integrated* as part of design considerations. Additionally, many of the process or product design projects in which a fledgling engineer might play a role are parts of a larger whole and do not present an opportunity to interact directly with stakeholders outside the immediate community (manager, technicians, operators, etc.) in the plant or manufacturing facility. These engineering solution models raise significant ethical issues because the engineer is making critical decisions based on limited or biased information, which could lead to negative impacts and conflict. As educators, our goal is not only to train competent and creative engineers, but also to prepare citizens with technical training who can systematically assess the impacts of technology on local and global populations and environments and implement engineering solutions. Service learning activities provide a window of opportunity for students to engage in civic duty while applying relevant engineering concepts.

The College of Engineering considers service learning to be one of the most important vehicles in the internationalization of engineering education. Service learning connects students with critical societal issues that can be solved or alleviated through technology. It gives students an opportunity to witness first hand how technology can be a powerful force in enhancing the quality of life worldwide, and how it can promote community prosperity and improve international relations. In this paper, curriculum features, such as engineering clinics at Rowan University's College of Engineering is presented. In addition, a detailed description of the service learning projects conducted in these clinics and their impact on Rowan and the host community is explained.

BACKGROUND

Service Learning (SL)

Research on service learning spanning the last three decades has revealed that service learning facilitates the development of leadership skills, self-esteem, team work, communication skills and acceptance of cultural diversity[1,2,3]. It has also been shown to increase the development of intellectual and cognitive abilities and improve academic performance[4]. From a pedagogical point of view, service learning is one form of experiential learning, in contrast to the "information-assimilation" model that typifies classroom instruction[5,6]. Both methods have their advantages and disadvantages. The "information-assimilation" model emphasizes a "top-down" approach to learning, in which principles and facts are presented symbolically (e.g. through books, lectures, or videotapes), and specific application of principles are learned primarily through deductive reasoning or "thought experiments rather than through direct experience with real world situations." The advantages of the "information-assimilation" method are that it can transmit large volumes of information within a short time span and it emphasizes logical, cognitive organization of that information within a short time-span. The method's weakness is that student's actual acquisition and long-term retention of information are problematical.

Utilizing Service Learning To Incite Student Passion for Learning

Certainly, student experience tells us that traditional lecturing (the traditional strategy with lowest retention rate) is not the method to use in order to spark student passion. While there is no question that reading and certain audio-visual materials can lead to student learning, experiential learning stirs more passion in students. Once the enthusiasm and desire for learning is instilled, the possibilities of learning breakthroughs are limitless. Service-learning (SL) allows students to put into practice their learning. Once the student sees that the service experience will make a real impact on people's lives; the "ownership" of the project and the desire to learn increase dramatically[7].

The typical retention rate for various teaching styles is shown in Table I based on a comparison study of a control group and students with SL experience. The study showed that the students in the SL group scored significantly higher[8]. Approximately 74% of the control-group students perceived the work load as being excessively high. However, the SL group students didn't perceive the workload as excessive and completion of the project twenty hours within deadline was not problematic.

TABLE I
RETENTION RATES VERSUS LEARNING STYLE [9]

Teaching Method	Average Retention rate
Lecture	5
Reading	10
Audio-visual	20
Demonstration	30
Discussion group	50
Practice by doing	70
Immediate use of learning	90

Impact of Service Learning on Faculty

An unanticipated consequence of service learning project has been a degree to which observation and feedback impacts faculty. Faculty learning is triggered as a result of analyzing student experiences, and usually as a consequence a change in the teaching methodology follows. The process of faculty learning and change seem to unfold in stages [10]:

1. ***Initiating and Framing***: Defining the scope, type and location of service opportunities while structuring conceptual outcomes to parallel service experience observations, and outcomes.
2. ***Monitoring and Assessment***: Collecting data and faculty observations concerning student attitudes and evidence of new learning which may require adjustments in the classroom.
3. ***New Learning through feedback***: Evaluation of the programs including data on satisfaction levels, student project outcomes, and shared observations provide new sources for faculty

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learning. Further, use of feedback encourages prescriptive changes in curriculum, learning activities, and entry into site work.

A deeper understanding of student commitment and confidence levels, while often latent factors may be additional triggers for faculty learning. Stage three of faculty development experience involves creating data, which is used to reflect and critically review students work. At this point, the student's individual and collective service experiences will serve as a vehicle for the faculty to view and comprehend the dynamics of applied learning. The creative tension between these assumptions and specific real world observations can result in actions that alter teaching methodology.

Engineering Clinics at Rowan University

The Engineering Clinic is a required eight course sequence that emphasizes engineering practice and professionalism in a multidisciplinary setting (Table II). It is a required course in every semester of study though the emphasis of each clinic is different. A two-semester Freshman Clinic sequence introduces all freshmen engineering students to engineering at Rowan University. In Freshman Clinic, the students are introduced to a hands-on, active learning environment through a 3-hour weekly lab and a 1-hour weekly class meeting schedule. The first semester of the course focuses on multidisciplinary engineering experiments using engineering measurements as a common thread. The theme of the second semester is reverse engineering of a commercial product or process. Sophomore Clinic I combines a 1-credit multidisciplinary engineering laboratory with a 3-credit college composition and rhetoric requirement and is co-taught by engineering and composition and rhetoric faculty. The 3-hour laboratory for the course is a semester-long multidisciplinary design project. Sophomore Clinic II follows the same structure as Sophomore Clinic I, with public speaking as the 3 credits of required technical communications[11]. Students enrolled in the Junior/Senior Engineering Clinic work in teams to carry out independent research projects. The Junior/Senior Engineering Clinic, a 4-semester required course, is an integral part of the engineering curriculum in which students apply engineering principles to emerging technologies. Students work on service related projects or research grants funded by industry or government in multidisciplinary teams [12]. The make up of the teams is driven by the requirements of the project. Teams of students will be organized based on their particular skills, interests and background, and matched to a particular project. The service related projects offered through the junior and senior clinics are not meant to be a volunteer extracurricular activity. The projects usually have regional, national or international impact. Some examples of SL projects offered through the engineering clinics will be elaborated on later.

TABLE II

OVERVIEW OF GENERAL TECHNICAL TOPICS IN THE EIGHT-SEMESTER ENGINEERING CLINIC SEQUENCE

Year	Engineering Clinic Theme (Fall)	Engineering Clinic Theme (Spring)
First Year	Engineering Measurements	Competitive Assessment Laboratory
Sophomore	Multidisciplinary Design Modules	16-Week Multidisciplinary Design Project
Junior	Product Development	Process Development
Senior	Multidisciplinary Capstone Design/Research Project	Multidisciplinary Capstone Design/Research Project

INCORPORATING SERVICE LEARNING PROJECTS INTO CLINIC SEQUENCE

The Junior and Senior Engineering Clinics are unique because the students are required to work on a broad range of projects over two years. These projects may be exploratory – pilot studies or funded projects, or service learning projects. Through this vehicle, students get a chance to apply engineering knowledge to practical projects. The opportunity to work on these projects over a longer period of time gives the project manager the flexibility necessary to execute service learning projects, which require significant community and stake holder involvement. Service learning projects, such as Hurricane Katrina Relief project, and EWB-USA present an ideal framework for incorporating social, cultural, and environmental considerations into the design process in a meaningful way. These activities help students realize the contribution that non-technical disciplines and points of view can have in implementing more socially equitable and environmentally benign engineering designs. They also prepare students to participate intelligently in public debates on technical policy issues. In addition, engineering students have worked in teams to conduct research projects with emphasis on social entrepreneurships. These projects that were done in the junior/senior engineering clinics will be explained in more detail here.

Learning Objectives of Jr/Sr Clinics

The principal learning objective of the clinics is to "apply the engineering tools learnt in the classroom to projects". The learning objectives of the individual projects are outlined by the respective supervising project manager. However, the learning objectives of the service learning clinic is for the most-part essentially linked to the tasks associated with helping the community. At the beginning of the semester, the students may be given the broad goal of the project. The students then develop the objectives necessary for the project and strategize and allocate work among them. These projects are mainly student driven; the project manager is primarily a guiding rather than a driving force.

National - Hurricane Katrina Project

A group of four students in the Junior/Senior clinic team worked on a series of projects just after the disaster brought about by Hurricane Katrina. The students that were involved in the clinic lead a group of 40 students; many of them were from different colleges, such as sociology and anthropology. The students were recruited through department clubs and university-wide calls for participation.

The first semester long project was to build a dug-out for a school in Picayune, Mississippi. The following semester, they were involved in clean-up and demolition of damaged structures in New Orleans, Louisiana. In the following semester, a team of engineers, anthropologists and sociologists developed a project management plan to implement clean-up of some impacted communities. The project involved not only the engineering aspect of the implementation but also obtaining an understanding of the socio-political and economic impact of Hurricane Katrina on various societal classes. This interaction provided a valuable lesson for engineering students on how their profession effects positive change.

Global – Engineers-without-Borders – International Collaborations

The majority of the SL related projects students have worked on have been through the Engineers Without Borders™-USA projects. The EWB-USA has as its mission "to help disadvantaged communities improve their quality of life through implementation of environmentally and economically sustainable engineering projects, while developing internationally responsible engineering students." EWB projects have provided students with an opportunity to use what they learn in the classroom to solve important community problems like water supply and waste water treatment, by adapting technology to the needs and resources of the host community.

EWB Project Team

Rowan project teams are usually multidisciplinary and ethnically diverse. They also include a significant number of women. Students are involved in all aspects of the projects including site reconnaissance, design, fund raising and building. The project team leaders (a team of 3-4) are part of the engineering clinic; they get two-credits per semester. These team leaders solicit help from the EWB student club members. They supervise and monitor the activities to achieve the objectives of helping the community. The length of the project depends on when the project is received by the group and the timeline of site-assessment to site-implementation. Usually a EWB project is approximately 6-8 months long. The students have the option to select their clinic projects every semester, but interested students are encouraged to continue in the same project as the previous semester. This ensures continuity that eventually leads to quality deliverables.

One of the challenges faced by the teams is that the design and equipment must be consistent with the host communities' abilities to maintain them and materials should be locally available. In addition, the design must be done in consultation with the host community. Thus, students are also involved in working with community members in the selection, operation and maintenance of equipment.

An example of such a project is described in the following paragraphs. Most recently, Rowan students and their faculty advisors traveled to the community of El Amatón in El Salvador[13] to assist with the design and implementation of a potable water system. Students completed land surveys and an analysis of the community's water use. In addition, students completed a series of water quality analyses of drinking water sources used during the dry season. Preliminary analyses indicated that water, when available, contained unacceptable levels of fecal bacteria and other forms of contamination. Students participated in community meetings to discuss the project and lived in the community. Thus, they experienced the culture first hand. In addition, they returned to the University with an appreciation for the importance of the technology in providing basic services and also an actual application of engineering design in improving the quality of life. The project team is presently designing three technically and economically feasible potable water systems. These designs will be presented to the community who will then get to select the design to be implemented. Students will then assist with the installation of the system. They have as a result of the project developed a clearer understanding of the importance of developing solutions that account for the community's culture and resources.

EWB students have also worked on projects in Honduras (La Habana, Lagunitas, La Fortuna and Mataderos). In La Habana, students designed and assisted with the installation of a micro-irrigation system. In the remaining communities, students designed and assisted with the installation of potable water systems. In these projects, the main challenge was waste water management. Students needed to develop methods to dispose of waste water and work with the communities to integrate a sustainable waste management system into the project. Similar projects in Thailand have served to help students learn how the same technical concept can be adapted to different situations and how the culture of the host country impacts the technical solution. Interestingly, these experiences have also helped EWB students to participate in projects in the United States. Recently, a Rowan fisheries project was approved for funding by the US Bureau of Indian Affairs. Students will work with the Cheyenne River Sioux Tribe Environmental Protection Department and apply what they have learned in their international water management projects to an important problem affecting the tribe. Students will also assist ranchers to develop a low cost solution for treating high sodium enriched water resulting from coal bed methane extraction in Eastern Wyoming. The goal is to use the treated water for livestock and other general purposes. Students have gained an understanding of how solutions developed with the assistance of collaborators in Latin America and Thailand can be used to develop solutions in the United States. This project reinforces for students that, in a global community, all participants have resources to share.

Rowan students continue to engage in international projects that have significant benefits to the host communities. They apply what they learn in the classroom and adapt it to the needs of communities worldwide. Rowan students also gain a first hand appreciation of the role of the engineer in improving the quality of life of people worldwide. These projects have served to spark student interest in international activities. The Rowan EWB Student Chapter in collaboration with the EWB Mid-Atlantic Professional chapter hosted the first annual EWB Mid Atlantic Regional Conference on the Rowan Campus in Fall 2006. The main focus of this conference was to build bridges among the students and professional chapters in the area and to develop long term relationships that serve to provide professional guidance and networking opportunities for area chapter members.

Faculty Involvement

The service learning projects pose an unusual challenge for faculty because the objectives of the clinic are harder to define. The faculty has to be creative in dividing the project into various parts such as:

1) determination of data that is required from site assessment,
2) analyses of data collected, if site assessment is done,
3) development of presentation slides for community outreach and fund raising,
4) conducting a social and cultural review of the community, learning basic language skills, and if necessary communicating with other departments in the university to help and
5) developing a health survey.

However, these objectives are fluid and may change depending on the situation on the ground, such as, lack of communication with community, inability of the team to travel, or lack of funds. The faculty has to be creative and change these objectives to ensure that students continue to learn within the time-frame of the semester. For example, a water distribution project in El

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Salvador did not go through because the community found other immediate sources of assistance. However, the students did the design in Excel to develop appropriate options for water distribution. The faculty also collaborates with the university foundation, which assists in fundraising efforts for these projects.

International Collaborations - Social Entrepreneurship

In January 2006, Rowan students traveled to Coquimbo, Chile and were part of a team from La Universidad del Norte Sede Coquimbo[14] assisting independent abalone farmers with water management and process control of their operations. Students developed programs using LabVIEW to monitor and control temperature, pH, and dissolved oxygen in abalone tanks. Abalones are high value mollusks that are a delicacy in many parts of the world, especially Japan. Chile is the world's second largest exporter of farmed salmon, and fish and mollusk farming are becoming important industries in the country. Rowan students interfaced seamlessly with the Chilean team members and installed the software and equipment necessary for the monitoring and control operations. Therefore, the Rowan engineering students got an opportunity to use technology to promote entrepreneurship in the host country.

IMPACT OF SERVICE LEARNING

Considering the project in Mataderos as an example, the impact of the project on the students is examined. The students who worked on this project designing water and waste water systems and those who depend on it live in very different worlds. Utilities such as water and electricity have long been part of most of the municipalities in the United States, so much so that they are taken for granted. None of the students involved grew up in conditions comparable to host communities, such as Mataderos. In the United States, systems such as the one designed and built in Mataderos are not designed and implemented by students, but by the government on the local, state, and federal levels. Citizens are not responsible for the systems and are not permitted to fix them when they fail. This project is a true departure from what is familiar to the students. They must re-evaluate any idea they have from the perspective of the host community. Availability of material and ease of diagnosing and remedying a malfunction must be considered. It is not enough to devise a solution that works; they must devise a solution that works for the people of Mataderos. In that regard, this project becomes much more than just an academic exercise. The families of Mataderos are depending on the efforts of very different people at Rowan to improve their lives.

Technical Design

Most of the service learning projects are technically challenging, not because the problem itself is complex, but, due to the following reasons:

1. The topographical and local materials data is relatively difficult to collect due to the remote location.
2. Need to develop a sustainable design using locally available materials.

The students address these technical challenges in two steps:

1. Conduct a thorough site assessment trip to collect the data necessary to complete the design, for example, a survey of the area, properties of locally available materials.
2. To develop a prototype of design using materials representative of what is available locally.

Students have developed an electronic "portfolio" of technical designs. The groups use these as a reference and ensure continuity between clinic teams.

Diversity

Diversity begins with the University students and faculty, and the various ethnic origins they bring to the team. Recognizing the cultural differences of the team members enables them to draw from their own differences when approaching the project tasks. Team members who grew up outside of the United States and in less developed communities were particularly beneficial to have on the teams especially in their interaction with the Native American reservation or with the communities in El Salvador.

The group is also diverse in that four different disciplines (chemical, civil, mechanical, and electrical/computer) of engineering are represented. As a result of these four disciplines working together, the analysis brings a more diverse perspective into consideration and impacts the resulting system components. The team also has to learn to deal with conflicts that arise from the differing views, but the process leads to a more comprehensive design.

Cultural Diversity

The cultural differences between those at Rowan and in the host community, such as Mataderos in Honduras or Ban Pateung in Thailand is significant to say the least. The most obvious difference is the language. The residents of Mataderos speak only Spanish; most of the members of the Rowan team speak only English. Some of the team members speak more than one language, including Spanish, but communicating is still difficult at times. This is a new challenge for an engineer, which reinforces the need for communication and also to learn a second language.

Another significant difference between the two cultures is economic. College students, from predominantly middle class backgrounds in the United States represent Rowan. The people of Mataderos or Ban Pateung are not people of privilege. Even by their own country's standards they are poor. It is humbling for someone from a university to experience the lifestyle of the community. The students are also amazed that while these communities maybe economically impoverished, they are also very generous. An engineer could only realize this lesson from an engineering project of this nature and while the technical value of such a lesson maybe minimal, it is one of the most profound lessons anyone can take away from having worked on these projects.

Intercultural Lessons

This project challenges students to apply their engineering theory to a real-life problem. A water distribution system requires the students to reference engineering courses such as fluid mechanics, solid mechanics, surveying, and structures. The system cannot be too complex or else it will be too difficult for the host community to maintain and too expensive to fund. This projects were somewhat unique and all the more educational, because these factors must be considered by the team.

The project did not only require the installation of a system, but education of the people on how the system functions. The people of Mataderos had to understand the system and how it works, so they can maintain it once EWB-USA is gone. This required the team to explain the fundamental concepts involved. The team had to draw up lessons on gravity, friction loss, and overall operation similar to a rough engineering tutorial. The lessons must then be written in such a way that not just a non-engineer, but any person of limited formal education can understand. These written lessons are challenging because the team had to take into account the minimal education within the community and the language barrier.

The components used were restricted by their availability to the community and must be purchased in the host country. The design components must also be priced reasonably enough, so that the people can actually afford to buy them. This ensured that the community can replace any part that breaks.

This experience is full of opportunities for both the host community and the Rowan communities. The people of Mataderos and Ban Pateung are getting the potable water system they have wanted and deserved for so long. They are also learning some basic engineering concepts, so that they can maintain and expand the system when necessary. The students at Rowan are learning lessons that they would never get in the classroom, while applying their classroom education to genuine engineering problems. They also get exposure to another culture and a way of life that most Americans never experience. The quantitative impact of service learning activities is currently being documented by conducting a survey of students in the non-service learning clinics, which will serve as the control group and clinics that have a service learning component. This data will be available after the data is analyzed.

Connecting with the Community

The success of any EWB project is dependent on the involvement of the community, the true stakeholders of the project. EWB-USA has an intensive vetting process to evaluate a project originating from a host community. After the project is approved and assigned to a chapter, the EWB student chapter develops a relationship with the non-government organization in the community through EWB-USA to ensure that appropriate understanding of the capabilities and expectations are established. In addition to that, the traveling team tries to connect directly with the community, through health surveys and communication with the women in the community, who are primary users of the design system. The Rowan EWB student chapter team maintains the relationship with the community as much as possible, via phone, or email even if they do not travel to the site. Such a connection is a big step towards confidence building and ensuring our commitment to the project. Several international development projects have failed in the past due to a lack of confidence building measures, but the process developed by EWB-USA keeps the likelihood of that happening to a minimum.

Reflection

The students do not have any specific assignments or lessons that help them reflect on their work but the biggest reflection component comes in when they have to present in various forums, for example in Rotary club meetings, professional society meetings, in-class presentations and conferences. They get a chance to interact with other fellow EWB members from other universities during regional and international workshops.

Developing Long-Term Relationship with the Community

The EWB-USA encourages that a student chapter establish a long-term relationship with the community and the region as a whole. This has several implications:

a) the chapter can monitor the progress of the completed projects in the region and assess their impact on the community,
b) reduce the learning curve associated with a new place and culture and hence increase the chance of success, and
c) most importantly, develop a common bond and feel vested in the community.

CHALLENGES

The clinics were instrumental in integrating service learning in the curriculum but not all the students can participate. Getting multi-disciplinary experience is limited to students enrolled in the clinic. It is harder to maintain productivity if interest is beyond the pool of students within the clinic. Some service learning projects are dependent on the community and stakeholders input and the timeline may not be in sync with the semester. The faculty has to be innovative in defining deliverables. Challenges are multiplied if people outside engineering participate in this endeavor. Students have helped with various activities ranging from writing applications to implementation to fundraising. It is a hard task to identify whether engineering skills were necessarily applied, when you have a wide range of duties being handled by the students, but it is nevertheless a valuable experience.

CONCLUSION

Projects and service based learning expose students to the culture and language of the host country through technical projects that benefit the host community and give students international experience. By applying what they learn in the classroom to a project that may be essential for the well being of a community, students learn that the most important engineering function is to improve quality of life. Students are often surprised to learn that there are more similarities than differences among the people of the world. The need for basic services, often taken for granted by students in the United States, is universal as is the need for respect and understanding. Students become better engineers when they learn to adapt technology to the needs and resources of the community instead of forcing a technical solution that may not be appropriate for an application. By learning to value and respect other cultures, they gain a better appreciation for all that they have, and the role that engineering and technology can play in the development of the global community.

The junior/senior clinics provide students with valuable experiences that give them advantages when applying for internships, scholarships, graduate school, and jobs after graduation. Often, Rowan Undergraduates can point to conference or journal publications, engineering reports, design and fabrication experience or field work as evidence of their exceptional preparation for the real world. This is supported by anecdotal evidence and internship surveys from employers. The engineering clinic sequence is an excellent platform for integrating service learning into the engineering curriculum.

In addition, offering service learning clinics, such as EWB, require the faculty to redefine the objectives identified by the students and innovatively adapt if the logistics does not permit them to execute the initial plan.

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