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Unlocking Deeper Insights: A Qualitative Approach To Evaluating STEM Outreach In Engineering Education

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Unlocking Deeper Insights: A Qualitative Approach to Evaluating STEM Outreach in Engineering Education (Practice)

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ABSTRACT

Much previous research and evaluation has been conducted of STEM Outreach activities in schools using quantitative approaches. Surveys in particular are popular as they are low-cost and time-saving. However, quantitative methods are limited in that they do not generally generate deeper insights into students' experiences in STEM; usually lacking rich detail about the context and complexity of the data being analysed. Hence, this paper proposes a different approach to evaluating STEM outreach: a unique multi-method, qualitative approach.

Starting with the Research Question "How to qualitatively evaluate STEM outreach in Engineering Education?", this paper is grounded in ongoing doctoral research that addresses a substantial gap in knowledge pertaining to how STEM outreach is evaluated. This methodological gap became apparent during the Pandemic when STEM activities were offered, yet there was not a robust way of evaluating the children's experiences. This paper outlines a qualitative research design that employs a Multiple Case Study approach with Grounded Theory. It argues that a qualitative design can be used to acquire an in-depth understanding of data that is both insightful and unique. The paper adds to knowledge in the area of methodological design within engineering education research, and such data can then be used to inform the provision of future STEM outreach. Furthermore, the researcher's ongoing fieldwork experience is also reflected to identify the unique challenges in the methodology execution. The insights on how to address these challenges can support academics in Engineering Education Community to engage in qualitative research.

1 INTRODUCTION

This paper is based on ongoing doctoral research in STEM outreach evaluation, reflecting on a qualitative research project in the West Midlands area of the United Kingdom. The research focuses on the evaluation of engineering outreach activities from the Lord Bhattacharyya Engineering Education Programme (LBEEP), which is designed for secondary students aged from 11 to 18 years old.

STEM outreach has been widely acknowledged as a beneficial complement to conventional in-class learning, as it exposes students to real-world settings and enhances their interest and attitudes towards STEM subjects and careers (Vennix et al. 2018). However, there is a lack of evidence of the actual effect of STEM outreach in increasing the number of young people studying engineering subjects at both higher and further education institutions, despite considerable efforts by the government, educators, and other stakeholders (Morgan et al. 2016). In recognising this, the research seeks to address the challenges faced by the evaluation of STEM outreach and to develop a qualitative methodology design as one of the possible solutions.

Current research on STEM outreach evaluation is predominantly quantitative, with surveys being the most commonly used method (Pearson et al. 2022), with 87% of organizations evaluating their outreach and 98% of these evaluations involving the survey as a research method (Morgan et al. 2016). The extent and nature of evaluation methods depend on the resources available to the outreach providers or education institutions, which may be limited. Hence, such kind of quantitative survey is widely used due to its advantages of low cost, time-saving, and easy-to-use features in the short-term STEM interventions' evaluation. However, they may not provide a rich description of complicated outreach settings or illuminate students' experiences (Leydens et al. 2004). Furthermore, the lack of a standard evaluation framework for STEM outreach interventions makes it difficult to ensure comparable quality assurance across a wide range of activities, which are significant to sustainable and scalable outreach evaluation.

To address these challenges, this work-in-progress proposes a qualitative approach to evaluate STEM outreach in engineering education. Thus, the research question is "How to qualitatively evaluate STEM outreach in Engineering Education?", to develop a qualitative design for STEM outreach evaluation to gain an in-depth understanding of students' experiences. This can help to generate a theoretical evaluation framework as a final deliverable. Therefore, the paper presents a new methodological approach and then follows a reflection on the methodology implementation, in order to propose recommendations on the experiences of data collection.

2 METHODOLOGICAL CHALLENGES IN STEM OUTREACH EVALUATION

While many STEM outreach initiatives claim to be helpful, few appear to provide convincing evaluation outcomes (Bogue et al. 2013). Potential reasons for this are the lack of a systematic evaluation framework and missing the individual participants' experience during the evaluation. This section discusses these two emergent methodological challenges when evaluating STEM outreach programmes.

2.1 Lack of the outreach evaluation framework

Frameworks for discussing and categorising STEM outreach activities are essential but significantly lacking (Miranda and Hermann 2010). The diversity of participants and outreach themes in outreach evaluation reflects the efforts of establishing evaluation measures in isolation, rather than as a collective evaluation framework applied across all outreach programmes on offer. Due to methodological obstacles, as well as financial and resource constraints, a standard framework has not been generated to evaluate STEM outreach interventions due to varied contexts, scopes, and aims. The lack of a standard framework also challenging to propose meaningful and credible data collection questions to probe the value of the outreach. To fill in this gap, developing a general assessment framework across diverse STEM outreach activities and comparing the effect of different STEM outreach activities is a significant opportunity for contribution.

2.2 Collecting data on individual experiences

Quantitative evaluation work using surveys is popular in STEM outreach assessment, especially in the evaluation of short-term initiatives (Saw et al. 2019). One of the reasons is the utilisation of qualitative methods can increase the complexity of the research design and data collection process, which may require additional resources and time to manage effectively.

However, relying on the survey to quantitatively evaluate the STEM outreach has limitations in obtaining a comprehensive understanding of the outreach impact. Firstly, surveys aim to generalise findings from groups rather than individuals, which may lead to ignoring the nuanced difference between a student's outreach experience versus others (Hazari et al. 2020). For example, some surveys collect data on attendance and satisfaction to measure outreach success (Felix et al. 2004; Sadler et al. 2018), as an indicator of students' interest and engagement in STEM outreach. Yet the survey results presented in numbers showing the group level success thus may not capture individual changes in knowledge, skills, attitudes, or the longer-term impact of the programme on their educational or career paths. Therefore, a promising alternative qualitative approach has its advantages in capturing the individual experiences of attending these STEM outreach, hearing their voices and enhancing the understanding of the outreach effectiveness (Demetry et al. 2009; Prieto-Rodriguez et al. 2020).

Moreover, the participants' experience of completing a survey may also impact the accuracy of the responses. Particularly, young students may have difficulty understanding certain survey questions or terms, leading to inaccurate or incomplete responses (Lewis 2011; Williams and Rudge 2016). This can be due to written language barriers, lack of familiarity with STEM education terms, or difficulty in articulating their thoughts. As a result, the data collected in a survey may not accurately represent the students' actual outreach experiences and attitudes towards STEM.

Considering the limitations of the prevailing quantitative approach in STEM outreach evaluation, more qualitative research is required to ensure a comprehensive and accurate assessment of the effectiveness of STEM outreach programmes. Hence, This research proposes a longitudinal evaluation of LBEEP's impact on students' attitudes towards STEM careers through a robust qualitative multiple-methods design. Multiple Case Studies, Grounded Theory and relative methods are applied to contribute to developing an effective outreach evaluation framework that can be used by educators and researchers to assess the impact of their STEM outreach programmes.

3 QUALITATIVE METHODOLOGY DESIGN FOR OUTREACH EVALUATION

In regards to the lacking a qualitative approach in the STEM outreach evaluation, this paper presents a qualitative methodology based upon Multiple Case Study Research and utilising an analytical approach based upon Grounded Theory and related research methods. Case Study Research provides the means with which to investigate the effectiveness of engineering outreach programs in enhancing or improving learning and teaching. Adopting an approach based on Grounded Theory will allow the researcher to generate new theoretical insights; this is particularly important when examining under-researched areas such as STEM outreach evaluation (Case and Light 2011). Using a Multiple Case-Study approach means that the theory generated will allow a variety of situations to be analysed from the research participants' perspective; allowing a richness and depth of data in which each emerging concept and sub-concept is examined in detail from several angles (Alzaanin 2020). Therefore, this paper adds to current debates by critically discussing how a rigorous evaluation of STEM outreach may be achieved.

To achieve the triangulation in qualitative research, multiple sources of data will be collected as listed below, including observation, focus groups with students, and interviews with adult participants (teachers, school governors, professional bodies and industry employers), to evaluate the performance of STEM outreach.

1) Non-participant observations are being used to critically study students' experience in STEM outreach on-site in schools. This involves using an observational framework to closely record how students interact with the learning environment; noting particularly how students go about solving STEM education problems through interactions with instructors and teamwork with peers. The observational data collected from students will be written down on a handwritten framework in real-time.
2) Focus groups with students are being undertaken to investigate students' learning styles in STEM subjects. Additionally, the interviews explore the students' perceptions of the transition between education stages whilst also touching on the potential for further engagement in STEM careers.
3) Semi-structured interviews with adult stakeholders such as teachers and industry employers are conducted to explore the emergent data from the focus groups and interviews whilst also providing the means for cross-verification of students' data.

The observational data will undergo analysis employing Symbolic Interactionist techniques. Symbolic Interactionism, a theoretical perspective within sociology, offers valuable insights into the dynamics and symbolic meanings embedded within social interactions (Teo and Osborne 2012). While all of the interview and focus group data will be digitally recorded and then transcribed verbatim before being subjected to a grounded theory analysis using initial and axial coding. Grounded Theory techniques are applied to qualitative data analysis including theoretical sampling, theoretical saturation, and qualitative coding. These data analysis techniques can ensure a comprehensive exploration of the qualitative data, enabling nuanced insights and a rich understanding of the multifaceted aspects within the research context.

4 REFLECTION ON FIELDWORK EXPERIENCE

This section will discuss initial challenges that emerged during the ongoing fieldwork and how they were addressed, including getting access to the field, unpredictable research environment, language barriers and ethical challenges. This reflection will help to facilitate gathering qualitative data with young people. on and further improvement suggestions are also proposed for sharing best practices with the Engineering Education Community.

4.1 Get access to the field

Gaining access to the field and building relationships with school gatekeepers presents significant challenges for a longitudinal research project on STEM outreach evaluation. School teachers or programme coordinators usually played the gatekeepers by controlling access to student participants, outreach stakeholders and other resources needed by the qualitative researcher (Harger and Quintela 2017). Access issues are made considerably more challenging when it comes to research involving children who are unable to give their consent.

To address significant challenges of access, a solution is to establish rapport with school gatekeepers through efficient communication. For example, the researcher met with school gatekeepers online or in-person to understand their concerns and priorities and gain insight into the school's context (i.e. Local environment, community engagement, student population, academic performance, STEM strategy, management and governance) prior to the formal data collection. During these meetings, the researcher provided clear and transparent information about the research, including data collection techniques to demonstrate ethical research practices and build trust. It is crucial to respect the gatekeepers' authority regarding access to resources and address any concerns they may have.

It is also essential to highlight the benefits of the research to the school gatekeepers in order to encourage their involvement. This can be done by emphasizing how the research can contribute to improving the STEM skills and career aspirations of the students and sharing the information on available outreach resources and educational partners to support the school.

In response to difficulties in accessing the research field, another solution is to adjust the methodological design. For instance, the case units were reselected based on schools' level of engagement in LBEEP. Another example is in cases of a stakeholder who provided limited access, the researcher may remove them from the sample. These adjustments facilitated a more targeted and effective data collection process despite the challenges faced. However, it is important to note that such methodological adjustments may require additional work thus impede the research progress, and may potentially introduce new biases due to missing important perspectives from excluded participants. Therefore, it is recommended that researchers approach such adjustments with resilience and flexibility, continually monitoring and adapting the methodology as needed to ensure the trustworthiness of the research.

4.2 Unpredictable research environment

To ensure the safety of children involved in the research, data collection was conducted during school hours and within the school premises. However, conducting research with children and in school environments is often unpredictable (Harris et al. 2015), which can necessitate adaptability, quick response and decision-making in order to ensure successful data collection.

Taking one student's temporary absence, for example, can undermine the quality of a planned 3-student focus group. In this circumstance, the researcher needs to make decisions quickly about whether to conduct interviews with 2 available students in this group. However, the data collected in this way may not be able to gather the same level of insights, opinions and dynamics as they would have in a 3-student focus group, where data can be rich and varied in a larger group (Gibson 2012). Hence, the researcher attempted to integrate these two students with another 3-student focus group, which expanded the number of participants in one focus group. While maintaining interaction within the group, this merging may result in a lack of focus during group discussions due to limited time. Additionally, the lack of cohesion, when compared with focus group data from other schools, may potentially impact the quality of the collected data.

This unpredictable challenge can influence the research by potentially changing the research design, affecting the data quality, and thus impacting the ability to draw meaningful conclusions and implications from the data. To address the challenges, recruiting students up to or slightly over the participant number upper limit for individual research activity will be helpful to ensure the successful implementation of the research activities. The researcher can also expand the number of research sessions to ensure enough data is being gathered even if some participants are absent. It is important to carefully consider the potential implications of any changes to the research design so that the data collected remains valid and reliable.

Another significant challenge encountered during data collection is the unpredictable behaviour exhibited by children, particularly those at younger ages. Behavioural issues of these children may hinder their learning STEM knowledge and skills, and also distract other students thus diminishing their engagement in the STEM outreach and research activities. Therefore, to mitigate these challenges and maintain a safe research environment, it is necessary to have at least one teacher present during the data collection process. The teacher's presence also provides support in addressing any unforeseen circumstances that may arise in research to ensure the safety and well-being of both the children and the researcher are prioritized. As a recommendation for practice, it is essential for researchers conducting studies involving children, particularly in school settings, to collaborate closely with teachers or school staff since their involvement can significantly contribute to creating a controlled and safe environment during data collection.

4.3 Language barriers

One challenge encountered by the researcher pertains to language barriers when communicating with students and stakeholders from diverse backgrounds, particularly for the researcher using English as a second language. To address this challenge, the researcher tailors the research protocols according to the specific needs of different participant groups. For example, the researcher utilized more accessible and child-friendly language, such as referring to "extra-curricular activities" instead of "outreach" for children participants. To ensure accessibility and avoid jargon or complex terms that may impede understanding, both student and adult versions of the research protocols were pilot tested. These adaptations aimed to align the language with the participants' developmental level, ensure their comprehension, foster participation and obtain accurate responses.

As a recommendation for practice, it is crucial for researchers to adapt their language and communication strategies to the specific needs and backgrounds of the participants (Einarsdóttir 2007). This approach promotes effective communication, improves participant engagement, and ensures that research findings accurately reflect the perspectives and experiences of the participants. Additionally, the utilization of qualitative research methods, which allow for interaction and clarification, played a vital role in enhancing data quality and facilitating a more comprehensive understanding of the research topic. These methods provided opportunities for participants to seek clarification on points they did not fully grasp, a unique advantage over survey-based approaches that lack interaction opportunities.

4.4 Ethical challenges

This research involved vulnerable participants, young children aged 11 to 18 years old, which leads to a rigorous and lengthy ethical application and approval process by the university ethics committee, as well as the Disclosure and Barring Service (DBS) check by the UK government. The meticulous review process and the researcher's careful preparations demonstrate a commitment to ethical research practices and a dedication to ensuring the safety and respect of participants' rights. This approach enhances the credibility and validity of research findings, particularly when working with vulnerable children (Einarsdóttir 2007). In practice, as this research involves participants under 18 years old, both assent from the children and consent from their parents were required. The researcher prepared handwritten assent forms for children, taking into account that not all students had devices to sign digital forms, which was particularly challenging for less privileged students. Obtaining consent from parents proved to be a difficult task, and delays occurred in some research visits if consent forms were not collected in time. The researcher did not have direct access to parents and relied on coordinators to act as a communication bridge. As highlighted in Section 4.1, establishing excellent relationships and receiving active support from school gatekeepers proved to be crucial when conducting research with children.

5 DISCUSSION AND CONCLUSION

In summary, quantitative surveys are widely used in STEM outreach evaluation owing to their advantages of low-cost, time-saving and easy-to-use features. Yet such approaches lack a contextual understanding of STEM outreach by capturing children’s interaction with the learning environment, learning materials, peers and instructors. Therefore, this research developed a qualitative methodology design combining Multiple Case Studies and Grounded Theory with associated methods of observation, focus groups and semi-structured interviews, to highlight the potential of using a qualitative approach in STEM outreach evaluation and spark further methodological discussion within the engineering education community. This research will contribute to knowledge by adding evidence of this innovative methodology design in engineering education.

While it is acknowledged that this research design incorporating multiple research methods can be resource intensive, and may be feasible in the context of a large-scale programme with greater access to resources. The standard framework developed through this research holds the potential to benefit evaluations that lack the necessary capacity, enabling a comprehensive understanding of the impact and effectiveness of STEM outreach initiatives.

After clarifying the rationale of conducting qualitative research in STEM outreach evaluation, the reflection on the fieldwork experience is also discussed to share the best practices as follows.

Table 1. Best Practices for STEM outreach evaluation fieldwork

Access to the field
- Establish rapport with school gatekeepers through efficient communication. - Gain insight into the school's context and address concerns by providing clear and transparent information about the research. - Highlight the benefits of the research to the school community and maximize networking opportunities.
Unpredictable research environment

- Recruit slightly more student participants and expand the number of focus groups to account for potential absences. - Carefully consider the implications of any changes to the research design to ensure validity and reliability. - Have a teacher present during data collection to address behavioural issues and maintain a safe research environment.
Language barriers
- Tailor research protocols to the specific needs of different participant groups. - Use accessible language, pilot test research protocols, and ensure comprehension for accurate responses. - Adapt language and communication strategies to participants' needs, promote effective communication, and improve participant engagement.
Ethical challenges
- Following the rigorous ethical application process from institutional ethics committees, and seeking guidance from local authorities about Disclosure and Barring Service check will help ensure compliance and responsible conduct in research involving children. - Obtain assent from children and consent from parents, considering the limitations of less privileged students. - Establish strong relationships with school gatekeepers and rely on their support for communication with parents.

In conclusion, it is anticipated that other researchers in the Engineering Education community can benefit from the insights and experiences discussed in this paper. The distinctiveness of the methodological approach means that the depth and breadth of data emerging out of the study will make a notable difference in academic understanding of Engineering Outreach. At a time when theoretical saturation seems to have been achieved, one final round of data collection is due before the analysis begins in earnest. There are exciting times ahead!

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REFERENCES

Alzaanin, Eman IM. 2020. "Combining case study design and constructivist grounded theory to theorize language teacher cognition." *The Qualitative Report* 25 (5):1361-1376. https://doi.org/10.46743/2160-3715/2020.4047

Bogue, Barbara, Elizabeth T Cady, and Betty Shanahan. 2013. "Professional societies making engineering outreach work: Good input results in good output." *Leadership and Management in Engineering* 13 (1):11-26. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000207

Case, Jennifer M, and Gregory Light. 2011. "Emerging research methodologies in engineering education research." *Journal of Engineering Education* 100 (1):186-210. https://doi.org/10.1002/j.2168-9830.2011.tb00008.x

Demetry, Chrysanthe, Jeanne Hubelbank, Stephanie L Blaisdell, Suzanne Sontgerath, Michelle Errington Nicholson, Lisa Rosenthal, and Paula Quinn. 2009. "Supporting young women to enter engineering: Long-term effects of a middle school engineering outreach program for girls." *Journal of Women and Minorities in Science and Engineering* 15 (2):119-142. https://doi.org/10.1615/JWomenMinorScienEng.v15.i2.20

Einarsdóttir, Jóhanna. 2007. "Research with children: Methodological and ethical challenges." *European early childhood education research journal* 15 (2):197-211. https://doi.org/10.1080/13502930701321477

Felix, Debra A, Mark D Hertle, Jill G Conley, Lori B Washington, and Peter J Bruns. 2004. "Assessing precollege science education outreach initiatives: a funder's perspective." *Cell Biology Education* 3 (3):189-195. https://doi.org/10.1187/cbe.03-10-0017

Gibson, Jennifer E. 2012. "Interviews and focus groups with children: Methods that match children's developing competencies." *Journal of Family Theory & Review* 4 (2):148-159. https://doi.org/10.1111/j.1756-2589.2012.00119.x

Harger, Brent, and Melissa Quintela. 2017. "The IRB as gatekeeper: Effects on research with children and youth." In *Researching children and youth: Methodological issues, strategies, and innovations*. Emerald Publishing Limited.

Harris, Catherine, Lucy Jackson, Lucy Mayblin, Aneta Piekut, and Gill Valentine. 2015. "'Big Brother welcomes you': exploring innovative methods for research with children and young people outside of the home and school environments." *Qualitative Research* 15 (5):583-599. https://doi.org/10.1177/1468794114548947

Hazari, Zahra, Deepa Chari, Geoff Potvin, and Eric Brewe. 2020. "The context dependence of physics identity: Examining the role of performance/competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates." *Journal of Research in Science Teaching* 57 (10):1583-1607. https://doi.org/10.1002/tea.21644

Lewis, Colleen M. 2011. "Is pair programming more effective than other forms of collaboration for young students?" *Computer Science Education* 21 (2):105-134. https://doi.org/10.1080/08993408.2011.579805

Leydens, Jon A, Barbara M Moskal, and Michael J Pavelich. 2004. "Qualitative methods used in the assessment of engineering education." *Journal of engineering education* 93 (1):65-72. https://doi.org/10.1002/j.2168-9830.2004.tb00789.x

Miranda, Rommel J, and Ronald S Hermann. 2010. "A Critical Analysis of Faculty-Developed Urban K-12 Science Outreach Programs." *Penn GSE Perspectives on Urban Education* 7 (1):109-114.

Morgan, Rhys, Chris Kirby, and Aleksandra Stamenkovic. 2016. "The UK STEM Education Landscape: A report for the Lloyd's Register Foundation from the Royal Academy of Engineering Education and Skills Committee." accessed 16th April 2023. https://www.raeng.org.uk/publications/reports/uk-stem-education-landscape.

Pearson, Meaghan I, Sarah D Castle, Rebecca L Matz, Benjamin P Koester, and W Carson Byrd. 2022. "Integrating critical approaches into quantitative STEM

equity work." *CBE—Life Sciences Education* 21 (1):es1. https://doi.org/10.1187/cbe.21-06-0158
Prieto-Rodriguez, Elena, Kristina Sincock, and Karen Blackmore. 2020. "STEM initiatives matter: Results from a systematic review of secondary school interventions for girls." *International Journal of Science Education* 42 (7):1144-1161. https://doi.org/10.1080/09500693.2020.1749909
Sadler, Kirsten, Efrat Eilam, Stephen W Bigger, and Fiachra Barry. 2018. "University-led STEM outreach programs: Purposes, impacts, stakeholder needs and institutional support at nine Australian universities." *Studies in Higher Education* 43 (3):586-599. https://doi.org/10.1080/03075079.2016.1185775
Saw, Guan Kung, Brendan Swagerty, Shon Brewington, Chi-Ning Chang, and Ryan Culbertson. 2019. "Out-of-School Time STEM Program: Students' Attitudes toward and Career Interests in Mathematics and Science." *International Journal of Evaluation and Research in Education* 8 (2):356-362. https://doi.org/10.11591/ijere.v8i2.18702
Teo, Tang Wee, and Margery Osborne. 2012. "Using symbolic interactionism to analyze a specialized STEM high school teacher's experience in curriculum reform." *Cultural Studies of Science Education* 7 (3):541-567. https://doi.org/10.1007/s11422-011-9364-0
Vennix, Johanna, Perry den Brok, and Ruurd Taconis. 2018. "Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM?" *International Journal of Science Education* 40 (11):1263-1283. https://doi.org/10.1080/09500693.2018.1473659
Williams, Cody Tyler, and David Wÿss Rudge. 2016. "Emphasizing the history of genetics in an explicit and reflective approach to teaching the nature of science: A pilot study." *Science & Education* 25:407-427. https://doi.org/10.1007/s11191-016-9821-y