# *Developing conceptual and methodological foundations for a cross-cultural, multi-institutional study of ethical reasoning and moral dispositions of engineering students*


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*Abstract— This full research paper develops a framework for using comparative case studies to triangulate with quantitative survey data in engineering ethics education research.*

*Ethics has long been recognized as crucial to responsible engineering, but the increasingly globalized environments of contemporary engineering present challenges to effective engineering ethics training. An overarching goal of our team's larger project is to examine the effects of culture and education on ethics training in undergraduate engineering students at universities in the United States, China, and the Netherlands to assess how this training impacts students' ethical reasoning and moral dispositions, and how this differs cross-culturally. To gauge students' moral dispositions and ethical reasoning skills and to measure any change in these, we administer the Moral Foundations Questionnaire and the Engineering & Science Issues Test to engineering students longitudinally over four years. Because the conditions related to engineering ethics education differ widely per participating institution, interpreting and analyzing survey quantitative data will require understanding the contextual conditions of education at each institution. In this paper we ask the question what and how can case study methods contribute to longitudinal and cross-cultural ethics educational research with large data sets? To answer it, we develop conceptual and methodological foundations for the design of comparative, multi-institutional case studies to contextualize, complement, and interpret quantitative and qualitative data on ethical reasoning and moral dispositions. We develop comparative case studies to supply missing contextual information for triangulation with quantitative and qualitative data and to provide a more complete picture of the engineering ethics educational contexts, strategies, and practices at each of the participating universities. In this project, case studies provide informational and contextual significance to the other sources of data our research produces, elucidating conditions required to understand and make sense of the results of the research. In the paper we introduce our research project, motivate the use of case studies in our research by reviewing literature on case studies and multi-method triangulation in educational research. We explain how specific cases will be designed, and by providing the first step of two cases, timelines of ethics interventions for two degree programs, demonstrate the informational and interpretive need for comparative case studies in triangulating with other data sources. By using multiple case design to compare universities' approaches in this frame, our analysis can respond to particular institutional educational contexts and cultural and language factors, make cross-cultural comparisons, and offer recommendations about responsible and culturally responsive engineering ethics education.*



***Keywords—engineering ethics education; mixed methods research; case study; multi-method triangulation; multiculturalism***


## I. INTRODUCTION

Ethics has long been recognized as crucial to responsible engineering, but the increasingly globalized environments of contemporary engineering present challenges to effective engineering ethics training. Our mixed-methods research project, **Responsible Engineering Across Cultures**, examines the effects of culture and education on ethics training in undergraduate engineering students at universities in the United States, China, and the Netherlands. In this paper we develop conceptual and methodological foundations for the design of cross-cultural, multi-institutional case studies to contextualize, complement, and interpret quantitative and qualitative data on ethical reasoning and moral dispositions of engineering students.


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Case studies are a useful method, according to [1], to investigate contemporary phenomena in greater depth than other approaches afford, especially where context plays an important role, and when analysis requires "multiple sources of evidence, with data needing to converge in a triangulating fashion" [1 p. 50]. Because the conditions related to engineering ethics education differ widely per participating institution, case studies provide an important method in our research. In designing comparative case studies focused on the university level, we will collect background information about ethics education at each institution. The case studies will allow us to contextualize and interpret our findings using multi-method triangulation.

This paper takes as its guiding question: *What and how can case study methods contribute to longitudinal and cross-cultural ethics educational research with large data sets?* We answer this question by motivating the use of case study and triangulation in our research project and by developing a framework for triangulating between quantitative survey data and qualitative findings (e.g., student and faculty interviews, students' learning artifacts) that will be useful for others who adopt mixed-methods approaches to studying engineering education.

In this paper we discuss these components towards the goal of developing our case studies for this project. To be clear, the main contribution lies in articulating the need for case study and triangulation approaches in such work, and in developing a framework for triangulating between quantitative and qualitative data. Case studies provide informational and contextual significance to various sources of data our research produces, *elucidating conditions required to understand and make sense of the results of the research.* In other words, comparative case studies, in combination with other methods, can illuminate assumptions, operating conditions, and integral processes that quantitative methods alone cannot. In work that attempts to make cross cultural comparisons and reflect on the (western) biases and cultural practices of ethics education, we recognize that these exist in not only in the educational methods and content but also in institutional norms and practices. Enlisting comparative case studies can bring these factors to light and include them in our analysis. We hope that by making these conditions clear and demonstrating the need for this interpretive work, we provide a framework that encourages others to reflect on and make clearer the contextual conditions and facts (which sometimes may be treated as "default settings") that frame their own data collection in engineering education research.

Our paper proceeds this way: after introducing our research project (II), we (III) motivate the use of case studies in our research by reviewing literature on case studies and multi-method triangulation (IV) in educational research. We (V) explain how specific cases will be designed, and (VI) by providing the first step of two cases, timelines of ethics interventions for two degree programs, demonstrate the informational and interpretive need for comparative case studies in triangulating between diverse data sources.

## II. RESEARCH PROJECT BACKGROUND

Our project assesses how ethics education that undergraduate engineering students receive impacts their ethical reasoning and moral dispositions, how this differs cross-culturally, and how to improve ethics education based on results derived from such an empirical investigation. To gauge students' moral dispositions and ethical reasoning skills and to measure any change in these over the course of the study, we administer the Moral Foundations Questionnaire (MFQ) and the Engineering & Science Issues Tests (ESIT)[1] to engineering students at participating universities repeatedly, once each year, during the duration of their undergraduate degree program. But because we want to use these results to understand the impact various forms and methods of ethics education have and make comparisons cross-culturally and cross-institutionally, the quantitative data from these instruments alone is inadequate: it must then be triangulated with specific information about ethics education students received over this period at their respective institution against the broader institutional contexts.[2]

A university-level, multi-case study design will thus be employed to map out the landscape of engineering ethics education from a cross-culture perspective, triangulating the findings from the quantitative instruments (MFQ & ESIT) qualitative methods (student and faculty interviews) with contextual information about programs of study. This part of the project will help us (1) gain a culturally sensitive interpretation of the results obtained from the MFQ and ESIT; (2) examine whether and how the two instruments work in assessing students' ethical development in the cross-cultural context; and (3) compare how different (extra-)curricular and institutional interventions affect students' ethical development in different cultures differently. To accomplish these objectives, our case studies will be built around comparing (across participating institutions) what ethics-related experiences students have during their undergraduate engineering training. These *Ethical Interventions*, which could take the form of standalone or integrated ethics courses or modules, extracurricular activities, institutional practices or codes of conduct (detailed in V), alongside demographic information, will be treated as independent variables in our analysis. In this way, the relative effects of culture and education can be assessed. Recommendations will be made about what kinds of interventions are the most effective in promoting engineering ethics. This will include whether certain kinds of interventions are more or less effective among different cultural groups, or how existing education can be altered to improve effectiveness or serve different groups. In general, our project aims to develop a more *holistic*, *culturally responsive framework* for engineering ethics education. Students' ethics learning is conceptualized as the totality of their diverse learning experiences resulting from both the *formal, explicit* aspect and the *informal, implicit* aspect of the engineering curriculum against *particular institutional*

[1] The ESIT was developed to assess the effects of ethics education on the development of ethical reasoning among engineering students [14]. Students assess six engineering-related cases to rank the importance of various ethical issues these cases pose. This hierarchical instrument will be combined with the MFQ, which is non-hierarchical and pluralist and assesses moral intuitions. Reference [15] provides a comparison between the ESIT and MFQ and discusses reasons for combining these two instruments.

[2] These institutions reflect where the authors work. As will be seen, developing the case studies requires detailed information about educational and cultural practices internal to these programs.

*cultures*. When they are developing and assessing curriculum priorities, assessment tools, and pedagogical strategies, engineering educators need to critically examine under what classroom and institutional contexts these educational components work or not work.

## III. WHY CASE STUDIES?

Case studies methodology is a widely used empirical approach that "investigates a contemporary phenomenon (the case) in-depth and within its real-world context" [1 p. 50]. However, case studies can vary considerably in design and theoretical and epistemological commitments: [2] observes that the term 'case study' commonly refers both to the object of investigation and the mode of investigation, which is methodologically underdefined, not "claim[ing] any particular methods for data collection or data analysis" [2 p. 28]. For the purposes of this paper, we will restrict our scope to qualitative case study in education research, first giving a general justification for the use of case study, and then providing a brief background of case study in education research to set up the case study multi-method triangulation we develop for our project.

When, or why, should researchers choose case studies in research? According to [1], "the distinctive need for case studies arises out of the desire to understand complex social phenomena," [p. 36] but as a method case study focuses on phenomena that are characteristically bounded in some way (that is, as a case) [2], and that can be investigated in the present [1]. Case study enables a deep, non-reductive analysis, and is a good approach for answering 'why' and 'how' questions in situations the researcher would not be able to control experimentally [1 p. 33]. One of the defining strengths of the method is that it can incorporate various sources of evidence and information: a case can be comprised of descriptions, narratives, interviews, artifacts, observation, and in some cases, quantitative data.[3] Thus, as [1] suggests, case study on its own affords "triangulation among multiple sources of evidence" [1 p. 55]. Reference [3] points out that though case study is limited in generalizability, it can bring to light relationships and context that may otherwise not be revealed.

Following [2], the qualitative case study is importantly *particular, descriptive*, and *heuristic*, and these characteristics help explain its merits. First, case study allows for focusing on *particularities*, which "makes it an especially good design for practical problems: for questions, situations, or puzzling occurrences arising from everyday practice" [2 p. 29]. Whereas other methods might emphasize generalities across examples or data, case study allows for greater attention to unique attributes that may be defining—by their difference—for a case. Second, given this focus, case study usually trades off number of samples or cases for depth, so one or a few cases will be *described* in much greater richness, detail, and duration than other methods which study much larger samples allow for.[4] But for these limited cases, "holistic description and explanation" [2 p. 29] is made possible to an extent not possible by other methods. The third feature, the *heuristic* characteristic of case study, emphasizes the interpretive and explanatory potential of the method. Case study is not only about richly describing complex, detailed particulars but using these cases to interrogate research questions and illuminate relationships within a case or between cases. The knowledge generated from case study, thus, is often more concrete and can give readers greater insight and understanding of relevant background or contextual conditions glossed or omitted by other approaches.

Case studies are a common method in education research [2]; [4]; [5]; [6]. The breadth and versatility of the method makes case study particularly useful in education settings, where their use can provide descriptions of the object of investigation in much greater detail and nuance than other methods afford. For instance, by including interviews with teachers, and students, and classroom observation (among other sources), case studies can elaborate on educational practices from the perspectives of those involved. Intensive case studies, especially when combined with other often quantitative data, can uncover patterns that the quantitative data alone do not reveal [3]. Case studies can also help interpret longitudinal data, making it a valuable method for studying educational trajectories of students [7] or career trajectories of teachers [8]. In their review of the use of case studies in sustainability in post-secondary education, [5] suggests that case study presents "the ideal research tool to investigate sustainability in higher education" that "allow the researcher to 'go deep,' to learn what works and what does not" [p. 10]. Case studies also allows researchers to make causal or explanatory inferences within a particular case study or draw more generalized conclusions or comparisons between cases. This can be especially useful in educational contexts for evaluating programs or educational reforms [9].

Reference [4] identifies three kinds of case study in education: (1) theory-seeking & theory testing; (2) story-telling & picture drawing; and (3) evaluative. Of these three, the evaluative case study, where the "worthwhileness" of some "educational programme, system, project or event" [4 p. 63] is under investigation through the case study, will be the most relevant for our project, although our project will also generate implications in other two case study approaches. Further, as will be discussed in the following section, using case study to triangulate between multiple methods in education research can greatly increase its evaluative capacity.

## IV. MULTI-METHOD TRIANGULATION

Triangulation is the combining of different (sources of) information to get a more accurate or complete picture of the phenomenon under investigation [10]. While triangulation is possible within single methods (for instance, triangulating using different data points, researchers, or theories[5]), triangulation is more common as a multi-method approach where complementary methods are used to overcome limitations and biases inherent in any single methodology and to increase the validity of findings [11]. Triangulation in this context is metaphorical, but involves methods of data collection put into analytical relationship to map out the phenomenon under

[3] Case studies are not only qualitative, though that is what we focus on here and plan to develop, using quantitative data as another data sources to triangulate with qualitative data.

[4] For example, thick description, in anthropological practice which interprets the actions and behaviors of individuals and ascribes intention and meaning is typically found in case studies.

[5] See Meijer et al. 2002.

investigation from complementary standpoints. In some cases, this enables researchers to cross-check their findings from one method to another. As [10] writes: "Multiple and independent measures, if they reach the same conclusions, provide a more certain portrayal of the…phenomenon" [10 p. 602]. More generally, multi-method triangulation, by drawing on different methods, adds dimensionality, layers, or scope and helps to build a more holistic account, "a full picture of the situation" [12 pp. 46-47].

In designing multi-method triangulation, the triangulating methods should be chosen in reference to each other, in light of how they can mutually complement and strengthen the study [13]. Though the details are particular to our research study, we aim to outline a more general framework for triangulating between qualitative and quantitative methods in (ethics) education that will be useful for researchers interested in multi-method studies.

Our research study aims to understand the relative effects of *education* and *culture* on engineering ethical reasoning, moral dispositions, and relations between them. Survey data from the ESIT and MFQ supply one main source of input: our analysis of data from these quantitative instruments provides longitudinal information about students' ethical reasoning and moral intuitions across the participating universities and representing three nations. On their own, these data can be used to make cross-cultural comparisons, which are especially interesting given the longitudinal dimension of this research. For example, are there differences between Chinese, American, and Dutch students in ethical reasoning or moral intuitions in their first year of study? Do differences or patterns emerge cross-culturally over the four years of their undergraduate education? However, very little can be concluded about the educational interventions and the impact of ethics education in the engineering curriculum unless the quantitative data are combined with detailed information about the ethics education that students receive. Some of this will come through interviews with students and faculty. However, we are also interested in assessing and understanding the differences between various ethics-related curricular and extracurricular educational and formative experiences engineering students have, which might also vary based on cultural context. Specifically, we ask: *Which kinds of educational interventions are the most effective, and how can these be altered for different national/cultural groups?* Methodological triangulation is necessary here because none of the individual methods (quantitative survey results, qualitative interviews) is alone sufficient to provide a full picture. Case study provides an ideal complementary method to the quantitative survey. As discussed in III, case study offers concrete, contextualized, and rich detail, analytical depth and evaluative potential. Because it supplies the contextual information (about each of the participating institutions, including when and what ethics education is delivered), case study provides interpretive power to the quantitative findings, especially in combination with insights from student and faculty interviews. Rather than solely attempting to use one method (qualitative data) to validate the findings of another (quantitative survey results), we develop case studies to elucidate the educational context in which the quantitative surveys are being taken. Illuminating context, [10] argues, is one the principal reasons to triangulate: "Triangulation may be used not only to examine the same phenomenon from multiple perspectives but also to enrich our understanding by allowing for new or deeper dimensions to emerge" [10 pp. 603-604]. In our project, this is precisely the purpose of triangulation. Only with such cases will the quantitative data have anything to say with regard to the respective educational strategies and practices each institution pursues, and that are the subject of key research objectives in the project.

Furthermore, the case studies supply information about practices, methods, and default conditions that can differ between institutions and *cultures*, that are crucial culturally-sensitive interpretation of our findings. While our abbreviated case in VI focuses primarily on educational context, elucidating the different cultural contexts and backgrounding conditions is one of the key points of the comparative case studies in our project. We explore questions such as *how institutional contexts expand or limit the impacts of various ethics education interventions on students' ethics learning experiences*.

In sum, case study in this research supplies the contextual information necessary for triangulating between quantitative and qualitative data. Importantly, the contextual key that case studies provide enable us to understand the impacts of both culture and education in this project, the two foci of the research objectives.

## V. BUILDING COMPARATIVE, INSTITUTIONAL CASE STUDIES – WHAT INFORMATIONAL COMPONENTS ARE NECESSARY?

Our case studies, in the first place, need to provide the contextual information about ethics education programs and practices at each participating institution in order to be able to interpret the findings from the ESIT and the MFQ. Additionally, because our research aims to help revise existing educational practices, better understanding of specifics of the various ethics interventions per institution is necessary, and case studies will supply this contextual information.

Reference [2] suggests that delimiting the case is "the single most defining characteristic of case study research" [2 p. 27]. What we will attempt in the following sections is to work through this aspect of comparative case study research in our project with the aim of generating cases that are useful for inter-institutional comparison and for intra-institutional analysis. We believe that this framework will also be useful and necessary for other research in education that takes a longitudinal approach and attempts to make comparisons between institutions and cultures.

### *A. Boundaries*

Whereas the boundaries of our cases are clearly defined (i.e., engineering ethics education at University 1 vs. engineering ethics education at University 2, etc.,) the more difficult definitional work entails decisions about institutional context, ethical interventions and respective artifacts and methods of analysis comprising each of the respective institutional cases we elaborate. The case studies should help us answer the following research questions:

> *What are the relative effects of culture and education on engineering ethical reasoning, moral dispositions, and relations between them? Which kinds of educational*

*interventions are the most effective, and how can these be altered for different national/cultural groups?*

Thus, key questions guiding decisions around case construction are: what forms does ethics engineering education at this institution take, how does it fit within the education context for engineering students, and in what ways does professional ethical acculturation occur within this program?

### B. Institutional Context

Providing information about the institutional context of each of the participating universities is a key part of the case study. This contextual information will include details for each university including: Degree program(s) and description; number of students enrolled, length & structure of program, language of instruction, duration of terms, retention rates, particularities in education innovations or approaches (e.g., problem based learning), etc.

This contextual information will be assembled with the aim of illuminating the assumptions and conditions operating within the participating universities, factors and details that are not captured by quantitative methods and that may not receive attention in interviews. In work that attempts to make cross cultural comparisons and reflect on the (western) biases and cultural practices of ethics education, we recognize that these exist in not only in the educational methods and content but also in institutional norms and practices. Enlisting comparative case studies brings these factors to light and includes them in our analysis.

### C. Ethics Interventions

Our case studies will also provide detailed information, per program, about the exposure to ethics students enrolled in the program get in their undergraduate educational trajectory. In short, we are interested in documenting all *Ethics Interventions*, that is, any encounters students have with ethics, associated with their undergraduate education, whether formally in the classroom, or informally outside. To allow for differences between institutions and perhaps between cultures, we construe *ethics interventions* broadly, and group them into three possible (though not necessarily mutually exclusive) categories: curricular, extracurricular, or institutional. The first, *curricular interventions*, might take the form of stand-alone courses in ethics/values or engineering ethics or ethics modules that are integrated into other courses or programs. These would encompass both micro- and macro- ethics teaching. The second, *extra-curricular interventions*, could include service learning or ethics across the curriculum-type projects or programs; internships; or other involvement in university-based clubs or student organizations that provide formative educational experiences related in some way to service or ethics. The final type, *institutional interventions*, refers to institutional commitments, most likely in the form of any professional or honor codes, or codes of conduct the university teaches or upholds, or other institutional-level commitments or pledges related to ethics. For all of the participating universities, we are interested in determining when these interventions occur, how they are assessed, and how they are included in the curriculum to gain some general picture of the role of these interventions in the educational trajectory of the students. The case studies will compile this contextual educational information to map a timeline for ethics education at each participating institution. This timeline information will then enable us to treat specific identified interventions as independent variables when analyzing the quantitative survey data, as well as contextualize the survey data per institution and intervention, thereby lending interpretive power to the quantitative results.

Beyond constructing the intervention timelines, the comparative university case studies will be comprised of other forms of information about these interventions. Specifically, we will collect educational artifacts like syllabuses and lesson plans, learning goals and assessment procedures. Such cases, combined with qualitative information from semi-structured interviews of students, faculty, and possible participant observation of all types of curricular, extracurricular, and institutional interventions, enable us to analyze the learning and teaching materials and the ethics interventions, providing a more detailed and complex picture of engineering ethics education practices and strategies at each of the participating universities. This can be triangulated with the quantitative longitudinal data from the ESIT and MFQ, allowing us make comparisons across the institutions, drawing inferences about which types of educational interventions contribute to ethical reasoning and moral dispositions and whether these should be tailored to different cultural groups. In addition to answering research questions, building these cases and triangulating with the quantitative work will surely generate new hypotheses and points of inquiry.

## VI. Building a Case-Timeline

Because our project is longitudinal and enquires about the effects of culture and education on students over the course of their degree, our case studies begin with mapping the timeline of education for respective programs and institutions involved in the project. These timelines form the structural basis of the case studies, from which we develop more detailed libraries of information, resources, educational objectives around each program/institution, and to which we can link interviews and correlate data.

A key requirement of the case study in our research is to provide us with the information we need to pinpoint the occasions in students' educational trajectories when they encounter ethics education in or outside of the classroom, that is, when ethics interventions take place. As described in V, these can take three forms: curricular, extra-curricular, and institutional. The curricular interventions can most straightforwardly be mapped in a timeline based on course guides or information about when and what occurs in a program or course of education. We construct two sample timeline using specific BSc programs at University 1. The first program, Civil Engineering (CE) is somewhat distinctive in that has implemented an ethics learning line in its curriculum, meaning that various ethical components are embedded in different courses throughout the program connected by and culminating in an ethics portfolio and two-part reflection assignment

students complete as a final part of their degree.[6] All of the curricular (and one possible extra-curricular) ethics interventions are represented in Table 1.

TABLE I. ETHICS INTERVENTIONS IN CIVIL ENGINEERING BSC AT UNIVERSITY 1

| No. | Year | Quarter | Ethics Intervention | Course Name |
|---|---|---|---|---|
| **1** | 1 | 1 | *curricular:* integrated ethics module in technical course | Structural Mechanics 1 |
| **2** | 1 | 1 | *curricular:* integrated ethics module in technical course | Introduction to Civil Engineering |
| **3** | 1 | 3 | *curricular:* integrated ethics module in technical course | Construction Materials & Sustainability |
| **4** | 1 | 4 | *curricular:* integrated ethics module in technical course | Transport & Planning |
| **5** | 2 | 3 | *curricular:* integrated ethics module in technical course | Designing Structures & Foundations 2 |
| **6** | 2 | 4 | *curricular:* integrated ethics module in technical course | Hydrology |
| *7* | *3* | *1&2* | *Possible* curricular or extra-curricular: *will depend per student* | *Minor/elective courses, internship, or study abroad* |
| **8** | 3 | 3&4 | *curricular:* ethics portfolio & reflection assignment | Bachelor Thesis |

Combined with the longitudinal data from student surveys, these eight points of ethics interventions can be treated as independent variables in our analysis of the survey data. Additionally, the ethics learning line, comprised of the first six and final ethics intervention, can be compared as a unit or strategy of approaching engineering ethics education to other types of interventions (e.g., stand-alone courses in ethics).

The timelines provide a structural center point to the cases: by organizing them temporally we reflect the longitudinal significance of the research project and create a format that is easily comparable across institutions and degree programs. From these we can develop the cases further by looking more deeply into specific interventions: collecting syllabuses and materials, analyzing learning objectives and assessment practices. However, building timelines as the basis of the case study demonstrates, even from this first step, the wide variation in engineering ethics education between, or even within institutions. In Table 2 we map the ethics interventions for a second degree program: Systems Engineering, Policy Analysis, and Management (SEPAM), also at University 1. Notably, compared to the eight or possibly nine ethics interventions embedded in the CE BSc, students in the SEPAM program have only one guaranteed point of curricular ethics intervention (though they may have a second point through minor, elective, or study abroad courses).

TABLE II. ETHICS INTERVENTIONS IN SYSTEMS ENGINEERING, POLICY ANALYSIS, & MANAGEMENT BSC AT UNIVERSITY 1

| No. | Year | Quarter | Ethics Intervention | Course Name |
|---|---|---|---|---|
| **1** | 2 | 4 | *curricular*: integrated ethics & technical course | Ethics & Safety |
| ***2*** | *3* | *1-2* | *possible* curricular or extra-curricular: *will depend per student* | minor/elective courses/study abroad |

Mapping these timelines brings attention immediately to the difference in the number of ethics interventions, but also the type of ethics intervention. Even between these two programs, we see evidence of different *approaches* to ethics education:[7] in the CE program, ethics instruction is embedded in modules in technical courses (taught by technical faculty). These are small parts of larger classes but allow repeated and cumulative exposure to ethics with the aim of build specific ethical competences in students throughout their degree. By contrast, the SEPAM program includes ethics in only one course, but in this single course, ethics education receives an approximately equal number of credit hours as ethics education in the CE ethics learning line. These program-level details are the educational context that case study illuminates; from the timelines we identify ethics interventions we can analyze as independent variables, but we also provide the contextual information about educational programs key to interpreting findings, and exploring differences between educational approaches to ethics in engineering. This information is not contained in the survey data and requires inquiry through case studies to collect and present: without compiling this in case studies, there is little the survey data can tell us about the relative effects of interventions in engineering education, or how these might differ culturally. The case study is both the informative link between the quantitative and qualitative methods and the interpretive key for understanding the effects of culture and education on the students in our study.

## VII. CONCLUSION

In this paper, we have answered the question of *What and how can case study methods contribute to longitudinal ethics educational research with large data sets?* by motivating the use of case study in our specific research project, and more broadly, the use of comparative case studies to triangulate with quantitative survey data and qualitative interview findings in engineering ethics education research. Case studies are ideal for supplying contextual information required for analyzing and understanding the quantitative data, and for elucidating contextual conditions or unquestioned assumptions or biases operating in educational practices and norms. Further, triangulation with quantitative data enhances the comparative and evaluative power of case study. We have described how case studies in our research will be designed around *Ethical Interventions* at each participating university, which will at the same time provide broad, university specific timelines but also zoom in on particular interventions of interest for cross-cultural,

[6] In such an example, referring to discrete ethics interventions may not be entirely accurate if the learning line emphasizes ongoing attention to ethical components and competences, but this is a question that would best be answered through detailed information from faculty members.

[7] To be confirmed by interviews with faculty, examination of learning objectives and teaching materials.

cross-institutional comparison to inform recommendations about responsible and culturally responsive engineering ethics education. We have taken the first step in building two comparative case studies by mapping the timelines of ethics interventions in two engineering degree programs at University 1, demonstrating the informational and interpretive necessity of case studies in comparative educational research.

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## REFERENCES

[1] R. K. Yin, Case study research and applications, 6th ed. Los Angeles: Sage, 2018.

[2] S. B. Merriam, Qualitative research and case study applications in education. San Francisco: Jossey-Bass Publishers, 1998.

[3] B. Achinstein, R.T. Ogawa, and A. Speiglman, A. "Are we creating separate and unequal tracks of teachers? The effects of state policy, local conditions, and teacher characteristics on new teacher socialization," American Educational Research Journal, vol. 41, no. 3, pp. 557-603, 2004.

[4] M. Bassey, Case study research in educational settings. Buckingham: Open University Press, 1999.

[5] P.B. Corcoran, K.E. Walker, and A.E.J. Wals, "Case studies, make-your-case studies, and case stories: A critique of case-study methodology in sustainability in higher education," Environmental Education Research, vol. 10 no. 1, pp. 7-21, 2004.

[6] T. Harland, "Learning about case study methodology to research higher education," Higher Education Research & Development, vol. 33, no. 6, pp. 1113-1122, 2014.

[7] K.B. Lucas and W.M. Roth, "The nature of scientific knowledge and student learning: Two longitudinal case studies," Research in Science Education, vol. 26, pp. 103–127, 1996.

[8] S.M Johnson and S.E. Birkeland, "Pursuing a "sense of success": New teachers explain their career decisions," American Educational Research Journal, vol. 40, no. 3, pp. 581-617, 2003.

[9] A.M. Martin and B. Hand, "Factors affecting the implementation of argument in the elementary science classroom: A longitudinal case study," Research in Science Education, vol. 39, pp. 17–38, 2009.

[10] T.D. Jick, "Mixing qualitative and quantitative methods: Triangulation in action," Administrative Science Quarterly, vol. 24, no. 4, pp. 602-611, 1979.

[11] L. Cohen, L. Manion, and K. Morrison, Research methods in education. 6th ed. London: Routledge, 2007.

[12] M. Oliver Hoyo and D. Allen, "The use of triangulation methods in qualitative educational research," Journal of College Science Teaching, vol. 35, no. 4, pp. 42-47, 2006.

[13] P. Meijer, N. Verloop, and D. Beijaard, "Multi-method triangulation in a qualitative study on teachers' practical knowledge: An attempt to increase internal validity. Quality & Quantity, vol. 36, pp. 145–167, 2002.

[14] Borenstein, J., Drake, M.J., Kirkman, R., and J.L Swann. "The Engineering and Science Issues Test (ESIT): A discipline-specific approach to assessing moral judgment," Science and Engineering Ethics, 16(2), 387–407, 2010.

[15] Clancy, R.F. "Ethical Reasoning and Moral Foundations among Engineering Students in China," In *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. 2020.