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Student ethical reasoning confidence pre/post an innovative makerspace course: A survey of ethical reasoning*

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ABSTRACT

Background: Challenges today are complex and rapid innovations are required. We instruct a transdisciplinary undergraduate course where engineering, nursing, and pre-professional health students produce tangible innovative solutions to community health challenges using MakerSpace technologies. Students receive evidence-based ethics instruction as part of the course using the 8 Key Questions for improving ethical reasoning. Design thinking, an empathy-based problem solving technique, was used to teach problem solving and provided context for instructing ethical reasoning.

Objective: The Objective of this research was to assess student ethical reasoning pre/post this course where students concurrently produce innovative products.

Design/Participants: Undergraduate students were assessed pre/post course for their perceptions of 1) the importance of, and 2) their confidence in their ability to ethically reason using a digital version of the Survey of Ethical Reasoning, an instrument previously tested in this population.

Results: Participants demonstrated a significant gain in their ethical reasoning confidence and maintained their high ranking of the importance of ethical reasoning concurrently to producing innovative products.

Conclusions: It is possible, with deliberate instruction, for transdisciplinary undergraduate students to develop ethical reasoning confidence concurrently to developing innovative products.

Despite the growing complexity of ethical issues related to technology and innovation there are few evidence based methods for teaching ethical reasoning within the context of innovation. This is concerning. Both innovation and ethical reasoning are listed by hiring managers as essential, yet lacking, skills for new college graduates (Hart Research Associates, 2015). Moreover, the rapid pace of innovation leads to unintended consequences and complex ethical issue which students and professionals are ill prepared to address (McGrath, 2013). The issues are particularly complex in Science, Technology, and Engineering, and related medical fields such as the health professions (STEMM).

1. Background/literature

1.1. Ethical reasoning

Ethics has long been embedded within the culture at large, and within medicine. Aristotle (2016) developed the concept of ethics, proposing philosophical questions and evaluating human behavior in daily activities. A historical example of ethics in medicine is the hippocratic oath, which is the enduringly and "resilient" commitment of physicians to uphold ethical standards (Davey, 2001). Yet, the teaching of ethics, and evidence to guide such education, particularly related to rapidly evolving complex biomedical problems remains elusive.

Ethics is an expansive field of which there are many components, ranging from the philosophical to the practical (Beauchamp and Childress, 2012). We focus on the practical side of bioethics, ethical decision making and most specifically the ethical reasoning needed to make decisions. The steps of ethical decision making begin with recognizing an ethical issue, then ethically reasoning the issue; next making, acting on, and evaluating the decision. Ethical reasoning is therefore part of ethical decision making. In undergraduate (UG) education there is evidence for ethical reasoning instruction, and instruments for it's measurement and thus our focus (Ames et al., 2017; Smith

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et al., 2014; Greco et al., 2018). Ethical reasoning requires critical thinking and is the process of thinking through an ethical dilemma to encourage informed decision making (Fultcher et al., 2018; Sternberg, 2012). The Madison Collaborative's 8 Key Questions (8KQ) are an evidence based method for teaching ethical reasoning to UG students (Ames et al., 2017; Smith et al., 2014).

1.2. 8 Key Questions as an Instructional Method for Ethical Reasoning (8KQ)

The 8KQ are the result of a Quality Enhancement Plan at James Madison University (JMU) and were developed in accordance with the goals of the Southern Association of Colleges and Schools Commission on Colleges (Ames et al., 2017). The questions are based on eight values, or lenses, that encompass much of ethical theory and thus need consideration when facing an ethical decision. The questions prompt the decision maker to investigate *Fairness*, *Outcomes*, *Responsibilities*, *Character*, *Liberty*, *Empathy*, *Authority*, and *Rights* (Madison Collaborative, 2013). UG college students who received 75 min of training using the 8KQ were significantly more able to ethically reason as compared to similar students who did not receive 8KQ training; as assessed by the ERIT, a rubric based direct measure (Smith et al., 2017). The 8KQ have been used in UG education for a variety of learning outcomes related to ethical reasoning. For example, in the humanities with the primary objective of providing language for meaningful ethical reasoning with less regard for guiding students through the remaining steps of ethical decision making (Piper, 2017). Alternatively, UG nursing students who identified ethical issues used the 8KQ to ethically reason then ultimately make, act on, and evaluate the decision (Greco et al., 2018). An in depth description of the 8KQ method has been provided elsewhere (Fultcher et al., 2018.) While the 8 KQ is one evidenced method for teaching ethical reasoning, a separate way of teaching one aspect of ethical reasoning, empathy, is design thinking. Design thinking's deliberate instruction in empathy with the final goal of innovation provides a uniquely strong context for specific instruction in ethical reasoning within the context of innovation (Beaird et al., 2018).

1.3. Design thinking

Design thinking is a problem solving framework. It has evolved from being a description of a process to a creative process used initially in design and engineering and eventually in business, education, and healthcare (Archer, 1965; Beaird et al., 2018; Faste et al., 1993; Kelley and Kelley, 2013). Design thinking holds the needs of the end-user as the most important driver in the problem solving process and begins with developing EMPATHY for that end user (d.Hasso Plattner Institute of Design, 2010). During empathy development, the design thinking team aims to understand the users' needs and wants related to the problem they are aiming to solve. Following the empathy gaining phase, practitioners DEFINE the problem as they understand it from their research. Then practitioners IDEATE potential solutions in the problem space and select some of these ideas for PROTOTYPING, in which models or mock-ups are built. The design thinking team then TESTS the prototype with potential end-users and make revisions or pivots based on the users' feedback. Design thinking is iterative and has been suggested as a method for teaching problem solving, critical thinking, creativity, and providing context for instructing ethical reasoning (Beaird et al., 2018).

1.4. Need for ethics education within innovation in STEMM education

The terms creativity and innovation have traditionally described conceptualization and implementation of an idea. Some authors suggest a cyclical effect of creativity and innovation, deeming it a recursive process of idea production and implementation (Anderson et al., 2014). Once a creative idea is proposed, innovation applies the solution to a given situation through assessment, validation, and dissemination (Chen et al., 2013). Practitioners, students, and faculty are encouraged to be creative and develop innovations in STEMM fields.

Although ethical reasoning, creativity, and innovation are valuable aspects in STEMM disciplines, for some there is a perceptible dissonance in their combined instruction. The concern is that being creative takes thinking beyond the status quo and perhaps “bending the rules”, which creates tension with a rule-based ethical reasoning framework historically common in STEMM disciplines. Per Pennock and O'Rourke (2017), ethical reasoning in science is thought to be determined by externally imposed rules rather than an intrinsic decision. For example, traditional training in responsible conduct of research (RCR) provides a set of rules and professional expectations in the areas of human rights protection, data fraud, research fabrication, authorship, and conflict of interest. Science ethics, consequently, gives the false notion that science is a matter of knowing and following a given set of rules. This can be burdensome for students, and too limiting for solving the complex problems students and professionals face today. Therefore, a method that is easier to apply is needed and students need to practice making ethical decisions within the context of complex issues. The American Association of Colleges and Universities (AAC&U) (2009) defines ethical reasoning beyond a set of rules, as being able to think about what is right and wrong about an action. We find that this more context based and less rule-oriented version of ethics fits with the production of innovations. Thus, the primary goal of this project was to instruct and measure ethical reasoning before and after a transdisciplinary course with deliberate ethical reasoning instruction where students concurrently produce innovative results.

2. Methods

We instructed a transdisciplinary course at James Madison University (JMU) aimed at introducing students to novel technologies. Students from traditionally design oriented (engineering), and non-design oriented (nursing and pre-professional health) disciplines worked together in the course to create innovative and tangible solutions to community health problems. The course was instructed in a MakerSpace; an open learning environment with tools for both quick and well-developed prototyping. In the MakerSpace, there are small tools such as measuring tapes and hammers, along with sophisticated equipment such as 3D printers. The course structure including objectives, activities, and grading plan are described in detail elsewhere (Nagel et al., 2017). Specifically related to ethics, at course end students could expect to be able to discuss the ethical implications of applying novel technologies, particularly as such implementations related to vulnerable populations.

In a qualitative analysis of the first iteration of the course students did not describe valuing ethical reasoning despite having explicit instruction (Ludwig et al., 2017). Interestingly, instructors noted deepening reflections in student ethics-related coursework. This outcome motivated instructors to increase the instructional time devoted to ethics in the second iteration and include a quantitative assessment of the students' attitudes toward ethical reasoning. In both iterations of the course students were required to read the text, The Immortal Life of Henrietta Lacks (Skloot, 2010), and both journaled on how the text related to their own technology development and responded to a question about the text in their oral final exam. In the second iteration of the course, the ethical reasoning content was delivered using the 8KQ method during two in-class lecture discussions. In one lecture students learned about the steps of ethical decision making, the JMU 8KQ, and applied the content to related fictional case studies and the The Immortal Life of Henrietta Lacks (Madison Collaborative, 2013; Skloot, 2010). In a second lecture, the content was revisited and students explored explicit implications of the JMU 8KQ to their product development.

Following Institutional Review Board approval for research, students registered for the second iteration of Medical Innovations in 2016 were recruited to participate in an electronic Qualtrics Survey of Ethical Reasoning (SER) at the beginning and end of the course. At survey time students consented to have their data analyzed for researches purposes, or not, and were given class time and privacy to complete the survey. Moreover, students were notified that no data would be analyzed until after course completion and grade submission. Statistical analysis was completed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., 2013).

2.1. Survey of ethical reasoning

The Survey of Ethical Reasoning (SER), created in collaboration with JMU's Center for Assessment and Research Studies and Madison Collaborative, is a non-cognitive measure designed to address student *confidence in ethical reasoning* and *student perception of the importance of ethical reasoning*. The SER is comprised of four sections that include rank-order items and Likert-scale items. The section of the instrument of primary concern to this study contains two, five-item sub-scales composed of Likert-type items. In addition to 1) the scales related to *Confidence/Importance*, students also 2) rank-order the importance of 10 life skills, including ethical reasoning, 3) rate the individual 8KQ in terms of importance, and 4) self-report on their frequency of ethical dilemma experience.

Confidence/Importance: The main section of the SER includes five statements about perceived importance of ethical reasoning and five statements about confidence in applying the ethical reasoning process. This section also includes six statements that correspond to the Madison Collaborative Student Learning Outcomes and the 8KQ (i.e., "*When faced with an ethical situation, I can correctly identify the most relevant key questions*"). Students are asked to indicate how much they agree with each statement using a five-point Likert scale (1 = *Strongly Disagree*, 2 = *Somewhat Disagree*, 3 = *Neither Agree Nor Disagree*, 4 = *Somewhat Agree*, and 5 = *Strongly Agree*).

Factor analysis results on a large sample of JMU freshmen (Smith et al., 2017) indicate that these ten SER items are comprised of two factors, which were labeled *Importance* and *Confidence* based on item content. Thus, we report two scores for this portion of the SER: an *Importance* subscale score and a *Confidence* subscale score. Each *Importance* score would be the total score for the five items that relate to importance of ethical reasoning, and each *Confidence* score would consist of the total score for the five items about confidence in applying the ethical reasoning process. These results also suggest that it is inappropriate to report an overall or total score for this section of the SER because it is not unidimensional (Smith et al., 2017). Given the two-factor internal structure of the SER, appropriate reliability estimates were computed for the *Importance* and *Confidence* subscales. Cronbach's alpha reliability estimates for the *Importance* subscale were 0.99, (very high) for the pre-course SER. Reliability for the post-course SER could not be completed because nearly all students answered almost identically. The *Confidence* subscale scores also demonstrated adequate reliability (0.91 and 0.90 for the pre- and post-simulation scores, respectively). Thus, subscale scores were computed as the mean *Importance* and mean *Confidence* scores at two time points: pre- and post-course.

The SER asks students to rank-order 10 different skills including: artistic, budgeting, critical thinking, ethical reasoning, oral communication, organization, programming, time management, interpersonal, and writing. Students are instructed to rank these skills from 1 (Most Important) to 10 (Least Important).

Another section of the SER lists each of the 8KQ separately. Student are asked to indicate how important each KQ is in their ethical reasoning process using a five-point Likert scale (1 = *Not At All Important*, 2 = *Slightly Important*, 3 = *Somewhat Important*, 4 = *Important*, and 5 = *Very Important*).

Table 1
Distribution of majors within sample.

Major	N	Percent of total
Engineering	8	33.3
Nursing	6	25.0
PPH[a]/Anthropology	1	4.2
PPH[a]/Biology	3	12.5
PPH[a]/Chemistry	1	4.2
PPH[a]/Health communication	1	4.2
PPH[a]/Health sciences	2	8.3
PPH[a]/Psychology, biology	1	4.2
PPH[a]/Psychology	1	4.2
Total	24	100.0

[a] PPH pre-professional health.

The final section of the SER asks students to respond regarding the frequency of engagement in certain ethical reasoning behaviors such as, "How often do you think about ethical issues" and "How often do you discuss real-life ethical dilemmas with others?"

3. Results

3.1. Sample

Approximately 24 students of varied majors participated in the pre- and post-test assessment (Table 1).

3.2. Confidence and importance

Subscale scores were computed as the mean Importance and mean Confidence scores at two time points: pre- and post-test. A dependent-samples *t*-test indicated that mean Importance scores did not change from pre- to post-test ($t(23) = -0.885$, $p = 0.385$). At pre-test, students scored an average of 4.67 out of 5 on the Importance scale, and 4.76 on the post-test, indicating a small increase in average *Importance* scores. This difference represents a small effect size ($d = 0.18$).

There was a significant growth seen in students' confidence in ethical reasoning ($t(23) = -3.208$, $p = 0.004$). Specifically, students gained approximately 0.325 points on the *Confidence* scale from pre-test ($M_{pre} = 4.16$) to post-simulation ($M_{post} = 4.48$), representing a large effect size ($d = 0.65$).

The remaining six self-report items, related to Madison Collaborative Student Learning Outcomes and the 8KQ, indicated a significant improvement in all items using a Wilcoxon signed-rank test. Students' self-reported abilities increased significantly from pre-test to post-test for all items (Table 2). For these items, higher medians imply higher agreement, in general, with the statement (1 = Strongly Disagree, 2 = Somewhat Disagree, 3 = Neither Agree Nor Disagree, 4 = Somewhat Agree, and 5 = Strongly Agree).

3.3. Ranking of skills

Ethical reasoning rankings compared to other life skills had a possible range of 1 to 10 (1 indicates students felt the skill was most important and 10 indicates students felt the skill was least important to their life or career after graduation). A Wilcoxon signed-rank test indicated the ranking of ethical reasoning importance differed from pre- to post-course ($Z = -2.65$, $p = 0\ 0.008$). The median rank for both the pre- and post-test was 3. However, the post-test had three times as many students ranking ethical reasoning as the most important skill when compared to the pre-test (Table 3).

3.4. Importance of individual 8KQ

The SER lists each of the 8KQ separately. Student are asked to indicate how important each KQ is in their ethical reasoning process

Table 2
Ethical reasoning.

Skill	Median PRE	Median POST	Wilcoxon signed-rank *Z*	*p*
I can state from memory the 8KQ of ethical reasoning	2	3	−3.535	< 0.001
When faced with an ethical situation, I can correctly identify the most relevant KQ	3	5	−3.685	< 0.001
I can weigh and balance the relevant KQ to make an informed decision	4	5	−3.624	< 0.001
I can apply the 8KQ ethical reasoning framework to aspects of my personal life	4	5	−3.696	< 0.001
I can apply the 8KQ ethical reasoning framework to aspects of my professional life	4	5	−3.797	< 0.001
I can apply the 8KQ ethical reasoning framework to aspects of my civic life	4	5	−4.014	< 0.001

Table 3
Ethical reasoning ranking in importance as compared to other life skills.

Rank	Pre-course		Post-course	
	Frequency	Percent	Frequency	Percent
1 = Most important	2	8.3	6	25.0
2	4	16.7	5	20.8
3	4	16.7	4	16.7
4	2	8.3	3	12.5
5	3	12.5	2	8.3
6	4	16.7	3	12.5
7	4	16.7	1	4.2
8	1	4.2	0	0
9	0	0	0	0
10 = Least important	0	0	0	0
Total	24	100.0	24	100.0

using a five-point Likert scale (1 = Not At All Important, 2 = Slightly Important, 3 = Somewhat Important, 4 = Important, and 5 = Very Important). A Wilcoxon signed-rank test indicated students ranked one key question (*Outcomes*) as less important after the Interprofessional Collaborations course than before ($Z = -2.361$, $p = 0.018$, Median_PRE = 7, Median_POST = 5). At both pre- and post-test time points, *Empathy* was the key question ranked as most important by students, using the median of each time point.

3.5. Frequency of ethical dilemma experience

A Wilcoxon signed-rank test indicated students had no change in the frequency of engagement with the behaviors.

4. Discussion

Students significantly increased their confidence in ethical reasoning by course end while showing important practical improvement (clinical significance). Moreover, students self-reported abilities increased (Table 2). This increase might reflect an increase in confidence in ethical reasoning, as opposed to an actual increase in ability, because students were asked whether they agreed with the statement not asked to perform the task (i.e., weigh and balance the 8KQ to make a decision). These findings add to the debate about teaching ethical reasoning concurrently to producing innovation, specifically that it is at least possible to increase student confidence in ethical reasoning while concurrently producing innovative products. Or, possibly producing innovative medical products is an educational vehicle for promoting ethical reasoning confidence, as students work on diverse teams to empathize and communicate the possible impact of their products on others. We believe that the 8KQ method of instruction allows for nuanced understanding of complex ethical issues as opposed to thinking of ethics only as following a set of rules and thus is a good fit for ethical reasoning of complex issues related to innovation (Fultcher et al., 2018).

The increase in student confidence in ability to ethically reason is similar to another study of nursing students only, which showed a statistically significant growth in students ethical reasoning confidence with a similarly large effect size (Greco et al., 2018). In that study, nursing students were trained over a much shorter time (several hours) using the 8KQ to ethically reason following a disaster simulation. The fact that similar statistically significant gains were seen suggests that it may not take a full semester to improve ethical reasoning confidence. However, learning skills in innovation was not part the disaster simulation experience. Thus, the added value that we bring is that ethical reasoning confidence can be gained while also producing innovative products. Additionally, our results persisted despite the passing of several weeks between the ethical reasoning instruction and the final survey, as compared to the simulation study where results were measured directly after the experience (Greco et al., 2018). Our result supports evidence from a case study of a course with similarities to ours, where UG student learned ethical reasoning while also "creating something different" than the norm to measure empathy (Hutchison, 2016).

The lack of difference in the Importance subscale represents a small effect size and is likely due to the ceiling effect of the item responses. That is, nearly all students initially responded in the highest response category for the five *Importance* items, leaving little room for growth. Interestingly, the ranking of ethical reasoning importance relative to other life skills such as writing, differed from pre- to post-course ($Z = -2.65$, $p = 0.008$). Three times as many students chose ethical reasoning as most important skill at the end of the experience. Cognitively, students recognize this importance, however they may be having difficulty translating this into behaviors given that there was no significant change in frequency of engagement in ethical reasoning behaviors. This result is congruent with prior qualitative finding that students did not reference ethical reasoning in their assessment of learning gains (Ludwig et al., 2017). An interesting paradox results; students consider ethical reasoning to be important, increased their confidence, and yet they were not more likely to report engaging in ethical reasoning at course end relative to pre-course. Perhaps students were engaged in ethical reasoning frequently prior to the course such that there was little room for change. Or, it is possible that improving ethical reasoning confidence has little impact on frequency of ethical reasoning. It is also possible that the high rankings of importance represent social desirability bias. Ethical reasoning is a highly complex skill. In our anecdotal experience, UG students fail to practically value ethical reasoning until after graduation despite theoretically valuing it during UG study. A planned longitudinal study will address this.

Design thinking may provide a strong context for instructing ethical reasoning and innovation. Our results show that it is possible to teach ethical reasoning while also teaching design thinking. However, we are unable to say whether students experienced any additional gains *because* of the design thinking context, as compared to instructing the 8KQ in another context. Design thinking inherently relies on multiple perspectives to promote creativity, and thus is a natural fit for transdisciplinary education. Students in prior iterations of our Medical Innovations course identified that they value the transdisciplinary nature of the course work and were able to increase their individual teamwork skills as a result (Ludwig et al., 2017). Students' positive attitude toward other disciplines affects their ability to learn ethical reasoning skills, such that students who are open to learning with other disciplines had significantly higher skill gain (Holzer et al., 2016). The

current study and other research support that ethical decision making in general, and specifically ethical reasoning, can be taught in the context of multiple disciplines and that ethics can provide important language for cohesion among the disciplines (Chou et al., 2016; Knight et al., 2017; McGrath et al., 2018; Wang et al., 2017). A longitudinal study in a human centered design course asked students to identify classmates they would ask for technical issues and then for ethical issues. Students increased the number of potential connections occupied over time (density) in both technical and ethical networks. Results also showed that students began to rely on multiple classmates for ethical advice rather than just a few individuals (Feister et al., 2016). This same work confirms, as we suspect, that there is an interesting interplay among design thinking, a human centered design approach, different disciplines, and ethical reasoning.

Design thinking may provide a strong context specifically for ethical reasoning. It is also possible, that design thinking provides a strong context for critical thinking; of which ethical reasoning is a subset (Fultcher et al., 2018). Geist et al. (2018) measured critical thinking pre/post a course with similar design thinking methods and similar majors (Engineering & nursing) and observed gains in student critical thinking by course end using a vetted instrument the Critical Thinking Assessment Test. As described prior, ethical reasoning has been conceptualized as a subset of critical thinking. Thus, our results and Geist et al. (2018) suggest that design thinking may offer a framework for teaching critical thinking in general. More research is needed to understand the relationships between design thinking, transdisciplinary work, ethical reasoning, and critical thinking.

There are limitations to this study. The SER is a self-report instrument and thus can only measure student perceptions, as compared to a performance assessment of student learning. Subsequent research could use the AAC&U ethical reasoning rubric a direct measure of ethical reasoning assess student ethical reasoning pre/post course (AACU, 2009). Our sample is relatively small, and given our University's focus on ethical reasoning it is likely that our students received prior training in this area, limiting the generalizability of our findings. The high rankings of the importance of ethical reasoning may indicate prior instruction. Moreover, this work assumes that students in the course produce innovative results. Although we see innovative results in the form of tangible products, there is potential for bias in that assessment. A measure of innovation pre/post course would strengthen that assertion.

5. Conclusion

We show that it is possible to increase ethical reasoning confidence for UG students concurrent to producing innovative work. We are interested in the complex relationship among the different disciplines, the method of design thinking, ethical reasoning and critical thinking. Based on our findings it is likely to be fruitful to further research these relationships. Nurse educators should begin to integrate ethical reasoning to courses on innovation. It is possible that this will be most successful if done with other disciplines.

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