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Developing Stories from Traditional Culture into Case Studies for Teaching Virtue Ethics in Engineering

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1 INTRODUCTION

Engineering is a valued and trusted profession and has a responsibility to protect society's health, safety, and welfare. The engineering profession's responsibility to society is supported through the practice of engineering ethics. However, studies have shown that employers often see a lack of ethical decision-making skills among recent graduates[1,2]. Therefore, it is critical for educators to develop more effective approaches for teaching students engineering ethics.

Traditional approaches to engineering ethics education have been largely limited to the use of codes of ethics of engineering societies and regulatory boards and the so-called "disaster cases" as case studies[3]. Engineering ethics has been expressed primarily in rules, and these rules are primarily negative or prohibitive in nature. However, the use of rules is limiting. 1) Rules cannot adequately account for the place of discretion, judgment, and background knowledge in meeting some professional obligations. 2) This rule-based approach, along with a focus on technical ethics, ignores the internal motivational element present in professional life that cannot be adequately accounted for by rules.

In addition to rule ethics, there is another ethical tradition with a long history that can provide a more adequate framework for teaching engineering ethics: "virtue ethics" or "ethics of character". The earliest moral theories in antiquity made virtue the focus of their account of the moral life. These include ancient Greek philosophy (Socrates, Plato, Aristotle and the Stoics) and in ancient China in the teachings of Confucius, Mencius, and other scholars. In Plato's Republic[4], Socrates laid out four cardinal virtues (wisdom, justice, fortitude, and temperance). Aristotle accepted Plato's four cardinal virtues, and added many more virtues in his book *Nicomachean Ethics*[5]. The *Analects*[6] and other books written about teachings of Confucius and other scholars in ancient China also had a strong focus on virtues, such as Ren (benevolence), Yi (righteousness), Li (propriety), Zhi (wisdom), and Xin (trustworthiness).

Virtue ethics focuses on questions of what kind of person one should be and how one may achieve that, thus it intimately ties moral behavior with one's character[7]. Compared to rule-ethics, virtue ethics offers a more holistic set of considerations, including thoughts, emotions, motivations, habits, dispositions, and actions[8]. Furthermore, it has been argued that a character education approach offers personal motivation and actionable dimensions to ethical reasoning[9,10,11]. This internal element motivates one to exemplary behavior, which often goes beyond what any rules could require or express[9].

Recently, a few engineering educators proposed to use virtue-based character education as the framework for teaching engineering ethics[8,9,12,13]. Outside of engineering, virtue ethics has been used for teaching research ethics[14] and in fields like medicine, education, nursing, and business[15,16].

Additional challenges with engineering ethics education include lack of interest by students and lack of context in case studies[8,17]. To address these challenges, we propose to develop stories from traditional culture of different countries into case studies to teach engineering ethics with the virtue-based approach. Stories have long been used in K-12 and college education. In particular, stories have been used in college education for students to learn about pioneers in STEM[18], practice decision-making[19], etc. Furthermore, stories from traditional culture contain cultural contexts that are often missing in case studies used for engineering ethics currently.

2 DESIGN OF TEACHING MODULES

For this project, we used stories as a vehicle to help students connect virtues to engineering ethics. The main teaching modules we developed are Virtue-of-the-Week modules. To give students more practice on connecting virtues to engineering ethics, we also developed an in-class activity and a student writing assignment.

2.1 Selecting Stories

We started by selecting stories using the criteria described in our previous publication[20]: 1) the story is from traditional culture (e.g., documented stories about historical figures, stories from traditional fables); 2) the story features people with virtues that are important for engineering students to learn; 3) stories will be selected from cultures in different countries; 4) since the emphasis is on the virtues presented in the stories, the stories do not have to feature an engineer.

2.2 Using Stories as Case Studies (Virtue-of-the-Week)

For this pilot study, we developed ten virtue-of-the-week modules using traditional stories from countries such as China, Greece, West Africa, the U.S, and the Philippines. These stories exemplified virtues such as perseverance, teamwork, honesty, integrity, kindness, courage, forbearance, and respect. Here we will summarize two of the stories. Figure 1 illustrates both stories.

2.2.1 Story 1: Lu Ban and Ya Zi

One of the virtue-of-the-week stories was about Lu Ban and his son Ya Zi[24,25]. This story exemplified the virtues of diligence of perseverance. Lu Ban (507 – 440 B.C.E.) is a revered engineer, architect, and a master of carpentry and masonry in ancient China.

Lu Ban's son, Ya Zi, was not sure about his dream job and future career. First, he told his father Lu Ban that he would like to become a farmer. Lu Ban was delighted to know it and encouraged Ya Zi to go to another place and learn the skills of farming from experienced farmers. One year later, Ya Zi returned home. He told his father that he did not want to continue because of the

(a) (b)

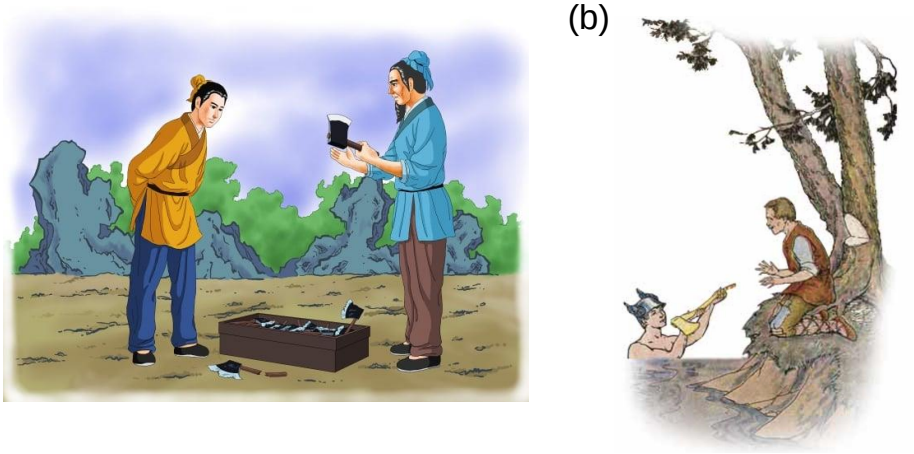

Figure 1: Two Virtue-of-the-Week stories. (a) Lu Ban and Ya Zi[21,22], (b) Mercury and the Woodman[23].

hardship involved in farming. Lu Ban thought for a while and asked his son what his plan was for the future. Ya Zi said he wanted to learn the skills of weaving and left home to learn weaving afterwards. One year later, Ya Zi returned home again. Lu Ban asked his son:

> "Why do you give up again?"

Ya Zi said:

> "It was too difficult to do for me."

Lu Ban asked his son:

> "I see. Then, what is your plan for the future?"

Ya Zi said:

> "Father, I would like to follow you and become a carpenter."

Lu Ban approved his son's career plan. But he did not teach his son the skills of carpentry directly. Instead, Lu Ban asked one of his students, Mai, to teach his son the expertise of using an axe in the profession of carpentry. Lu Ban required his son to finish 3 years of internship under the guidance of his student, Mai. One year later, Ya Zi returned home again. Lu Ban asked his son:

> "Why do you give up again?"

Ya Zi complained about Mai and said:

> "Teacher Mai always gave me a hard time. He asked me to practice the same skills over and over again until my skills are perfect and until the products look flawless. He asked me to work, rain or shine. He asked me to work hard until he saw wear and tear on my axe. Who can tolerate this kind of hardship?"

This time, Lu Ban taught his son a life lesson seriously:

> "It is impossible to obtain any expertise and meet the expectations in any profession without hard work. You dislike the hard work required in the process of becoming a good farmer and a good weaver. And now, you dislike the hard work required in the process of becoming a professional carpenter. What do you expect to do to support yourself and become an independent person in the future?"

Lu Ban opened a big box and let his son see a lot of axes that Lu Ban used before:

> "Look at the wear and tear on my axes. None of them looks new. They speak for themselves."

Ya Zi was speechless after listening to his father's words and witnessing the diligence and professionalism of his father. He felt ashamed for complaining and giving up so many times. Finally, Ya Zi decided to continue his internship with Teacher Mai and work hard with enough determination and perseverance. He would like to be as successful as his father, Lu Ban. Lu Ban patiently let his son learn and grow from mistakes. His son succeeded in the profession of carpentry eventually.

2.2.2 Story 2: Mercury and the Woodman

Another story that focused on the virtues of honesty, kindness, and generosity was Mercury and the Woodman from Aesop's Fables[23]. Aesop is a Greek story-teller who lived between 620 and 560 B.C.E.

A poor Woodman was cutting down a tree near the edge of a deep pool in the forest. It was late in the day and the Woodman was tired. He had been working since sunrise and his strokes were not so sure as they had been early that morning. Thus it happened that the axe slipped and flew out of his hands into the pool. The Woodman was in despair. The axe was all he had with which to make a living, and he did not have enough money to buy a new one. As he stood wringing his hands and weeping, the god Mercury suddenly appeared and asked what the trouble was. The Woodman told what had happened, and straightway the kind Mercury dived into the pool. When he came up again he held a wonderful golden axe. Mercury asked the Woodman:

> "Is this your axe?"

The Woodman answered:

> "No, that is not my axe."

Mercury laid the golden axe on the bank and sprang back into the pool. This time he brought up a silver axe, but the Woodman declared again that his axe was just an ordinary one with a wooden handle. Mercury dived down for the third time, and when he came up again he had the very axe that had been lost. The poor Woodman was very glad that his axe had been found and could not thank the kind god enough. Mercury was greatly pleased with the Woodman's honesty. He said:

> "I admire your honesty and as a reward you may have all three axes, the gold and the silver as well as your own."

The happy Woodman returned to his home with his treasures, and soon the story of his good fortune was known to everybody in the village. Now there were several Woodmen in the village who believed that they could easily win the same good fortune. They hurried out into the woods, hid their axes in the bushes, and pretended they had lost them. Then they wept and wailed and called on Mercury to help them. And indeed, Mercury did appear, first to this one, then to that. To each one he showed an axe of gold, and each one eagerly claimed it to be the one he had lost. But Mercury did not give them the golden axe. Instead he gave them each a hard whack over the head with it and sent them home. And when they returned next day to look for their own axes, they were nowhere to be found.

2.2.3 Using the Stories in Class

We developed the stories into modules that help students identify virtues exemplified in the story and connect the virtues to engineering ethics. These teaching modules were short 10-minute discussions at the beginning of class each week. The first author of the paper is the instructor of the course. The first Virtue of the Week module was implemented after students filled out a pre-survey[20], in which students were introduced to the definition of virtues and some examples of virtues. When implementing the Virtue-of-the-Week modules, the instructor first gave a brief background about the story, then told the story and included key information and figures on PowerPoint slides. Next, the instructor asked students the following questions: 1) What virtues are present in the story? 2) How are these virtues related to engineering ethics? After asking for a few student volunteers to share their thoughts, the instructor offered her perspectives on the virtues that are exemplified in the story.

For example, the main virtues exemplified in the story of Lu Ban and Ya Zi are diligence and perseverance. These virtues help support aspects of engineering ethics including "accept responsibility for their actions, seek and heed critical review of their work" and "build their professional reputations on the merits of their services", which are excerpts taken from the AIChE Code of Ethics[26]. The main virtue exemplified in the story of Mercury and the Woodman is honesty. This virtue helps support aspects of engineering ethics including "issue statements or present information only in an objective and truthful manner"[26].

2.3 Connecting Virtues to Ethics Activity

The connecting virtues to ethics activity was an interactive, group-based exercise designed to help students visualize their understanding of the connections between virtues and engineering ethics. We used the Google Jamboard for this activity; other alternatives that allow group brainstorming (such as Google slides) can also be used. The Jamboard was set up with digital sticky notes representing various virtues that had been discussed in Virtue-of-the-Week modules and sections of the AIChE Code of Ethics[26]. The activity was split into two parts, each completed in separate quarters of the course. In part 1, students in each group were asked to draw arrows from the virtues to the elements of engineering ethics they believed were supported by those virtues. Students were also required to provide a brief explanation for two of the connections they made. In part 2 of the activity, students were asked to revisit the Jamboard their team made in part 1. Students were prompted to add more connections between virtues and engineering ethics while also adding any additional virtues or codes of ethics that were important to them. More details

about the activity can be found in our previous publication[20].

2.4 Student Writing

A writing assignment was designed to assess how effectively students were able to connect virtues to engineering ethics. Students completed this assignment near the end of the second quarter of the course. For this activity, students were prompted to select a story from their own culture or a culture of interest and analyze it by identifying the virtues highlighted within the story, then discussing how those virtues support engineering ethics. The purpose of this exercise was to allow students to demonstrate their learning and understanding gained throughout the course.

3 IMPLEMENTATION

As a pilot study, the teaching modules were implemented in the 2-quarter chemical engineering (CHE) capstone design course at a large public university in the Southwest US. Students in the course worked in teams of five to design a chemical engineering process. This project was reviewed and approved by the university's Institutional Review Board (IRB protocol number: 30232). The first author is the course instructor. The control group for the study is the environmental engineering (ENVE) capstone design course taught at the same university. The two courses have one hour of shared lecture per week and each course has six hours of tutorial/team consultation per week. In the shared lecture, the first author of the paper taught both CHE and ENVE students the engineering code of ethics and case studies from engineering ethics textbooks[27,28] (not the teaching modules we developed). In the section specifically for CHE students, the first author of the paper implemented the teaching modules as described above.

50 students were enrolled in the CHE course and 44 of them gave consent for using their course data for research. 20 students were enrolled in the ENVE course and 11 of them gave consent for using their course data for research. All the data presented in this paper are from the CHE course. The comparison between the CHE and ENVE courses will be discussed in a future publication.

4 RESULTS

For this pilot study, we designed pre- and post-surveys that were distributed to students at the beginning of the first quarter and end of the second quarter. The pre-survey asked students for their perspectives on engineering ethics and virtues. The post-survey asked students some questions that were similar to the pre-survey and had additional questions that asked for students' feedback on the teaching modules. Additional assessments were used, such as ethics quizzes. For this paper, we will focus on the results from the pre-post surveys, because these give us the most insight into students' reactions to the teaching modules. An outline of other assessments we used can be found in our previous publication[20]. We will collect more data in the upcoming year and will report results of more rigorous assessment in a future publication.

4.1 Students' Previous Experiences with Virtues and Ethics

In the pre-survey we asked students where they have learned about engineering ethics and which sources are the most important for their learning of virtues. For both questions we provided the identical list of choices: "College, Family, Workplace, K-12, Community" and students can write in "Other" if needed. Students can choose multiple choices from the list. 44 students responded to both questions. Figure 2 summarizes the percentage of students who chose each option. 100% of students listed College as a source for learning engineering ethics. Of these students, 68.2% listed College as the only source for learning engineering ethics while 31.8% listed College and other options (e.g., family, workplace, K-12) as sources for learning engineering ethics. Of the students who selected College, 72.7% mentioned a specific course on professional development that they took in senior year as the main source for learning engineering ethics. On the contrary, when asked to identify sources for learning virtues, all of the students who listed College as a source for learning virtues also listed one to four other options as sources for learning virtues. Family, College, K-12, Workplace, and Community were all selected by 50% or more students. Only 2 students selected just one source for learning virtues, while 42 out of 44 (or 95.4%) students selected two or more sources for learning virtues.

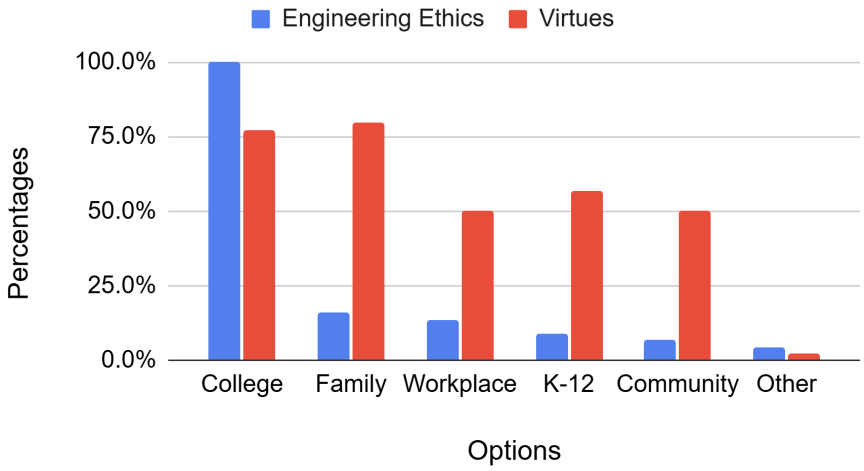

Figure 2: Pre-survey results about sources for learning engineering ethics and virtues. The percentages of students who chose each option are represented as the bars. Blue is for engineering ethics and red is for virtues.

Overall, the results suggest that many students seem to have a narrow focus on engineering ethics and recognized the professional development course they took in college as the only source for learning engineering ethics. At the same time, students recognized that they have learned about virtues since their childhood (e.g., K-12, family) and the influence is life-long. Additionally, several students explained virtues in different contexts. For example, a student mentioned:

> "In several classes in college, we've discussed virtues and ethical behavior. My family has also instilled a lot of virtues, like work ethic and patience. These virtues were also reinforced in any job I've had."

4.2 Virtues That Students Value the Most

In both the Pre- and Post-Survey, students were asked to write down which virtues they value the most and how they exemplify these virtues. Figure 3 summarizes the list of virtues identified by the most number of students from both surveys. Only virtues that were mentioned by at least 5 students in either the pre-survey or the post-survey are included in the figure. These results helped us choose some stories that covered virtues many students valued and some stories that introduced more virtues to students.

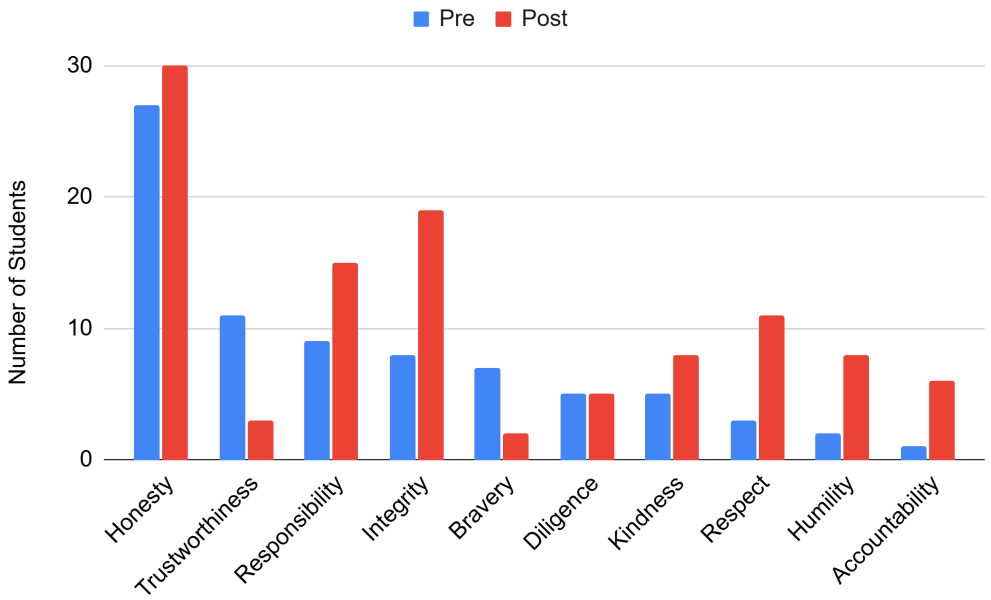

Figure 3: Pre- and post-survey results about virtues that students value the most. The numbers of students who wrote each virtue are represented as the bars. Blue is for the pre-survey results and red is for the post-survey results.

4.3 Student Feedback on the Teaching Modules

After the students were shown ten different virtue-of-the-week stories throughout the course, in the post-survey, we asked students to select the top three stories that resonated with them the most and explain why the stories resonated with them. Out of 43 students who answered the post-survey and gave consent, only 2 students mentioned they do not remember the virtues related to the stories, all the other students gave detailed responses for the virtues in the stories and why the stories resonated with them. We will include a few quotes from students' responses in the Analysis section.

4.4 Students' Self-Reported Effectiveness

To assess students' self-reported effectiveness of the teaching modules, we also asked students the following questions in the post-survey: 1) Did the inclusion of stories from traditional culture help you better understand virtues? If yes, how? 2) Do you think the inclusion of stories from traditional culture will help you act as an ethical engineer? If yes, how? As shown in Figure 4,

86% of students felt that the inclusion of stories from traditional culture helped them understand virtues, while the remaining students still felt it somewhat helped them. Additionally, 92.9% of students thought that the inclusion of stories from traditional culture will help them act as an ethical engineer.

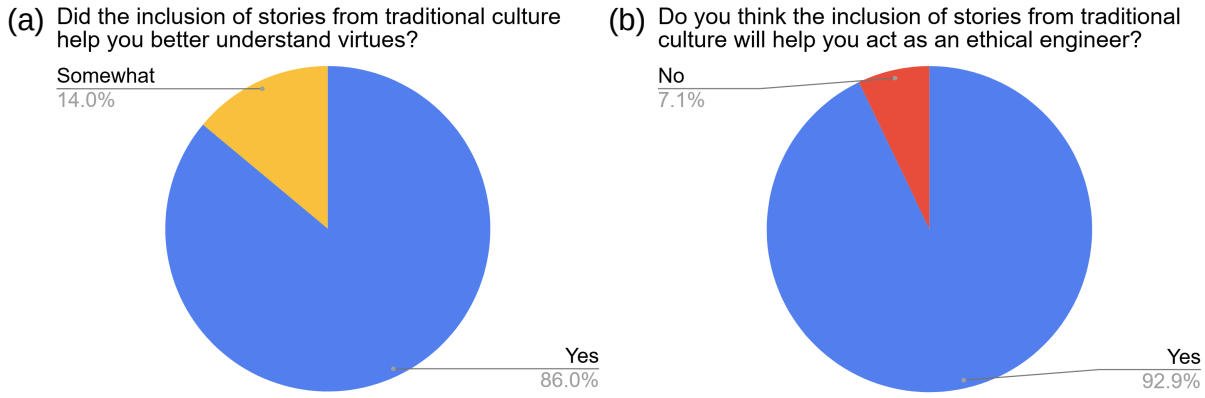

Figure 4: Post-survey results about whether the inclusion of stories from traditional cultures help students better understand virtues and (b) act as an ethical engineer. Blue represents Yes, yellow represents Somewhat, and red represents No.

5 ANALYSIS

5.1 Student Feedback on the Teaching Modules

To better understand the reason why the stories resonated with students, we conducted preliminary analysis on the students' written responses to the question: "Which virtue-of-the-week story resonated the most with you? Please briefly explain why the stories resonated with you", and looked for common themes among the student responses. The following quotes from students' responses represent the three common themes.

1) Stories are related to the culture the student is from:

> "The stories are closely related to my culture so it was easier to resonate with them."
>
> "One is because it is a story from my own culture which helped me connect instantly."

2) Stories exemplify virtues that are the most important to the student:

> "These stories exemplify some of the virtues that are the most meaningful to me. I enjoyed getting to hear about them in a more narrative manner."
>
> "They resonated with me because they had virtues I found valuable not only to my career but to my life as well, helping me realize how I can be a better ethical person."

3) It's nice to see different perspectives on familiar stories:

> "Journey to the West resonated with me because I heard about this story since I was little but never saw the virtues behind it until now." (Note: Journey to the West is one of the stories we used for the Virtue-of-the-Week modules.)

> "Some of them were stories I have heard before but the one told in class was a slightly different version. It was nice seeing a different perspective on stories I know before and talking as a class to make those connections."

5.2 Reasons for Students' Self-Reported Effectiveness

To better understand the reasons behind students' yes/no answers to the questions shown in Figure 4, we conducted preliminary analysis on the students' written responses and looked for common themes among the student responses. Here we will include several quotes from students' responses to illustrate the common themes we found. For students who felt the inclusion of stories from traditional culture helped them better understand virtues, their common reasons are:

1) The stories help contextualize virtues.

> "The stories helped a lot, because they contextualized the virtues that otherwise were somewhat abstract. The story about Lu Ban was a good example of this."

2) The stories are engaging and enjoyable.

> "Using stories to showcase different virtues was very engaging and helpful. This class was the first time I heard many of the stories, and I genuinely enjoyed them."

Other students also mentioned that the stories helped broaden their perspectives on different cultures and helped them identify virtues that have been found in many cultures and throughout time.

For students who thought the inclusion of stories from traditional culture will help them act as ethical engineers, their common reasons are:

1) Stories provide situational examples.

> "Yes, as they provide situational examples of what is and is not ethical."

> "I do think these stories will help me act as an ethical engineer by providing examples that I am able to look back on and look up to."

> "I feel that I can relate back to the stories in the future and see how they compare to the current tasks at hand. I can see what virtues were learned and apply them to my daily life."

2) Stories help students understand consequences of actions.

> "Yes because these stories showed me that even the smallest action can be related to virtues. Every small detail done in general could have a large effect on the world and it is important that every step taken should be done so with precaution."

> "I think it will help because it shows the consequences and the benefits of whether or not one chooses to value virtues."

3) Stories help students with decision-making.

> "Yes because in the stories, a lot of the time the characters were faced with a decision and had to face the consequences for those decisions whether they were good or bad. I believe that during my engineering work I may be faced with a similar situation as the characters in the stories and must make a decision, and I will think of what I believe is best, and the consequences that follow." (Note: This student also mentioned consequences of actions.)
>
> "Yes. These stories are usually short and easy to connect with. I could see myself thinking "what would this character from that story do in this situation."

4) Stories from traditional culture broaden students' perspectives on different cultures.

> "The people that we serve and work with will (hopefully) be from many different backgrounds. Having at least an inkling of an idea of their values and stories is just the beginning of making engineering solutions and a workplace which will be culturally appropriate. Additionally, understanding cultures beyond my own gives me new words to describe what I may see, including in situations where good ethical practice is at stake."
>
> "I find stories from other cultures fascinating, so learning about them and understanding the moral behind them makes me want to apply these virtues myself in both my professional and personal life."

5) Stories are relatable to real-life/engineering.

> "Yes, the virtues from the stories can be easily exemplified in the day to day life of an engineer. Especially kindness, respect, and honesty as I deal with coworkers in the future and teammates now."

6 DISCUSSION

The results from our first year of piloting the teaching modules were quite promising. Overall, we found that students were interested and engaged in the teaching modules and students felt the stories from traditional culture helped them better understand virtues and act as an ethical engineer. Here, we'd like to offer our perspectives on why we think students are interested and engaged in our teaching modules.

As shown in Figure 2, on the one hand, most students recognized that they have learned about virtues since their childhood (e.g., K-12, family) and the influence is life-long; on the other hand, many students seemed to have a narrow focus on engineering ethics and chose college as the only source for learning engineering ethics. By introducing engineering ethics through the lens of virtues, we are helping students connect a seemingly new concept (engineering ethics) to concepts they are more familiar with (virtues).

Additionally, engineering ethics and virtues differ in that engineering ethics focuses on ways a person can orient themselves professionally as an engineer, whereas virtues focus on ways a person can orient themselves internally as a human being. By integrating virtues in the teaching modules, students can bring their whole selves and not just their professional selves.

Furthermore, stories, by design, are full of interesting dialogs, different characters, plot twists, and cultural elements, making them quite interesting and engaging. This aspect was mentioned by students repeatedly in the post-survey and students also expressed they enjoyed the virtue and ethics teaching modules in the anonymous end-of-course evaluations (administered by the university). Many students also noted the stories helped contextualize the virtues and gave them good examples that they can reflect on when they need to make ethical decisions in their future career. Stories from traditional culture have the added benefit of teaching students intercultural competencies (i.e., the ability to function effectively across cultures, to think and act appropriately, and to communicate and work with people from different cultural backgrounds)[29]. In the post-survey questions, several students recognized the stories helped broaden their perspectives on different cultures.

In many engineering ethics programs offered in universities, case studies (derived from disaster cases or situations at companies) are frequently used. These case studies are helpful for students to practice decision-making in an engineering setting. But oftentimes, these case studies lack cultural contexts. Stories from traditional culture can serve as a new type of case study to complement existing case studies for engineering ethics education. We observed some preliminary evidence for this in students' written responses to the post-survey questions about 1) which stories resonated the most with them and 2) whether they thought the stories from traditional culture will help them act as ethical engineers. Although we didn't ask students to practice decision-making explicitly as a part of the virtue-of-the-week modules, several students noted that the stories will help them with decision-making and understanding the consequences of actions:

> "Because these stories make me think the opposite of the choices the characters made. I would think the effects of the choices, what happens if the characters chose to do the opposite."

Additionally, some students noted that the stories evoked them emotionally, which made the stories more memorable and helped them better understand virtues and engineering ethics:

> "I'm always driven by my emotions, so I feel like these stories left the most impact on my feelings, whether it was feeling sad for the mother frog, or feeling angry for the soldier, finding out the resolution for those stories made the virtues they represent more memorable for me." (Note: the mother frog and the soldier are from two virtue-of-the-week stories we used.)

> "The inclusion of stories from traditional culture will help us act as an ethical engineer because instead of simply reading the definitions of ethics and virtues, we get to hear them through traditional culture stories which allow us to actually understand the meanings and feelings evoked due to certain ethical choices made during these stories."

Our results suggest that with this holistic approach of using stories from traditional culture to teach virtue-based engineering ethics, there was more student interest and engagement in the teaching modules. Additionally, stories from traditional culture can serve as a new type of case study for teaching virtue-based engineering ethics.

7 LIMITATIONS AND FUTURE WORK

With only 44 CHE students and 11 ENVE students who gave consent, our sample size is quite small. We will continue this research study in future iterations of the senior design course. Specifically, we plan to develop teaching modules to teach students ethical decision-making, for example, by incorporating consideration of virtues in existing ethics case studies or modifying our virtue-of-the-week modules to incorporate more decision-making opportunities for students. Additionally, we are in the process of developing more rigorous assessments to quantify improvements in students' understanding of virtues, engineering ethics, and ethical decision-making. Furthermore, we plan to collaborate with other engineering faculty to implement these teaching modules in their courses as well.

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