Personal Values Inform Student Preference for Household Toilet Systems That Use Human "Waste" as a Natural Resource

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ABSTRACT

This study contributes to understanding pro-environmental behavior in toilet system adoption by examining the core values that inform decision-making processes. Undergraduates participated in an educational module on conventional and alternative wastewater systems, followed by composing essays envisioning their ideal toilet system for a future home. Qualitative analysis of responses established a codebook outlining the values students mention when describing their preferences. The identified values include: 1) Contributes to Something Good, 2) Uses Resources Wisely (water, nutrients, and money), 3) Practical (economical and easy to maintain), and 4) Avoids Causing Harm (environment and people). Findings suggest that students use emotional and cognitive domains in decision-making. The study suggests that, after learning about various wastewater systems, students do not adhere to the social norms of adopting conventional toilet systems. Students' preference for systems designed to utilize human "waste" as a resource supports the literature on social change toward the widespread adoption of sustainable sanitation systems. Importantly, students view toilet systems as potential mitigators of harm and producers of something beneficial. We also show that the awareness of how a poorly designed and managed system could cause harm and the value of caring for the Earth may overcome the feeling of disgust associated with the social taboo related to human excrement. Our research can assist sustainability sanitation advocates and educators because it gives evidence that a group of people are motivated to adopt regenerative sanitation systems.

INTRODUCTION

Why do some households have toilet systems that utilize human waste as a resource, and others result in polluting the environment? Knowledge of the efficacy of toilet systems protecting freshwater resources is missing from public discourse in the United States. This is problematic because the predominate toilet systems (sewage and septic) present limited opportunities for utilizing the water and nutrients in the systems as a resource (1). Further, these systems are prone to cause sewage pollution because they are fragile, often antiquated, and unable to accommodate a growing population (2–4). Newer systems tend to be reclamation systems that partially recycle either water or nutrients (5). However, they are not designed to utilize urine and feces as a natural resource (6).

In contrast, Scandinavian countries have systematically managed human waste as a natural resource for decades (7). Other European countries are removing barriers and increasing support for larger-scale water and nutrient reclamation systems (8). Alternative systems, such as urine diversion, composting toilets, vermicomposting toilets, and biogas systems, are readily available and implemented at household and district scales.

Systems that fully utilize urine and feces are often described as sustainable or ecological sanitation systems (9). The term regenerative sanitation systems is also used, which accurately describes the goals shared with ecological and sustainable systems: to employ water and nutrients effectively, rendering human excrement a profitable natural resource that regenerates that land and water (10). They conserve freshwater and energy, cycle water and nutrients back into soil ecosystems, and promote economic stability in a

community (11,12). Regenerative sanitation systems are still rare and face socio-technical challenges (13).

Changes in both infrastructure and social norms are necessary to move away from conventional wastewater systems and towards regenerative sanitation (14). The technological advances and appropriate application of sanitation systems designed to maximize the use of human excrement are available (15). The lack of public awareness of options and demand is minimal. However, garnering support for something that has not been seen, heard of, experienced, or imagined as an option is unreasonable. Individuals need to know about different systems, imagine using them, and identify them as preferable (16). Then, communities may demand something other than the standard conventional system, which is a cornerstone to shifting to having country-wide or global adoption of sustainable sanitation systems (17).

A primary explanation for the lack of widespread adoption of ecological toilet systems is the “yuck factor” (18). This is significant because the way people feel about an idea is a powerful marker of behavior (19). Some regenerative systems in the United States have been rejected because the public feels a sense of disgust (20). Unfortunately, the assumption that the topic of toilets is taboo makes it unpopular to discuss, promote, and difficult to garner political will (21). However, in a recent study on the openness to the adoption of human-derived fertilizers, “holistic” values, including the desire to care for the Earth, motivated people to want to recycle urine and was more significant for many than any feeling of disgust (11). This finding aligns with the well-documented phenomenon that a desire to care for a loved one, such as needing to change a baby's or elder's diaper, can be

a catalyst for overcoming disgust (22). These examples support the literature that when presented with a scenario where people are asked to make a decision, they draw from their value system (19).

In a review of the literature on theoretical models that explain pro-environmental behavior, Kollmuss, and Agyeman illustrate the complexity of social, psychological, and logistical reasons people act environmentally (23). One significant influence on peoples' decisions is cultural and personal values (24,25). Studies show that people who value the environment and community health are more inclined to adopt sustainable technologies and purchase wastewater-derived products (26,27). There is also evidence that knowledge about the impact on the environment plays a role in an individual's values and pro-environmental behavior (28). Further, supportive cognitive reasoning can influence consumer preferences for pro-environmental products (29). For example, one study showed that information on drought changed individuals' consumption habits and household water management (30). What people know about the potential benefits of using the constituents of human excrement as a resource can influence how they feel, therefore playing a role in their support for adopting waste-derived products such as fertilizers (31). We consider adopting and participating in regenerative sanitation systems through using an ecological toilet or purchasing products derived from them as examples of pro-environmental behavior.

Study Purpose

This study investigated students' toilet system preferences and the accompanying values that describe their *why*. Participants in the study experienced an educational module

that explored the social, environmental, and infrastructural facets of toilet systems. Our research questions:

1. *What* systems would students prefer to use in their future homes?
2. *Why* do students want a particular toilet system?
3. *How* do students describe *why* they want their chosen system?

A codebook was created through inductive analysis of open-response questions. This data presents novel insight into the preferences and values of young adults recently educated about the functioning of conventional, reclamation, and regenerative toilet systems. Students demonstrate an ability to articulate what toilet system they would ideally use *and* why they chose that system. This study has discovered that students focus on several topics related to toilet systems and a few key values, explaining their choice in both emotional and cognitive terms. The descriptions shared in this article represent a range of feelings and reactions that elucidate what undergraduates find important for their households. Their messages present an optimistic future for pro-environmental behavior.

MATERIALS AND METHODS

Context and Participants

The study population consisted of undergraduates enrolled in an upper-level "Soil and Hydrology" course at a public southeastern R1 institution. The course is required for wildlife and natural resources management, agriculture, and environmental science majors. Its content focuses on physical processes, methods of analysis, and management practices. The course structure includes lectures and a lab. All 63 juniors and seniors in the course were invited to participate; 44 students provided written informed consent and completed

the survey and essay assignment according to approved Institutional Review Board protocol.

Demographic data was completed via an online survey before the educational intervention. Standard physical traits were included, along with items related to childhood wastewater systems, political leaning, perception of interconnectedness to nature, and environmental behavior. Participants in the study represented a diverse range of behavioral characteristics. There was an array of political leanings (Republicans and Democrats), habits with composting food (never before to actively managing a compost pile), perspectives of interconnectedness with nature (separate from nature to one with nature), and the amount they talk with family and friends about the way they affect the environment (never to daily). Most students were aware of the type of toilet system they had during childhood. Forty-three percent had a septic system, and twenty-five percent used the sewer system. Thirty percent of students had both, likely because they had moved homes during their childhood. Race and age were the least diverse characteristics. The majority of the population identified as white. Gender identity was slightly skewed toward men. See the S1 Appendix for the complete demographic profile data.

Educational Exposure to Water and Wastewater System Module

Students completed a Water and Wastewater Systems Module during the tenth week of the semester. The module consisted of two 50-minute active learning lectures and a 105-minute lab. The module's relevant aspects for understanding this study's context are described below.

Students were exposed to several types of toilet systems during the module. Conventional centralized and decentralized wastewater systems (sewer and septic, respectively). These are the standard systems in the United States and are most commonly used by students (S1 Appendix). Options for resource reclamation that pair with these conventional systems were also explored. For example, biosolid processing methods for land application and struvite production for fertilizer were explained alongside wastewater treatment plants. Modified septic systems, including the twin-pit system and constructed wetlands, were introduced as reclamation systems. In addition, students learned about several regenerative systems designed to employ water and nutrients as a natural resource. Examples in the module included composting toilets (foam flush and bucket systems), Urine Diversion, Vermicomposting Toilets (using compost worms), the Living Machine (series of ecosystem cells), and Biogas (i.e., anaerobic digesters). The table in S2Appendix shows a comparison of educational materials for each system.

Data Collection and Analysis

Student essays were the source of qualitative and quantitative data. The essay prompt asked them to imagine their ideal toilet system in their future home and describe why they preferred it. The complete prompt and grading rubric are presented in supporting information, S3 and S4 Appendices, respectively. Essays were the last part of their lab assignment, concluding the Water and Wastewater Systems Module. The essay portion made up 50% of the Lab 9 grade or 1% of their total course grade. Essays were assigned a unique ID number before analysis. The average number of words in an essay was 647; the median was 588 words.

Qualitative analysis was conducted in an iterative process by two researchers, one who designed the study and the other as an outside researcher. Essays were initially read without an analytical lens so that the coders could become familiar with the language and structure used by students. Essays were reviewed independently, coded, and then compared following a standard protocol (32). If a discrepancy arose, it was discussed until consensus was established. This process was repeated at each stage of the analysis, which is illustrated in Figure 1 and described in detail in the supporting information, S5 Appendix.

Fig 1: Process of qualitative methods. The flow chart describes the steps taken during four rounds of qualitative analysis.

How students tended to talk about *why* they wanted the toilet system determined the domains. Themes where students described how they felt, were represented by the emotional domain. The themes that described logical aspects were organized in the cognitive domain. Figure 2 includes typical examples, categories, themes, and domains.

Fig 2: Codebook for qualitative analysis of student essays. This figure shows examples of student phrases that led to the development of the categories of topics, value themes, and domains described in the codebook.

RESULTS

Toilet System Preferences

Nine toilet system types were represented in student essays. The most common toilet system described as ideal was the composting toilet system (27%, n=12). The second most common was a conventional septic system (20%, n=9). Two students explained

wanting both systems in their future homes. The Living Machine was the next preferred system (18%, n=8) described. See Table 1 for toilet system categorization.

Most students (56%, n=25) described wanting a toilet system designed to be a regenerative sanitation system. Systems represented included composting toilets, living machines, vermicomposting, and biogas. Eighteen percent wanted a reclamation system. Three individuals described wanting a sewer system with a treatment plant to either process and compost biosolids for land application or produce struvite for fertilizer. Five students described modified septic systems that allow for reclamation, including a constructed wetland or a twin-pit system designed for harvesting aged biosolids as a soil amendment. Twenty percent of students (n=9) selected a conventional septic system. A fourth category that emerged from the data, which was not described during the module, included having both a traditional septic and a regenerative composting toilet system. The vast majority of students (97%) depicted wanting a non-sewered. See Figure 3 and Table 1 for the distribution of selected systems.

Figure 3: Pie chart showing the ratio of toilet system categories described by students. The toilet icon indicates the system design. Conventional systems are designed to pass water and nutrients through the system. Reclamation systems partially recycle either water or nutrients. Regenerative systems are designed to capture and cultivate a maximum amount of water and nutrients to regenerate the land and water.

Table 1: Toilet system category and system types described in student essays. The toilet system types are grouped into categories based on their design principles.

Most students (89%; n=39) did not choose the toilet system they had during their childhood as their ideal. The exception was five students who grew up using a septic system and stated that they wanted traditional septic for their future home. Some also cited the familiarity of the system as a reason. Alongside saying they wanted what was familiar, they tended to explain that they would manage it differently than their parents.

Why Do Students Want a Particular Toilet System?

Students discuss *why* they wanted the system in terms that revealed their values toward household toilet systems. While some of them described topics presented in the module, students were not instructed on which ones to discuss. They had the freedom of choice to describe what was meaningful and would influence their decision.

The range of student "voices" are represented. Following a student's quote is their ID number (S#) and the type of system they described. Sixty-four percent of student essays contribute to the narrative. Selected quotes exemplify students' descriptions related to a theme. For a smooth narrative, the words "I," "me," and "my" were replaced with "they" and "their." Student explanations sometimes included more than one reason within a sentence or paragraph, resulting in multiple themes. Therefore, quotes related to the theme being discussed may also mention other themes. Student quotes represent a population of people who, up until the module, had limited knowledge of how toilet systems function and were largely unaware of the existence of reclamation or regenerative systems.

Results are organized by the themes from the codebook. Student essays had a range of two to six themes, with a median and mode of five themes. The order of the results reflects the degree to which they occurred in the essays (Figure 4). An equal number of

243 students (n=40) described the top two themes: "Contributes to Something Good" and "Wise
244 Use of Resources." Most students (86%) had both in their essays. The majority of students
245 also included topics categorized into the "Practical" (86%) and "Avoid Causing Harm"
246 (80%) themes. These four themes were twice as common as the themes "Natural" and
247 "Social Norm" (39% and 36%, respectively).

248 Figure 4: A Graphical Representation of Qualitative Results. This figure illustrates the
249 themes and categories discussed in student essays explaining why they wanted a particular
250 toilet system. The themes and categories are ordered based on their overall prevalence in
251 the essays.

252 Quantitative data shows that not all themes are equally represented. What we see is
253 that the top four themes were more common and covered a wider range of topics
254 mentioned in the essays (Figure 4). We inferred students' core values from the themes that
255 emerged in student essays as they described why certain topics informed their conception
256 of an ideal toilet system. This data gives insight into their vision of a future home and
257 preference for the critical infrastructure that facilitates human waste management. The
258 qualitative data in the next section serves to clarify how the essays were coded into themes
259 while demonstrating that students with limited homeowner experience and education on
260 wastewater systems consider multiple facets of toilet systems.

261 *Theme: Contributes to Something "Good"*

262 Almost all students expressed that they wanted a toilet system that was "good"
263 because it would "produce something beneficial," "contribute" in some way, or "create"
264 something. We interpreted these sentiments as a theme that they wanted the outcome of

the treatment process to produce something good. This concept was often directly articulated as wanting a "good" system that would allow resources to be "placed back into the environment in beneficial ways" (S10, Septic).

Students typically demonstrated an understanding of the process of how a system would give back to the natural environment in a way that would help replenish what humans used. For example, a student explained how "a constructed wetland converts what we might see as waste into carbon-rich, nutrient-rich food for plants and bacteria; it essentially gives back to nature the nutrients we took for our food" (S46, Modified septic-Wetland).

Making the connection between plant growth and giving back to the environment was common. Some students explicitly stated that they liked "the idea of reusing [their] wastewater to grow plants" (S34, Living Machine). Other students specifically outlined that they "plan to have a garden, so using waste from [their] home as humus for growing crops is very appealing" (S41, Composting Toilet). For those who referenced wanting to garden, students often provided details on the efficacy of using the product for good. For example, one student described how "the compost produced by the worms is nutrient rich and is perfect for use as a plant fertilizer. Vermicompost has been known to not only increase growth of plants, but also prevent some pests and diseases, as it is rich in both macro and micronutrients. This compost can be used in a cultivated garden…" (S30, Vermicomposting Toilet).

Those who focused on creating something good through the support of non-crop plants often pointed out how plants contribute to the aesthetics of a space. One student

shared how "the idea of taking human waste and using it to create beautiful environments within urban areas is amazing. I believe that they provide such a peaceful and calming atmosphere and I love seeing them displayed in public places, especially urban cities where nature is often excluded" (S31, Living Machine).

Visual appeal was also thought to contribute to a system's overall acceptance. Having an "aesthetically pleasing wastewater system…is one way to positively shift societal views of how waste is viewed, managed, and treated" (S45, Living Machine). On the other hand, one student pointed out that "due to it being located underground, it will be out of sight and be aesthetically pleasing. The grass around the septic system should actually be greener and lusher due to nutrients that they are receiving" (S13, Septic).

There was a general sentiment of excitement at the prospect of having a household system that could contribute something good for the environment. One student expressed that they were "ecstatic that something as mundane as going to the bathroom can be turned into something beneficial for the planet rather than harming it" (S23, Vermicomposting Toilet). Sometimes, students went as far as to reflect on how their toilet system would shape their relationship with the natural environment. One student explained that by actively transforming their excrement into a valuable resource, they "would also gain a deeper connection to nature, not just from living in a more rural environment, but consciously giving back to the environment with [their] waste and water conservation" (S20, Septic and Compost).

Theme: Wise Use of Resources

The desire to use human excrement as a resource was a salient reason students preferred decentralized systems. In some cases, "the most appealing aspect of this system" was being able to "keep all [their] waste cycling through a self-contained system" (S28, Composting Toilet). The focus was on nutrient cycling, but a few students highlighted that they wanted the system for its water conservation features. This was most mentioned in essays describing composting toilet systems because they "would not be using water for flushing...which would help [them] conserve water" (S9, Composting Toilet). The ability to reduce water usage and reuse the water after treatment were both mentioned as reasons. Another student explained that "the two major benefits to [a biogas] system would be its source of renewable energy and recycled water" (S25, Biogas). The Wise use of resources theme is best summarized by student 25 who said that "the ability to recycle 'waste' and turn it into something incredibly useful (and not wasteful at all) is tremendously appreciable." Students highlighted the benefits of conserving and reusing water resources and creating a renewable resource.

Theme: Practical

The theme of practicality encompassed explanations related to the basic management of the system. Students found it appealing to have a system that they could imagine taking care of at the household scale. Some students described how they would manage the system. For example, one person explained how "it is important to monitor the system to fix any issues before they become major problems. Periodically, finished compost can be removed and new organic material added to the tank. It is important to add carbon-

rich materials such as wood chips and shavings so that the system can process the high level of nitrogen in human waste...Overall, I would prefer the vermicomposting toilet system because of its ease of installation, maintenance and because of its sustainability" (S43, Vermicomposting Toilet). The concept of being easy to handle was common, as seen in this typical quote: "An attractive feature is the idea of how simple and relatively low maintenance this would be" (S39, Modified Septic – Twin-pit). Some students pointed to the convenience of having access to professional services, mostly mentioned in essays describing septic tanks. As one student explained, "there are companies that come and pump it for you. This ensures that your waste will be treated safely" (S24, Septic). "There would also be people who work on septic systems nearby in my area, so if maintenance is necessary it won't be difficult to get it fixed" (S13, Septic). Along the lines of having a system that already has a set infrastructure, a few students mentioned the benefit of having a toilet system that "…can be well-integrated into a building's infrastructure" (S45, Living Machine).

The economics of a system was often discussed in practical terms. It was common for students to address short-term and long-term expenses. For example, "the financial cost initially is a little higher…but once it is set up, it is energy efficient and low cost" (S34, Living Machine). A perk mentioned for a decentralized system is that "expensive underground infrastructure involving kilometers of pipes to transport waste would not be necessary" (S46, Modified Septic- Wetland). A couple of students extrapolated the concept of cost to fertilizer production. One student explained that "there are initial investments to establish the infrastructure however they will last long durations and regain their value

over time...With the extraction of the phosphorus to create struvite the cost of fertilizer would also decrease which is pertinent because of increasing prices of imported fertilizer" (S17, Sewer with Struvite). Another line of reasoning around money was in comparison to other systems. As one student pointed out, "…it [composting toilet] would save money over using a septic system..." (S28, Composting toilet).

Theme: Avoid Causing Harm

Most students (80%) expressed wanting a toilet system that avoids causing harm to humans and the natural environment. An Example of this pattern is a student stating that they "don't want to cause a toxic environment for the fish, turtles and other organisms residing there, but also to keep myself from consuming anything toxic....to try and avoid long term damage to natural ecosystems" (S27, Composting toilet). Here, the student cited a waterless toilet as a way to reduce freshwater pollution. Students who described water-based systems also demonstrated wanting to avoid causing harm by having a modified system designed to reclaim nutrients. One student explained that this design would "avoid the eutrophication of a local creek and keep its fauna and flora in mind…Also the plant roots would sequester contaminants…" (S37, Modified Septic- Wetland). Examples describing the motivation to prevent pollution of ecosystems, wildlife, and animals were typical in the essays.

Wanting to reduce the dependency on landfills was cited in the context of not wanting to strain the natural environment. For example, after saying they wanted to "keep a large mass of organic material out of landfills," the student explained, "the opportunity to compost this waste and reuse it is an important way to keep more waste out of landfills and

have more soil resources for agriculture and landscaping" (S44, Sewer—Biosolids Production). The byproducts of landfills were considered potentially harmful. As one student pointed out, keeping waste out of a landfill would also "reduce the amount of greenhouse gasses that are generated at landfills" (S23, Vermicomposting Toilet).

Decreasing the need for fossil fuels was highlighted as an attribute of reclamation and regenerative systems. Students emphasized that human excrement is a renewable resource and pointed out the possibility for systems to reduce their carbon footprint. While the biogas system was not a top pick for students, the description of the relationship between toilet systems and fossil fuels exemplifies the same points made by other students.

> Humans continue to produce endless amounts of waste, as eating is necessary for life and thus pooping is too. Human waste is part of a constant cycle so it can be seen as a very reliable source of energy…this can help to reduce the use of fossil fuels and lower the carbon footprint, which is a great scientific and environmental perk to this form of wastewater treatment...It is much more sustainable to rely on human waste as a source of energy rather than petroleum gas or other more environmentally harmful methods of sourcing energy (S25, Biogas).

In concluding remarks, one student claimed that "owners should feel pride in replacing modern treatment practices with an alternative that doesn't harm the environment" (S15, Modified Septic – Wetland).

A couple of students highlighted the importance of a system not compromising their or other people's drinking water. One student didn't want a water-based system because they thought they were "much more likely to pollute our drinking water or not be treated

395 properly." They then explained that composting systems "are incredibly safe, if done
396 correctly, and are not likely to get you or anyone around you sick" (S9, Composting Toilet).
397 Another perspective was wanting a system that would address current issues caused by
398 antiquated infrastructure that exposes people to sewage pollution. In reference to the
399 relationship between wastewater treatment and environmental justice, one student
400 posited that "implementation of living machines in [low-income communities] could
401 potentially contribute to the solution of reducing contaminants and pollutants in water and
402 more equitably distributing new, functional wastewater treatment systems" (S45, Living
403 Machine). These quotes illustrate how students were considering how their preferred
404 system might ensure that they would not cause harm to others.

405 *Natural*

406 The theme "Natural" emerged from students saying that they chose a system
407 because it mimicked nature. Student 32 described their ideal as a composting toilet system
408 because "these systems almost completely match the natural processes that break down
409 waste. This is valuable because it requires almost no energy and very few resources to
410 complete the decomposition." Another student noted that they chose the system because it
411 "works by harnessing the wisdom of nature's systems, the entire process feels very organic
412 and in harmony with the world around me" (S19, Living Machine). One student stated that
413 they "chose to research the living machine, mainly because my gut instinct is always to tend
414 towards what would be the solution closest to natural processes" (S29, Living Machine).
415 Later in the essay, they explained a sentiment other students expressed; that the
416 naturalness of a system would increase its acceptability. "Since it's made up of plants, I

417 think people would be more likely to accept it as an 'organic' system to want to use. And
418 while other waste systems are just as good, they seem a lot less 'natural,' aka a lot less
419 pleasant to maintain."

420 *Theme: Social Norm*

421 The Social Norm theme encompassed students' comfortability, familiarity, and social
422 acceptability of the toilet system. Topics were often mentioned as a bonus feature, not a
423 primary reason for choosing the system. Some directly pointed to wanting a "flush toilet."
424 One student reflected that even though they were aware "they are not the most
425 environmentally friendly, I am rather fond of flush toilets" (S30, Vermicomposting Toilet).
426 Occasionally, students referenced how others would be more comfortable with a water-
427 based system "because they can still use their (almost) standard toilet… making it much
428 easier for people to accept it in their own lives" (S16, Vermicomposting Toilet). Using a
429 system that adheres to social norms influenced some students' decisions regarding what
430 toilet system they wanted in their homes.

431 Social acceptability was tied to systems not requiring any change in already
432 established habits and using something familiar. One student directly stated that
433 "something [they] value" was having a system that did "not require a huge lifestyle change"
434 (S4, Modified Septic – Twin-pit). Another student said they "felt personally connected to
435 the septic system because they had one at [their] parents' house" (S20, Septic). A student
436 who wanted a sewer system with reclamation noted how it "is already very similar to what
437 is occurring in terms of wastewater treatment in my area. Additionally, it has very little
438 effect on how I carry on [with] my daily life." (S35, Sewer with Biosolid Production).

Considerations for Success

Students' considerations for success span across all toilet categories and domains. The quote below represents several topics that shape this theme.

> "I would have to worry about the occasional flooding, septic tank failure, blockages, and getting the biosolids pumped out every few years. As long as this system is placed properly in the right loamy soil, then it should drain and filter well. Also, if I avoid flushing down things such as paper towels, I can minimize my risk of blockages. I need to make sure to educate my guests on the reasons why not to flush things like that when they come over" (S13, Septic)

The student first identifies the role environmental conditions and hazards could play in the system's functioning. Then, they acknowledge the need to have it professionally maintained. They also address the need to avoid placing items in the system that could compromise its function. Lastly, they take responsibility for teaching their guests about the system. All these ideas are presented in the essays.

The concept of responsibility as a necessary aspect of keeping the toilet system functioning was also described in terms of household upkeep. One student noted that the decentralized system would "require more personal upkeep than a centralized sewage system" (S20, Septic and Composting Toilet). Another student idealized that the transformation of human excreta would be the responsibility of someone who could be hired. The rationale is that "if there was funding to afford full-time employees to manage the collection and treatment of the humanure, the system is more likely to succeed" (S7, Composting Toilet).

Students would sometimes mention how others might respond to the prospect of adopting a non-conventional system or using human excrement as a natural resource. As one student stated, "convincing people to make the necessary changes, such as piping systems … would be challenging. Additionally, the acceptance of utilizing the high-quality soil would be difficult to convince the average person due to the stigma against human waste" (S16, Vermicomposting Toilet). The socially related considerations were consistently discussed as an aspect that would need to be addressed. Considerations for the legality and infrastructure appeared in essays. Several students pointed out that "there are laws prohibiting people from using wastewater systems such as living machines" (S26, Living Machine).

How do students describe _why_ they want a particular toilet system?

Analysis indicates that most students (98%) described their preferences with *both* emotional and cognitive terms. The trend shows that more students described topics in emotional terms than cognitive ones. An outlier was a student who exclusively explained their reasoning for why they wanted a septic system by themes in cognitive terms. This student also wrote an essay with fewer than the average number of words. There were a total of 108 occurrences of topics in the emotional domain, compared to 78 in the cognitive domain. Another way to understand this is that 58% of the total explanations fell into the Emotional Domain (Figure 5). See the codebook in Figure 4 to review categories, themes, and domains. These findings suggest that students' feelings about their toilet systems had a slightly greater influence than their reasoning.

Figure 5: Pie chart of proportions of students that provide explanations that align with the emotional and cognitive domains.

DISCUSSION

The findings in this study can be directly used by advocates for the adoption of regenerative sanitation systems. The values framework outlines the big topics future homeowners consider when imagining their ideal toilet system. These can be used to help outline talking points, guide interview questions in the future, or inform public awareness campaigns. Our results show that when people imagine the prospect of a new household toilet system, they consider how they feel (emotional domain) and what they think makes practical sense (cognitive domain). It is important to acknowledge emotional and rational topics when discussing toilet systems, especially deviating from the conventional norms.

Our study suggests that the social norm of having a standard flush toilet system designed to treat human excrement as waste is not as powerful a value as other values. This supports the theory that an initial sense of disgust can be overcome with values of caring for the environment and others and being practical. Researchers investigating pro-environmental behavior can use this finding to further advance our understanding of factors that motivate people to adopt sustainable habits and products.

Preference for Toilet Systems that Use Human Biowaste as a Natural Resource

When presented with various toilet system options and given the freedom to choose, a majority of students opted for regenerative designs. Interestingly, even when expressing a preference for conventional septic systems, students detailed how such

systems could be redesigned and managed to integrate water and nutrients into the environment as a natural resource.

Notably, students' conceptualizations of their ideal toilet systems deviated from their childhood experiences, indicating a receptivity, perhaps even a preference, for a different type of system. Despite lacking prior exposure to reclamation or regenerative systems, these designs garnered significant favor among the sample population. This is a promising finding, suggesting that with minimal education, young adults are considering the adoption of alternative toilet systems that facilitate the sustainable utilization of human excrement as a valuable resource.

The popularity of students describing the management of an onsite system for their future home suggests they imagine taking a more participatory role in the functioning of the toilet system. Over half of the students described wanting to live in a rural environment independent of centralized systems. Others described a suburban environment but also wanted onsite treatment and regenerative systems. This inclination aligns with solutions proposed for addressing the challenges of broken water and nutrient cycles (6,13,33,34) Students' descriptions of how they would need to take care of an onsite system suggest a shift away from a "flush and forget" mentality and toward the perspective to "capture and cultivate". A preference to adopt a system that keeps nutrients in the local ecosystem is a prime example of identifying a sustainable sanitation system because it promotes a circular economy. Further, they support food and energy systems that communities rely on. Conceptually, these aspects of a human infrastructure system are what contribute to the possibility of a city being a "force for good" (35).

Values Inform Preference for Household Toilet Systems

Students conveyed the value of using a toilet system that allows them to be a producer of something beneficial. The commonality among the top themes described ("Contributes to Something Good," "Wise Use of Resources", "Practicality," and "Avoids Causing Harm") is that they are attributes of being a productive and helpful individual. These themes reflect students' values for how they move through the world, including how they interact with the natural environment via their household infrastructure. It was not just that students described doing something good by "answering nature's call" or that the system was able to transform urine and feces into something useful; it was that they helped create and contributed to the betterment of the natural environment and society. This sentiment is found in environmental psychology, which posits that "people value goods not just for the tangible benefits they bring but also for what they represent to themselves and others" (Trudel 2019). The relationship between what we use and create and how we see ourselves is also observed in student essays. We see that students discuss how using a toilet system can offer a concrete and localized way to produce something beneficial, *and* it fosters a feeling that by using a toilet system that contributes to something good, they are also good.

The value of creating something beautiful was described in terms of producing something good, which students conceived as a proxy for being part of something beneficial. Students preferred an aesthetically pleasing toilet system and concluded that others would concur. This assumption is consistent with research showing that the adoption of composting toilets is influenced by aesthetics (36). Aesthetics also affects how

a person relates to an environment and the ethics that follow (37,38). As Wohlwill found, when something is aesthetically pleasing, people are more likely to care for the system (39). This positive feedback loop is relevant to toilet systems because they require regular maintenance and care. This means that toilet systems that result in beauty are likely to be more valued in part because they symbolize participation in something good.

The awareness of daily use of a system and its potential to create something good for the environment in a relatively short amount of time differs from many other pro-environmental habits. Most sustainability-related behaviors are abstract and psychologically distant, requiring consumers to engage in cognitive reasoning to consider their impact (40). For example, a person's reduction of greenhouse gas emissions is difficult to conceptualize because of the global scale. Conversely, transforming urine into a fertilizer, composting feces to create soil, or supplying a wetland with nutrients that grow plants offers tangible results at a local scale. The relatively immediate feedback loop is more easily conceived. While students tended to describe household-scale systems, it is reasonable to conceptualize participating in larger-scale systems that transform human biowaste into something beneficial. The implication is to highlight the appealing attribute of being able to witness a positive impact via using sustainable sanitation systems. Thus, using a toilet system that contributes to something good can reinforce pro-environmental behavior.

On the flip side of wanting to contribute something good, students clearly expressed that they did not want to use a toilet system that causes harm to other living beings. In the essays, producing something good and avoiding causing harm are described separately,

signaling a different but similar motivation for adopting a system. Research shows that a universal moral orientation is not wanting to cause harm; people are inclined to care for the things and people they value (19). Because the connection between the household toilet system and the health of communities and the environment was established in the essays, it is reasonable to interpret that the values expressed are not directly related to the toilet system but more about how the toilet system will function as a mediator between the individual and the natural environment. Students commonly wrote about not wanting to harm the Earth, pollute habitat or drinking water, add to landfills, or propel climate change. We interpret that students do not want to use toilet systems that cause harm to those whom they care for, such as nature and people. The most significant implication here is that the awareness of how a poorly designed and managed system could cause harm is a possible pathway for motivating people to adopt a system that aligns with these values.

Students' detailed descriptions of a toilet system's management and economic facets show that they not only value aspects of the system that feel good but also have logical reasons for preferring one system over another. For example, students would focus on the cost of installation of a compost toilet system or the return on investment for more expensive systems like the living machine or struvite reclamation. What this tells us is that they value money as a resource and want to feel good about allocating it toward systems that align with practical values, such as investing in a system that makes a space beautiful or protects water. This research supports findings that show practical logistics play a significant role in system preference (41). It also affirms the need to emphasize the role

590 economic viability plays in the adoption of reclamation and regenerative sanitation
591 systems (42).

592 The fact that most students explained considerations for success demonstrates
593 engagement with imagining "real-world" tasks related to being responsible for a portion of
594 the functioning of the systems. This shows that they acknowledge that this type of system
595 will impact regular household management, including maintenance and financial
596 contributions. Familiarity with systems and an infrastructural support system are practical
597 considerations. The concept of adopting a system that is already in place presents the path
598 of least resistance to installing a toilet system. This is especially the case with conventional
599 systems. However, students also found practical reasons for choosing alternative systems
600 that are not yet established in the United States. What we see in the data is that students
601 tend to discuss the same topics for all the different toilet systems.

602 **Social Norms are Less Important than Other Personal Values**

603 Surprisingly, social acceptability was not a primary factor in student preference. We
604 suspect that it was a combination of education and values that align with participating in a
605 toilet system that helps instead of harms is more important than maintaining the status
606 quo. When students learned of the options and realized that some had a higher likelihood
607 of using human waste as a resource, even if it was different than the social norm and would
608 require greater awareness of the reality of creating human excrement, they valued toilet
609 systems that would do no harm. This knowledge and different perspectives on a toilet
610 system may have inspired them to want a system that would allow them to transform a
611 potentially hazardous substance into something that contributes to life. Students

612 explanations of using resources wisely to be able to turn “waste '' into something good that
613 won’t cause harm echoes the cultural phenomenon of admiring the ability to transform a
614 pollutant into something safe and useful (43).

615 Our research supports the narrative that people’s sense of disgust is malleable and
616 diminishes with education and the desire to care for something (22,31). The values
617 identified in the analysis are consistent with anecdotal evidence from case studies where
618 people reported being pleased with adopting a system that helps regenerate the land
619 (20,46). These observations point to a shifting landscape of what people in the United
620 States want from toilet systems. We see that the desire is to have a toilet system that
621 maximizes the potential of water and nutrients as a natural resource. Lastly, our findings
622 support the effectiveness of focusing on future thinking about how individual use of toilet
623 systems in a household can impact the local environment (47). The implication is that the
624 threshold for overcoming the social stigma barrier may not be as high as some literature
625 suggests (44,45).

626 **Limitations and Future Work**

627 The sample of convenience was in a natural science-related undergraduate course
628 who were predisposed to caring for the Earth. The sample size did not allow for analysis
629 among student demographics and toilet preference or values. Influence via an instructor
630 cannot be ruled out. We are aware that students have limited experience with
631 homeownership; thus, their preferences only reflect what they imagine as ideal. While this
632 limits their ability to anticipate some challenges, it does not compromise the significance of
633 finding that students prefer systems that will treat their human biowaste differently than

most conventional systems. A longitudinal study to determine if students follow through with realizing their ideal toilet system would give insight into the reasons and circumstances that prevent or lead to adopting alternative toilet systems.

More research is needed with populations who have not experienced the module as a control group to determine if these findings could be more generalizable. Future work should also include various populations (e.g., different age groups, majors, or regions). The analysis would allow for comparing values and reveal disparities and commonalities among diverse populations. Findings would further the ability to target education and messaging to specific groups and predict the likelihood of adopting different toilet systems.

The codebook can be used as an analysis tool to investigate how values may influence the adoption of other innovative household infrastructure. The themes and categories can be applied to a broader context. For example, the codebook can be used to analyze responses that consider the type of energy source (e.g., solar or wind). Applying the codebook to other kinds of infrastructure options would help further the theory of how values determine decision-making as it relates to pro-environmental behavior.

CONCLUSION

When given the freedom to dream, people want more sustainable toilet systems. The next generation of homeowners prefers toilet systems that are *not* the current wastewater systems—they want toilet systems to be a source for creating something "good". Our research posits that the value of wanting to be part of something good overcomes the feeling of disgust associated with social taboos related to human excrement.

Young adults in this sample population prefer toilet systems that "capture and cultivate" the water and nutrients in urine and feces instead of treating them as waste.

The developed codebook serves as a dynamic framework that helps anticipate engaging topics and values that resonate with individuals. Advocates can leverage this tool to make informed decisions and shape narratives. The outlined themes can guide the creation of educational, outreach, and marketing materials that foster a deeper connection between individuals and sustainable toilet systems.

Building on our findings, we propose targeted approaches to address emotional and logistical (cognitive) aspects of toilet systems, emphasizing their alignment with fundamental values. Moreover, our recommendations underscore the importance of showcasing both the positive environmental contributions of well-managed regenerative systems and the potential harm resulting from conventional systems and inadequate management. We recommend illustrating the treatment process and the outcomes of conventional, reclamation, and regenerative toilet systems and having people imagine how a toilet system aligns with their values. Sustainable sanitation advocates should focus on describing how a system uses water and nutrients to contribute to the overall well-being of communities and the natural environment.

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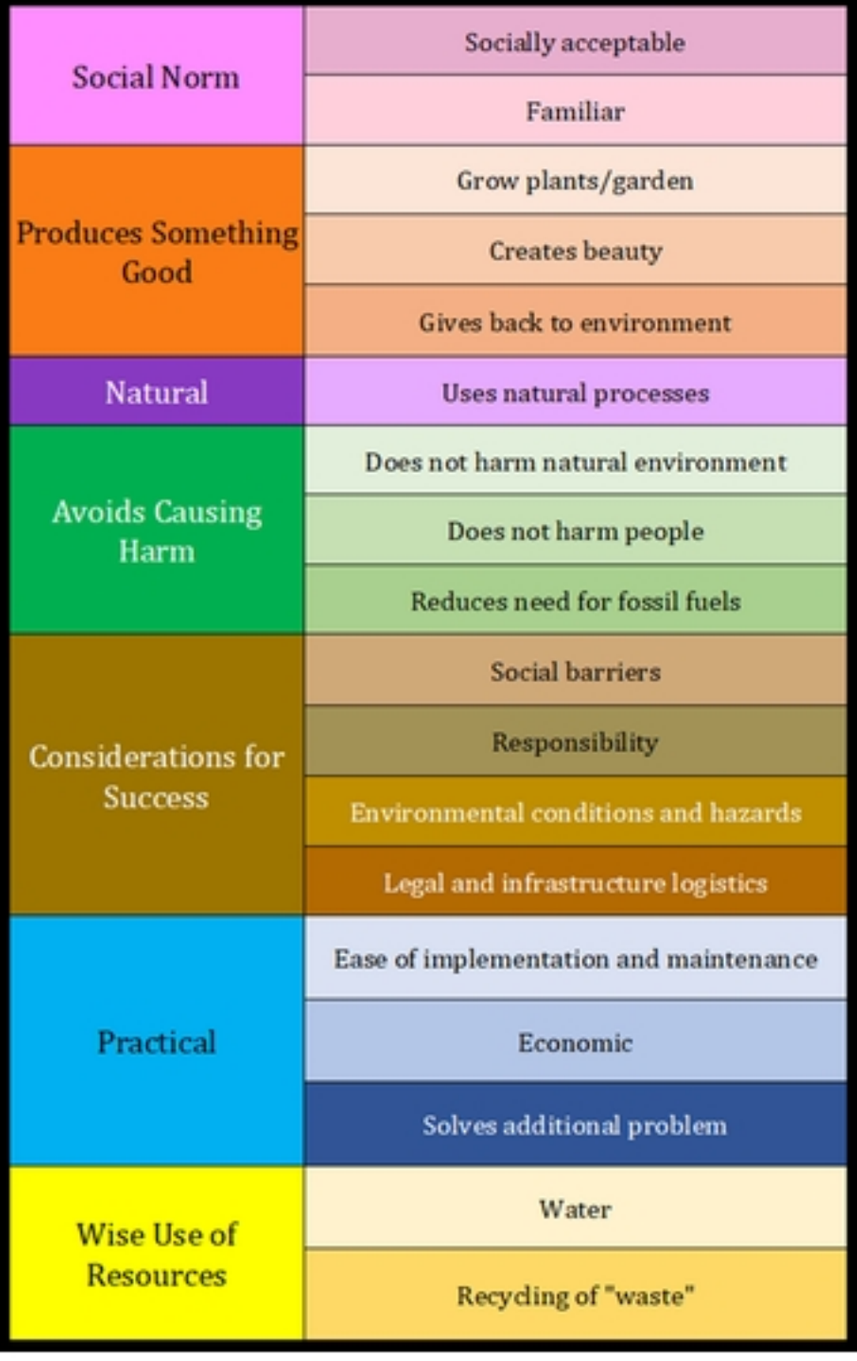
Social Norm
Socially acceptable
Familiar
Produces Something Good
Grow plants/garden
Creates beauty
Gives back to environment
Natural
Uses natural processes
Avoids Causing Harm
Does not harm natural environment
Does not harm people
Reduces need for fossil fuels
Considerations for Success
Social barriers
Responsibility
Environmental conditions and hazards
Legal and infrastructure logistics
Practical
Ease of implementation and maintenance
Economic
Solves additional problem
Wise Use of Resources
Water
Recycling of "waste"

Fig 2

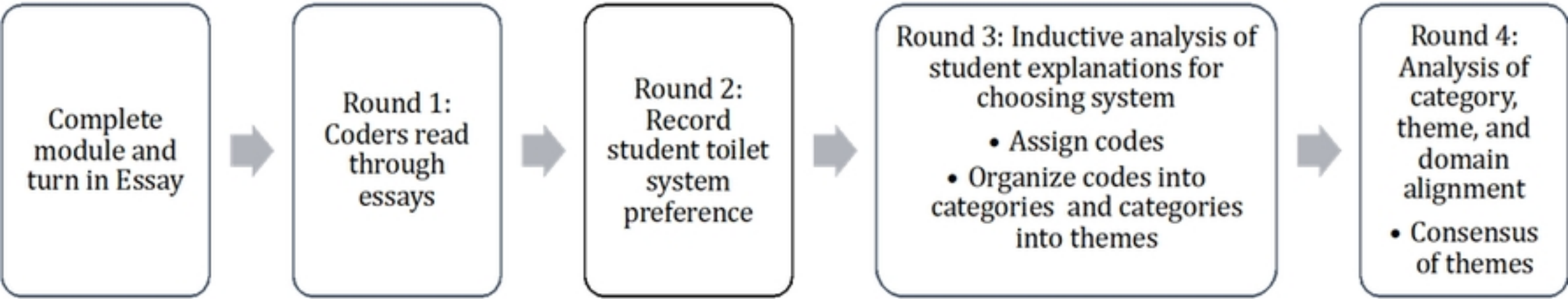
Complete module and turn in Essay
Round 1: Coders read through essays
Round 2: Record student toilet system preference
Round 3: Inductive analysis of student explanations for choosing system
• Assign codes
• Organize codes into categories and categories into themes
Round 4: Analysis of category, theme, and domain alignment
• Consensus of themes

Fig 1

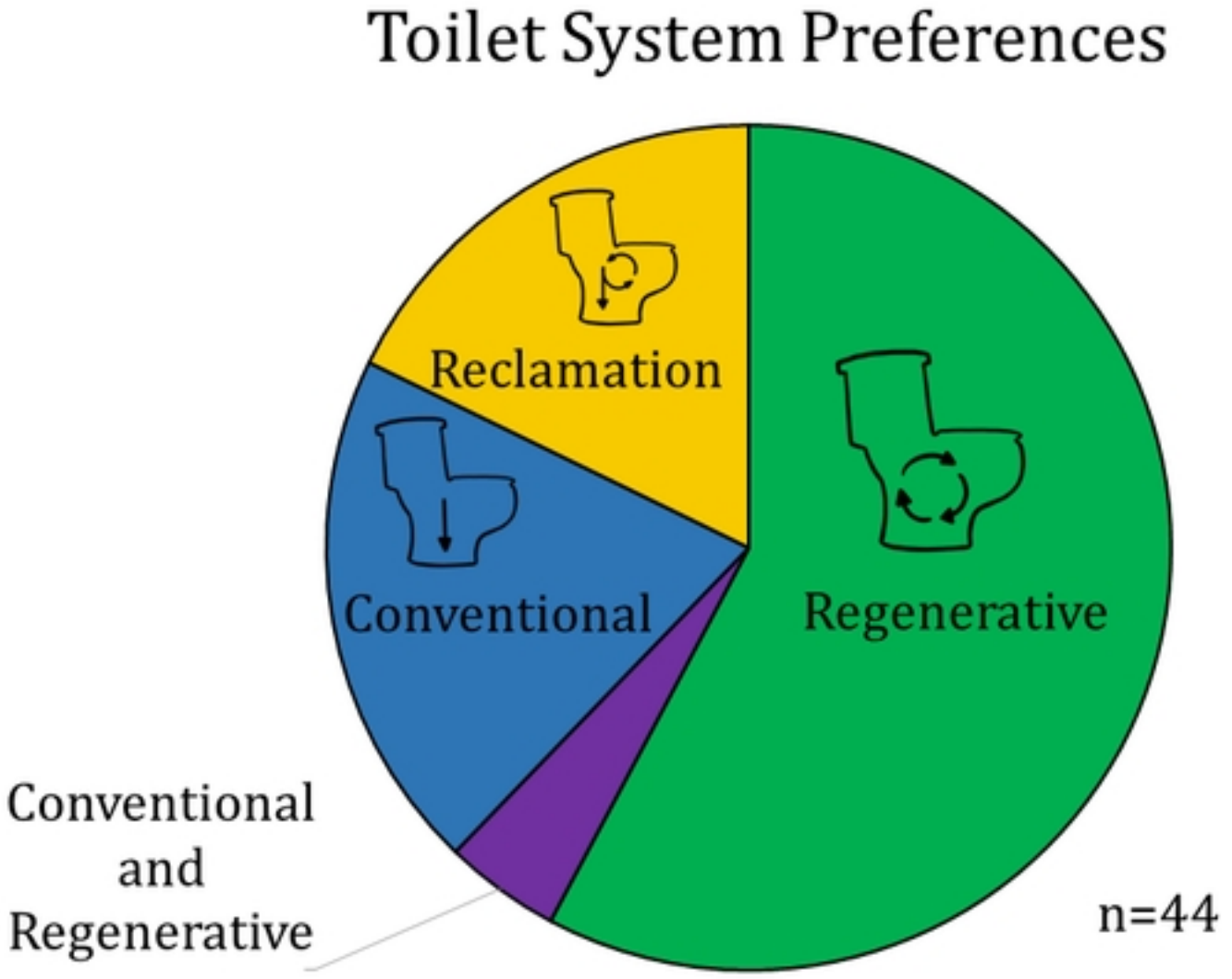
Toilet System Preferences
Reclamation
Conventional
Regenerative
Conventional and Regenerative
n=44

Fig 3

An individual uses the emotional and cognitive domains when considering attributes of a toilet system

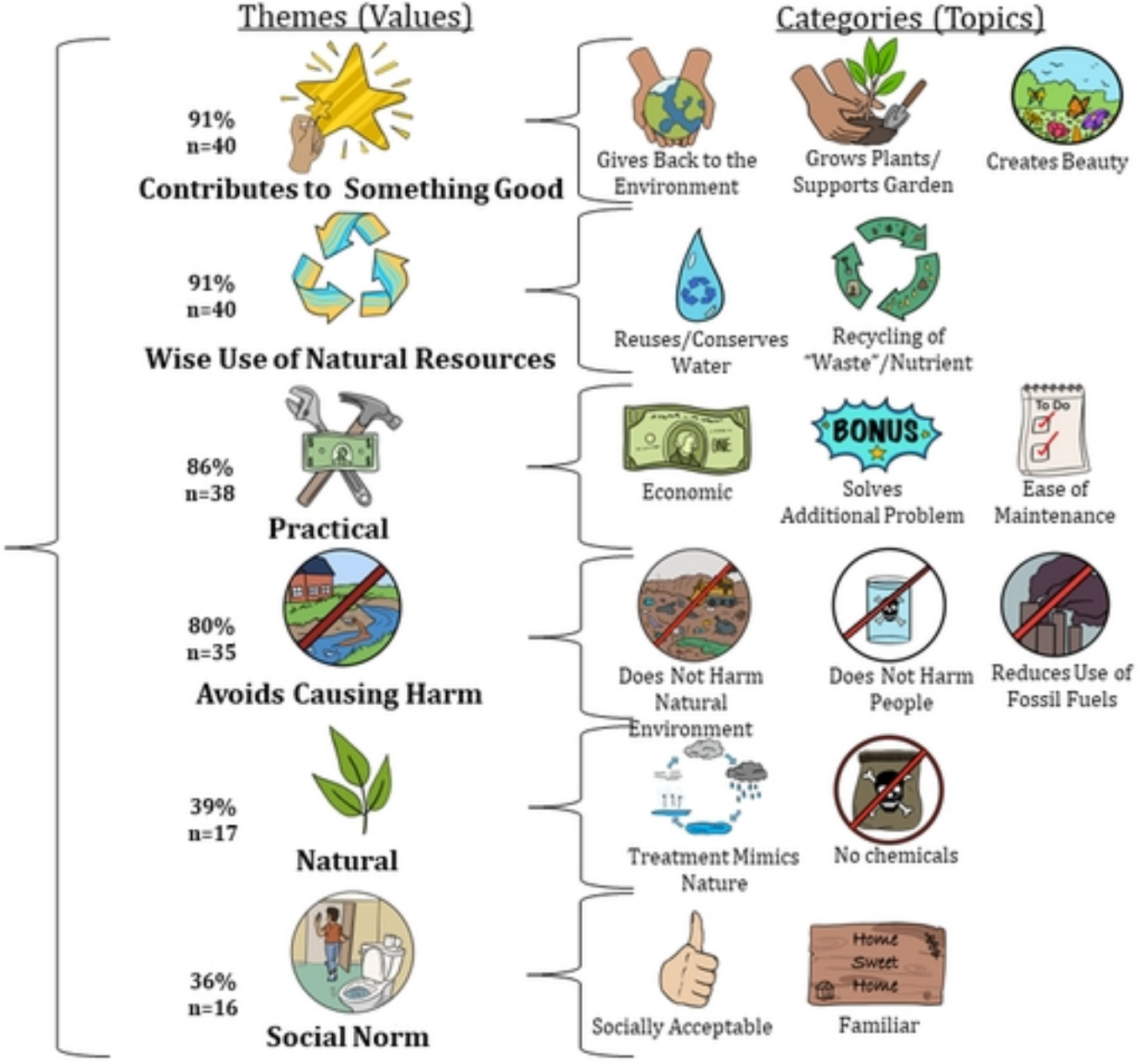

Fig 4

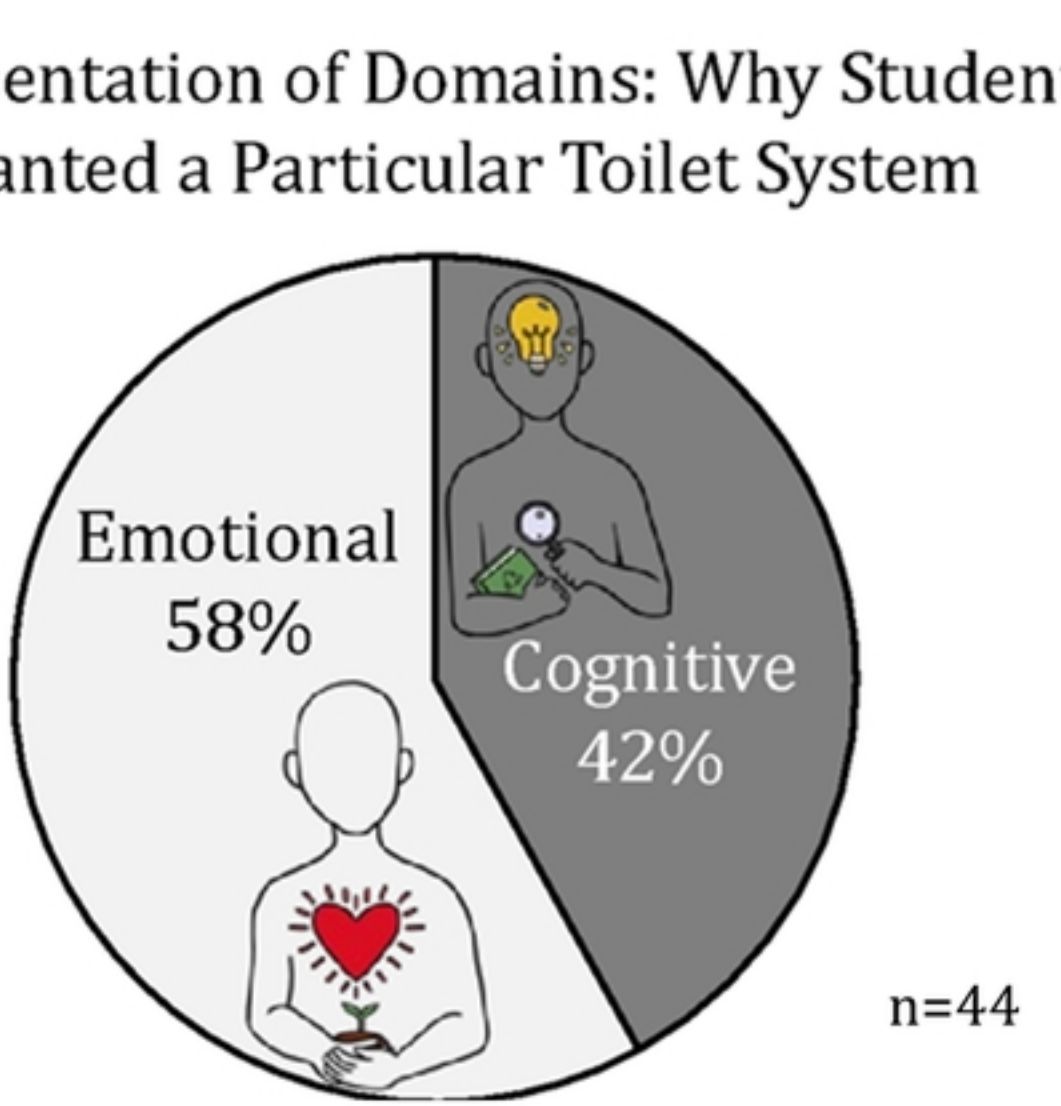
Representation of Domains: Why Students Wanted a Particular Toilet System
Emotional
58%
Cognitive
42%
n=44

Fig 5