Promoting Diversity in Welding Engineering Technology through the Medium of Art

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Utilizing Project-Based Learning to Promote Diversity in Welding Engineering and Technology

Abstract

The Art and Science of Metalwork is an outreach event targeting 9th-12th grade girls hosted by Weber State University. This multi-day summer camp event introduces high school aged girls to various manufacturing technologies through the medium of metal art utilizing problem-based learning (PBL) methodology and organized as a partnership between the department of Manufacturing Systems Engineering and the department of Visual Arts. This paper describes the need to address some of the psychological factors of under-represented minorities (URM) within engineering and engineering technology. By creating an environment where belonging is promoted and stereotyping is decreased, the Art and Science of Metalwork Event achieves an atmosphere that is inclusive of women and girls. This camp is designed to demonstrate the role and place of women in the engineering disciplines through guest speakers and facilitators as well as engaging and interactive projects. This paper describes the basic structure of the event and schedule and details the art projects that have been used in the past years of hosting the event. This paper describes key lessons learned in the organization and facilitation of the event. Finally, this paper concludes that the Art and Science of Metalwork event is a positive way to promote the inclusion of girls into engineering fields and connect with the K12 community.

1.0 Introduction

Research has shown there is overwhelming evidence that women are underrepresented in engineering and technology [1]. Ample research has been done over the past several decades to

understand this reality as well as the progress that has been made. In 1954, women made up less than 1% of the engineering B.S. degrees compared to 23% in 2020 [2]. This data is encouraging and matches research for degree intentions of freshman students. 2.6% of freshmen women had intentions to major in Engineering compared to 13.7% for men in 2007 and by 2014, the percentage of freshmen women intentions increased to 5.8% and freshmen men intentions increased to 19.1% [3 -6]. These increases are likely be attributed to many factors. Primary and secondary education has increased a focus on Science, technology, engineering and math (STEM) education. The clear evidence of women going into these disciplines can be attributed to a number of efforts in outreach to women and other under-represented minorities (URMs).

While these numbers look encouraging, there remain large gaps in certain sectors, in particular, welding engineering and engineering technology [7]. Engineering technology, in particular is often misunderstood. Many undergraduate welding engineering programs produce graduates with degrees in engineering technology. This degree can be unappreciated by industry and often engineering technologists are barred from employment or are considered technicians rather than engineers [8]. This is largely due to social gaps in understanding of what is the difference between engineering and engineering technology [8]. While this topic is notable, it is beyond the scope of this study.

The purpose of this camp is to build upon the social science research regarding belonging and stereotyping and stereotype threat to create a positive and inclusive environment for female students to explore welding and metal work technologies through the principles of project-based learning (PJBL). This camp contributes to student learning by exposing high school-aged girls to welding engineering technologies as well as other manufacturing engineering technologies

through the medium of art. Student gain tangible skills within the Engineering Technology domain and confidence in their own ability to learn new skills in areas they are unfamiliar.

2.0 Background

The pronounced gender disparities in engineering and engineering technology disciplines give rise to a challenging dilemma and one that has yet to be solved. Achieving a critical mass of women in these fields could pave the way for greater representation in both educational institutions and industry and alleviate critical upcoming labor shortages. This, in turn, might help mitigate or eliminate obstacles linked to stereotypes, stereotype threat, and a sense of belonging.

Stereotyping is a perception that certain groups of individuals possess lesser academic ability, a notion that can significantly impact their engagement in educational pursuits. This tendency is particularly pronounced in the realm of engineering technology, with fields like welding engineering being no exception. Often female students have less experience in a high school setting in a shop environment and therefore believe they do not fit a certain mold to excel in those fields [7]. The stereotypical belief that certain groups may lack the required academic prowess can result in dis-identification—individuals distancing themselves from these academic paths—and even lead to a higher likelihood of dropout rates within these disciplines. This underscores the critical need to challenge and dismantle such stereotypes to foster an inclusive environment that encourages diverse participation in welding engineering and related fields.

Stereotype threat is the psychological phenomenon where individuals, when aware of negative stereotypes associated with their social or demographic group, may experience anxiety or concern about confirming those stereotypes. This concept was first identified by social psychologists Claude Steele and Joshua Aronson [9]. Their work showed that when students

from stereotyped groups are placed in an environment where stereotype is relevant, they become aware of the potential of being judged through the lens of that stereotype. This awareness can lead to increased stress, pressure to disprove the stereotype, self-doubt as well and impaired performance [9-11]. This can have a detrimental impact on their performance in academic, professional, or other achievement-oriented settings. Stereotype Threat has been identified in a number of studies [11-14]. For example, it was observed that women exhibited lower performance on mathematical GRE items when they took the test alongside two men, as opposed to taking it with two women [10]. Schmader and Johns explained that gender imbalance can influence math task performance through a decrease in working memory capacity. Their findings suggest that when subjected to an environment with a gender imbalance, individuals may experience a reduction in cognitive resources like working memory, which can subsequently impact their performance on mathematical tasks. [11-14].

Belonging serves as a crucial predictor of success and retention in engineering and engineering technology degree programs. Belonging encompasses a subjective assessment of a student's sense of acceptance, value, inclusion, and encouragement from both peers and instructors within the academic environment. It also entails feeling integral to the class and recognizing one's importance in the educational community [13]. Studies indicate that students who persist in STEM majors tend to experience a heightened sense of belonging compared to their counterparts who transition out of STEM fields. However, individuals from underrepresented groups, including females, are less likely to perceive a strong sense of belonging. This disparity is, in part, attributed to the numerical underrepresentation of women both in educational settings and within the industrial landscape [13-18]. This paper shows that

using art as a medium, students can interact with manufacturing technologies in a creative and engaging way.

2.1 Project-Based Learning

Established in 1965, Problem-Based Learning (PBL) emerged from the collaborative efforts of five faculty members in the Health Sciences, with the visionary leadership of founding Dean John Evans at McMaster University [19]. This innovative pedagogical approach places students at the center of their learning experience, fostering problem-solving skills within the context of small group dynamics under the guidance of a tutor [19].

In the PBL framework, the learning process is intricately student-driven, with the tutor assuming a facilitating role. This methodology is rooted in an educational philosophy that emphasizes learning through the application of knowledge, essentially encouraging learners to actively seek understanding by posing questions and engaging in problem-solving [19, 20]. PBL is recognized as a transformative strategy in medical education, shaping independent thinkers and learners within the academic community. This approach not only equips students with problem-solving capabilities but also instills a sense of autonomy and critical thinking essential for success in the medical field [20, 21].

Following the implementation of PBL in the education of medicine, it has since been expanded to other fields and is considered a solution to some of the issues facing today's engineering education [21]. Project-Based Learning (PJBL), a variation of PBL, has been shown as a promising approach to achieve learning outcomes in engineering education. While both methodologies are based upon the same framework, PJBL results in a tangible product, project or outcome while PBL does not necessarily result in an outcome.

For example, faculty at Weber State University established a PJBL center to achieve a double mission of being an active community member and providing opportunities for engineering students to gain needed skills in problem solving and project management [22-25]. It has also been shown as an effective means of introducing URM to engineering disciplines [26]. It has been found that the PJBL learning approaches greatly facilitated the training in competencies related to interpersonal skills and technical aptitude, experience of solving real-world problems from an engineering perspective, and collaborative learning as well as promoting diversity and inclusion [25-27]. Liu and coworkers successfully integrated the PJBL model in his senior mechanical engineering classes by introducing more than 20 projects from industry sponsors, university research centers, and a state agency [28-39]. Liu found that the implementation of PJBL in course curricula struck the balance between achieving desired student learning outcomes and creating opportunities for enriching the student's educational experience [28-31].

3.0 The Art and Science of Metal Work

3.1 Background of Event and Funding

The format of The Art and Science of Metalwork camp is an overnight camp. It is typically scheduled during the summer months over the span of three days and two nights.

The event has been made possible by a grant from the National Center for Welding Education and Training (Weld Ed), sponsorship from the Weber State University student chapter of Society of Women Engineers, Miller Electric, John Deere, and a number of local industries. The event has a budgeted cost of approximately $5,000 which includes the advertising and promotional materials, facility costs, challenge materials and related safety equipment, t-shirts, meals for all participants and volunteers, instructor wages, and accommodations. A small registration fee for the student of $150 is required for registration with a scholarship option for

students in need. This camp is run as a partnership between the department of Manufacturing Systems Engineering and the department of Visual Arts. The partnership was formed based on a shared interest in combining engineering and technological skill building with the creative problem solving associated with visual art, to foster a match of experimentation with critical thinking and STEM based lessons for students. For example, one project included creating a light-based sculpture where students learned the fundamentals of basic electronics to apply solar power to LED-lit projects.

The facilitators do all the planning of the projects and provide all of training and instruction for each of the projects. The Center for Technology Outreach office provides the marketing materials and also organizes many of the logistical details of the event including securing the accommodations, arranging a website for sign-up, and recruiting volunteers to help support the event. The event typically engages 15 each year. The capacity of the camp is primarily based upon lab space and work stations. The majority of the students are from the Northern Utah area but students from neighboring states have also attended in the past.

3.2 Format and Schedule

Table 1 shows an example schedule of the camp. The visual art project detail is listed as an example. Camp projects are intended to be unique for each year of the camp as many students return in subsequent years.

Table 1: Example Camp Schedule.

	Tuesday, June 28	Wednesday, June 29	Thursday, June 30
8:00 AM	Check-in / Continental Breakfast PT Towers	Get Up/ Eat Breakfast @ SU Atrium	Get Up/ Eat Breakfast @ SU Atrium
9:00 AM	Welcome - Bldg. Room # Camp Expectation Project Description	Project (1hr. 45 m.)	Guest Speaker - Lauren Sprott Project (1 hr.)
10:00 AM	Facility Tours for MFET/Welding and EET Programs		
10:30 AM			Snack/Break
10:45 AM	Snack/Break	Snack/Break	Rockwall/Open Gym
11:15 AM	Welding & Electronics Engineering Safety Course	Board Bus for Barnes Aerospace Tour Arrive at 11:30 - Lunch generously provided by Barnes Aerospace.	
12:15 PM	Lunch in SU Atrium		Lunch in SU Atrium
1:00 PM	Break		Project Completion (1 hr. 15 m.)
1:15 PM	Lesson in DGET		
1:30 PM		Project (1 hr)	
2:15 PM	Snack/Break		Build your own Ice Cream Bar Engineers can do Anything!
2:30 PM	Begin Project (3 hrs)	Snack/Break	
2:45 PM		Project (2 hrs. 15 m.)	
4:30 PM			Clean/Pack Up Dorms
5:30 PM	Dinner in SU Atrium	Dinner in SU Atrium	Parent Pick -up Student @ Dorms
6:00 PM	Free Time	Free Time	Parent/ Daughter BBQ & Showcase @ University Village, Great Room
7:00 PM	Movie: Promontory Tower - Popcorn & Drinks	Bowling/Billiards- SU	
9:00 PM	Reflection Notebook	Reflection Notebook	Thank You For Coming!
9:30 PM	Free Time	Free Time	

3.3 Example Art Projects

A summary of the theme and description of the art projects is a useful way of demonstrating the objectives of the event to introduce girls to concepts in engineering and engineering technology through PJBL. In this camp, students have been exposed to computer aided design through the software Solidworks, Metal Inert Gas (MIG) Welding, waterjet cutting, and computer numerical control (CNC) plasma cutting as well as safety principles related to the technologies. Some of the completed past projects are shown in Figures 1-3 below.

Figure 1: Students working on pond log project.

Figure 2: Student displaying completed flower pot project.

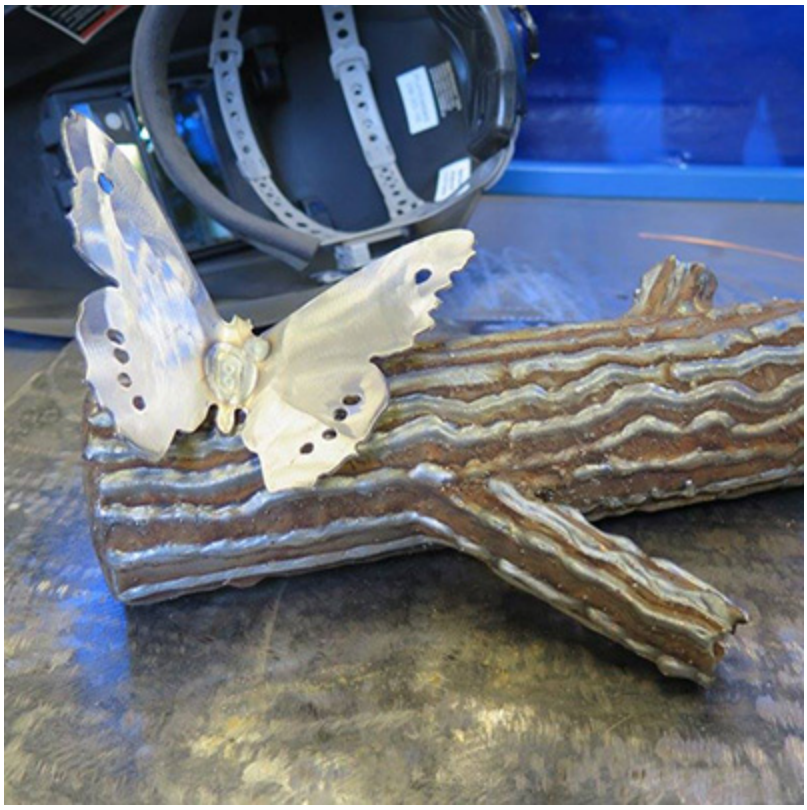

Figure 3: Completed pond log project.

4.0 Lessons Learned

4.1 Guest Speakers

Guest speakers should also represent the focus of women in welding engineering. It is preferable if they are close to the next stage from the students, meaning they are college students themselves or recent graduates. Guest speakers that are closer in age to the attendees are easier to relate and connect to [40, 41]. The impact of guest speakers cannot be emphasized enough. Exposing students to guest speakers that share their insights, real-world experiences, and industry perspectives have enriched students' understanding of the field. This allows the field the be more relatable and also helps students visualize themselves in the field. Many students are interested in how guest speakers have overcome challenges such as discrimination and stereotype threats. Guest speakers have a unique opportunity in sharing their own personal

stories and highlighting resilience-building experiences that they have had and what strategies they have employed. This can function to help empower students to thrive in the field.

Events in the past have had guest speakers including industry representatives from Barnes Aerospace and Miller Electric. The most impactful guest speakers share personal stories of their experience in welding engineering in a relatable way. These stories help to create a playful atmosphere for all attendees and also make the guest speakers more relatable as they describe the experience of being a welding engineering student and/or as a woman engineer.

This portion of the event is often the most surprising because there tends to be a lot of engagement between the guest speaker and the attendees. Attendees may have a lot of questions about the rigor of the degree and the career culture afterwards. These questions are often tricky in this environment, but the best answer is the honest answer. Students may ask questions about failing course work or about experiencing discrimination. These kinds of questions and stories can be so impactful to all students that question whether they belong in the engineering discipline when they experience failure in their degree [40].

While it might be tempting to paint the experience of women or any URM as free from discrimination, this can function to alienate those that are experiencing it. The reality is, the story of women in engineering is complex and is understandably not without growing pains. It is better to address the reality that it is likely women will face challenges related to their gender over the course of their careers and the strategies to handle these challenges as well as support networks. By using lived experiences to answer questions from parents and daughters, attendees can be prepared for some of the challenges they are likely to face [40, 41].

4.2 Icebreaker

When students arrive, there is a sense they are stepping out of their comfort zone and many are visibly nervous. Dedicating 10 minutes is a huge investment in lightening the mood and setting the tone for the event. Many girls may come in with the predisposition that engineering is serious and there is no room for lighter subjects. An icebreaker is a great way for introductions to be made and for attendees to get more comfortable get a better understanding of what to expect from the evening. Foss has observed, it is oftentimes the parents that are most concerned. Parents might worry they won't be able to help their daughter or feel that they don't belong. By starting the evening with an ice breaker, everyone has a chance to connect on a personal level. Attendees can understand that the goal of the event is to make welding engineering more approachable and inclusive.

4.3 Make it fun

One of the primary objectives of the event is for students to see that engineering is fun and there is a place for women in engineering. Attendees are not looking for a lecture, they are interested in an activity that will challenge their problem solving and creativity. They also want to be a part of a high-energy and positive environment. This is accomplished in all of the details and the atmosphere that is created by the event organizers. Attention to details such as music, food, t-shirts, and ways to decorate and personalize the design challenge are critical.

Foss has learned that few attendees are interested in solving calculations and even spending a lot of time in brainstorming or planning. In general, the challenges should be structured to be the most hands-on as possible. Attendees seem to love the building aspect of PJBL methodology and want to focus their energy and time on creating and trouble-shooting instead of designing and planning. While this is counter to the engineering design cycle that

engineers use, it is reasonable to save some of the more rigorous aspects of engineering education for post-secondary classes.

4.4 Introduce a variety of challenges touching on varied disciplines

Participants frequently enter the event with preconceived notions about the role and appearance of engineers. The objective of the event is to showcase the diverse spectrum of individuals and roles within the field of engineering. While the art challenges are fundamentally rooted in a PJBL methodology, they should encompass a range of applied physical science elements. Attendees anticipate a positive and affirming atmosphere that is also interactive and entertaining. In essence, the event aims to spotlight the most thrilling and creative facets of welding and metal manufacturing engineering disciplines.

4.5 Guiding the students that struggle

Some participants might encounter difficulties during the camp. Students may find themselves outside their comfort zones, leading to frustration with their perceived capabilities. Handling these situations effectively involves offering positive encouragement and asking insightful questions. The camp's overarching aim is to make welding engineering more accessible to a broader audience; therefore, introducing excessive background information could risk disengagement from some students. Formulas and calculations introduced should be presented at a level understandable to the general public.

Encouragement is often the remedy for the challenges participants face. Students should be reminded that the design process throughout history is marked by failures, and from failure, valuable lessons are learned. Consequently, there's no wrong way to approach the art challenges, and success can be redefined as active participation rather than winning or creating a masterpiece. By structuring the event based on the PJBL methodology, attendees can interact

with welding engineering disciplines in a hands-on and creative manner, supported by the volunteers and event organizers.

4.6 Allow time for rest

It is recommended that the camp schedule incorporates restful activities to balance the physically demanding nature of welding. Given the strenuous nature of the hands-on work, intervals of seated activities should be included. These could involve sessions on computer-aided design with tutorials and easy design challenges or engaging in a seated art project. Providing moments of respite not only contributes to the overall well-being of the participants but also enhances the learning experience by diversifying the types of activities involved.

4.7 Allow time and materials for unstructured creativity

It is advised to incorporate scheduled time and provide materials at the end of the camp for students to embark on additional projects. As students become acquainted with the fundamentals of welding processes, many express eagerness to further explore their creativity. Foss has noted that, with the opportunity of time and materials, students often produce remarkable sculptures and functional items for personal use or as heartfelt gifts for their loved ones. These additional projects not only showcase the students' skills but also instill a profound sense of pride and satisfaction.

4.8 Partner with an Artist

The partnership between the department of Manufacturing Systems Engineering and Visual Arts for this camp increases the impact of the camp for the students. Introducing engineering concepts through an interdisciplinary lens allows the field to be broadened in reach and also allows students to understand that the skills in both fields overlap. A good artist and a good

engineer need to have confidence in their abilities in creative problem solving. Structuring the camp with a theme of art allows students more opportunities to feel like they belong in the field.

The sculpture area at WSU provided hands-on practices in three-dimensional art including sculpture and jewelry/small metals as part of our contribution to the camp. Most often the workshops applied the welding skills students learned from the engineering lessons to create experimental sculptural forms in metal with an emphasis on being playful, creative and having fun. However, the most notable project with the strongest impact and depth in learning professional art and design issues was titled *Haiku Fence*, 2018. This project integrated creative writing with digital fabrication using water-jet cutting to create a collaborative outdoor sculpture.

The project's main objective was to introduce the participants to the use of writing and incorporating personal poetry into a collaborative sculpture within the context of public art. This had three stages of development including: a writing workshop, creating a design layout for applying text to a pattern, and the sculpture fabrication. The project concluded with a public reception of the finished outdoor sculpture, made with aluminum that was installed at the Bountiful Davis Art Center.

The writing workshop for *Haiku Fence* began with a short art history lecture to discuss female sculptors and visual artists who incorporate writing in their art practice, focusing primarily on the artwork of Jenny Holzer and Barbara Krueger. The group was then led in a discussion on the guidelines for haiku poetry and looked at examples while creating some quick rough drafts and sharing results. The syllable requirements of a haiku poem allowed the participants a basic structure to begin writing a poem which they all responded well to and were highly engaged in the process. After producing a rough draft the students were given another day to finalize a finished haiku poem for the project. A pattern was created for the students to

apply their poems and think about how it would fit on the shape of a picket fence board. Creative experimentation was encouraged and several students created drawings as part of the design. This project was effective in inspiring creativity and confidence as the participating students' poems were realized in a finished sculpture as shown in Figures 4-7. The presentation of the sculpture at Bountiful Davis Art Center elevated their creations within the context of an outdoor sculpture on view for the public, which is intended to have an impact on building confidence through firsthand experience of the artistic process— from conception of an idea, to the realization of the design and the act of exhibiting for the public.

Figure 4: Workshop participants developing haiku poems in the poetry/visual art workshop.

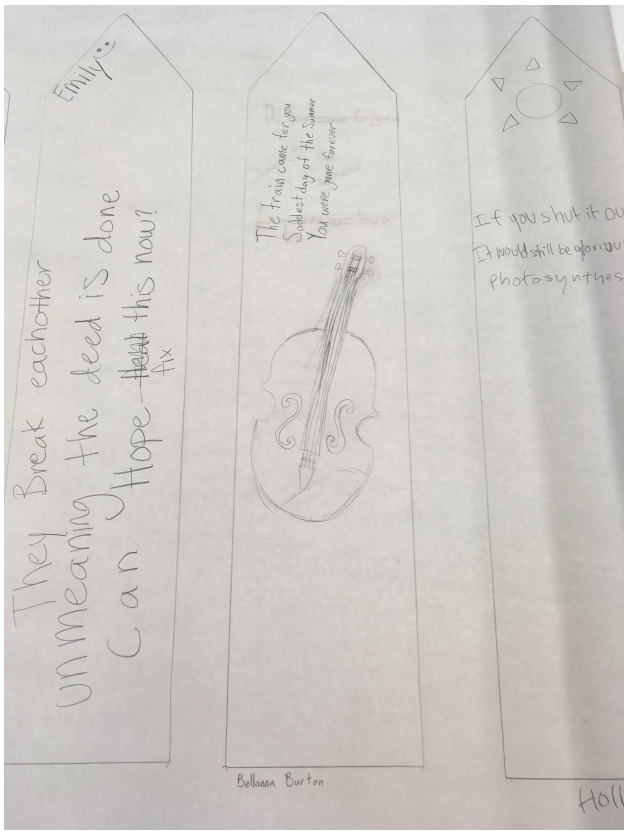

Figure 5: Haiku poems were finalized in the second meeting to form a finished design for 3D fabrication.

Figure 6: Poems were water-jet cut in aluminum plate and welded into a collaborative sculpture.

Figure 7: Completed Public Art Project.

Partnering with a local art center with a special interest in community-based projects, Bountiful Davis Art Center presented the project in a flower planter in front of the art center. A public reception was held at a later date following the welding camp which many of the students attended and was also available for them to view as an outdoor sculpture for an extended period of time.

4.9 Family Showcase

The event should feature a Family Showcase, providing an opportunity for a communal gathering where dinner is served. This special occasion allows girls to showcase and share their art creations, offering guided tours to their parents and celebrating their accomplishments. The Family Showcase serves as a festive platform to recognize and appreciate the participants' achievements, fostering a sense of community and shared pride in the creative endeavors of the

girls. Often the family show case is combined with the closing BBQ dinner where Instructors and lab aids can meet the parents and families of the participants.

4.10 Recreation and Social Events

If possible incorporate recreation and social events to allow the camp attendees to bond outside of the lab areas. Activities in the past have included Rock Climbing, Bowling, hiking and in-dorm games.

5.0 Conclusion

In order to continually advance the field of welding engineering, more diversity is needed. The role of women in engineering has been historically complex but is also changing in a very dynamic way due to efforts in outreach to all STEM fields in the primary and secondary school systems. Promoting diversity, however, it not so simple and there are many factors that have been discovered in the learning environment that have been shown to increase belonging and decrease stereotyping. The Art and Science of Metalwork summer camp has been designed to capture this research by demonstrating an environment where women and girls are included and thriving in the fields of welding engineering. By designing the event using PJBL methodology, the welding engineering field is experienced in an interactive, challenging, and creative way that is also a fun and enjoyable way for the attendees to grow and maybe even return to camp the next year [42].

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