Using survey questions to identify and learn more about those who exhibit design thinking traits

Jacqualyn Blizzard, Denver Schools of Science and Technology Public Schools, 2000 Valentia St, Denver, CO 80238, USA
Leidy Klotz, Glenn Department of Civil Engineering, Clemson University, 208 Lowry Hall, Clemson, SC 29634, USA
Geoff Potvin, Department of Physics and STEM Transformation Institute, Florida International University, Miami, FL 33199, USA
Zahra Hazari, Department of Teaching & Learning and STEM Transformation Institute, Florida International University, Miami, FL 33199, USA
Jennifer Cribbs, School of Teacher Education, Western Kentucky University, Bowling Green, KY 42101, USA
Allison Godwin, Department of Engineering Education, Purdue University, West Lafayette, IN 47907, USA

Questions intended to identify design thinking traits were developed and tested on a national survey distributed to U.S. college students. By applying exploratory factor analyses and regression models to the survey data, nine of the questions were mapped to five related characteristics of design thinking: collaboration, experimentalism, optimism, feedback-seeking, and integrative thinking. Survey questions alone cannot fully identify the qualitative traits of design thinkers, but these nine questions do enable basic exploration of compelling relationships between design thinking traits and other variables. Our analyses found design thinking traits correlated with higher achievement; with a desire for careers helping others and solving societal problems; and with recognition of and desire to address sustainability obligations.

Keywords: design thinking, design behavior, research methods, sustainability

Researchers have long been interested in design thinking and other terms used to express similar concepts. *Design Thinking* is the title of Rowe's 1987 book on the topic. An initial 'Design Thinking Research Symposium' was held at Delft University of Technology in the Netherlands in 1991 and 2014 saw the 10th of these Symposia, which have been held at leading research Institutions all over the world (Open University Design Group, 2014). This *Design Studies* journal has devoted a 2013 special issue, edited by Paul Rodgers, to 'Articulating Design Thinking' and a 2011 special issue, edited by Susan Stewart, to 'Interpreting Design

Corresponding author:
L. Klotz
leidyk@g.clemson.edu

www.elsevier.com/locate/destud
0142-694X *Design Studies* **38** (2015) 92–110
http://dx.doi.org/10.1016/j.destud.2015.02.002

Thinking.' Dorst's 2011 *Design Studies* article provides an excellent detailed review of the history of the concept in research. In recent years, the design thinking concept has reached a broader audience as practitioner/educators like Tim Brown demonstrate and communicate the value of design thinking with examples of applications to fields including management and service industries (Brown, 2008).

Just as there are various terms for design thinking, there are multiple definitions for each of these terms (Blizzard & Klotz, 2012; Charnley, Lemon, & Evans, 2011; Coley & Lemon, 2009). This ambiguity should be embraced; a constant definition is not necessarily needed, or even desirable. Indeed, we agree with Dorst (2011), who points out the dangers of trying to oversimplify concepts for study in a field that 'cherishes multiple perspectives and rich pictures.' Based on the literature, design thinking traits include, but are not necessarily limited to: asking questions and seeking input from others to make decisions and change directions; analyzing at a detailed and holistic level to develop novel solutions; resilience to not back down from challenging problems; predisposition to ask questions and take new approaches to problem solving; and the ability to work with many different disciplines. Again, these are just some commonly mentioned design thinking traits, not a strict definition. The evolving concept of design thinking and the related terms and definitions require continuous study. This is occurring in practice (e.g., Brooks, 2010; Martin, 2009) and among students in various engineering and architecture disciplines (e.g., Goldschmidt & Rodgers, 2011; Adams, Daly, Mann, & Dall'Alba, 2011; Carmel-Gilfilen & Portillo, 2010).

While there may never be agreement on a single definition of design thinking, the need for design thinkers is widely recognized (e.g., (Brown, 2008; Charnley et al., 2011; Coley & Lemon, 2009; Dym, 2008; Dym, Agogino, Eris, Frey, & Leifer, 2005)). The research we present in this paper, and research that builds on it, can help advance understanding about design thinkers – those who exhibit design thinking traits.

While the nuanced, diverse, and evolving conceptions of design thinking must be studied and kept in mind, quantitative approaches to identify design thinkers are also a worthy goal for research. This article describes the design, testing, and analysis of survey questions to measure design thinking traits, and the subsequent statistical analysis which demonstrated that those with these traits are also more likely to possess qualities such as career outcome expectations and sustainability beliefs and actions that make them well-suited to address humanity's biggest challenges.

1 Background and method

This study was comprised of two major components: (1) developing, testing, and refining design thinking survey questions and, (2) using the preliminary

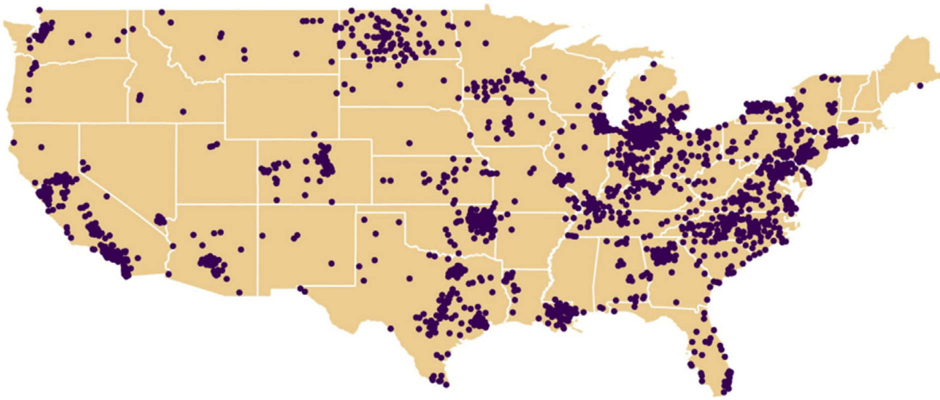

Figure 1 SaGE respondent distribution. Dots indicate home zip codes for one or more respondents. Figure created using (Wickham, 2009) and (Lewin-Koh et al., 2011)

measures of design thinking to explore relationships between design thinking and other qualities of interest. Literature served as the foundation for the initial development of a series of questions intended to identify design thinkers. After evaluating and modifying these questions through an iterative process to improve face and content validity, 18 questions were included as a part of the Sustainability and Gender in Engineering (SaGE) survey distributed to a national sample of college students in the U.S. (N = 6772). Statistical analyses were applied to these survey responses to further reduce these 18 questions down to those which appear to best indicate design thinking traits. These survey items were then used to characterize the level of design thinking traits among responding students. Finally, regression models were employed to evaluate relationships between levels of design thinking and other qualities of interest, which were measured through other items on the same national survey.

1.1 Data collection

Data for the analysis came from the Sustainability and Gender in Engineering (SaGE) survey, which was administered using an approach modeled after previous national studies (Potvin, Hazari, Tai, & Sadler, 2009). A random sample of institutions was recruited for participation using a comprehensive list of U.S. colleges and universities provided by the National Center for Educational Statistics. The sample was stratified by institution type and the number of enrolled students: 4-year large (23 051 or above), 4-year medium (7751−23 050), 4-year small (7750 or less), 2-year large (15 650 or above), 2-year medium (6726−15 650), and 2-year small (6725 or less). Institutions were recruited to participate in the study through an initial email and then through follow-up phone calls and emails. Ultimately, all 50 institutions which agreed to participate in the research returned some number of student surveys (100% institutional response rate). In total responses were received from 6772 individuals enrolled at these 50 institutions. Home zip codes of respondents are shown in Figure 1.

Between October and December of 2011, representatives at the randomly selected participating institutions distributed the paper-based SaGE survey to students as part of their introductory college English classes. Surveying students in introductory English classes allowed researchers to collect a sample that included perspectives of students interested in all majors. The SaGE survey is designed to take 20–30 min. It includes 47 anchored, numerical, multiple choice, and categorical questions. The survey is divided into 5 sections: Your Career Goals, Your High School Experiences, Sustainability and You, About You, and Demographic Questions. Analysis of the SaGE data was performed using the R language and environment for statistical computing (Team, 2012).

1.2 Background and methods to develop, test, and refine questions intended to identify design thinkers

A list of questions were drafted intended to identify design thinking traits. Initial questions were based on literature summarized in Blizzard and Klotz (2012) and Blizzard, Klotz, Pradhan, and Dukes (2012). Prior to inclusion on the national survey, the draft questions were refined with feedback from educators with expertise in design thinking and piloted on several iterations of surveys given to students at two different 4-year institutions. Student focus groups were also conducted to gather more in-depth feedback on how questions were being interpreted. Based on the pilot testing, focus groups, and expert feedback, the draft questions were revised to eliminate or reword unclear questions while seeking to enhance their face and content validity. Ultimately, eighteen questions related to design thinking were included on the national survey. Ten of these questions asked students to report on a scale from 0 – Strongly disagree, to 4 – Strongly agree, 'to what extent do you disagree or agree with the following:' I prefer to focus on details and leave the big picture to others; I hope to gain general knowledge across multiple fields; I often learn from my classmates; I prefer to focus on the big picture and leave the details to others; I identify relationships between topics from different courses; I analyze projects broadly to find a solution that will have the greatest impact; I seek input from those with a different perspective from me; I seek feedback and suggestions for personal improvement; when problem solving, I focus on the relationships between issues; and when problem solving, I optimize each part of a project to produce the best result.

Four questions asked students to report on a scale from 0 – Not at all important, to 4 – Very important, 'how important are the following factors for your future career satisfaction:' helping others; working with people; inventing/designing things; and solving societal problems.

Finally, four questions asked students to report on a scale from 0 – Strongly disagree to 4 – Strongly agree, 'to what extent do you disagree or agree with the following:' environmental problems make the future look hopeless; I can personally contribute to a sustainable future; nothing I can do will make things better in other places on the planet; and I think of myself as part of nature, not separate from it.

1.2.1 Exploratory facor analyses and regression modeling

A series of exploratory factor analyses (EFA) and regression models were applied to this data, which reduced the 18 potential questions to nine final questions. Results from the EFA's elucidated the pattern of correlations between observed measures, in this case the 18 questions intended to identify design thinking. EFA can be applied to identify relationships between individual questions and underlying factors. For example, one hypothesis could be that an EFA of the data will reveal recognized traits of design thinkers, such as empathy and collaboration (Brown, 2008), as some of the underlying factors for our questions. In EFA results, highly correlated questions are likely influenced by the same underlying factors, while uncorrelated questions are likely influenced by different factors (DeCoster, 1998). Factors are one way to determine which of the 18 potential design thinking questions group together. An EFA also helps detect misfit questions that do not group with the others. Detecting misfits helped narrow down the list of design thinking questions to only include those which fit into the statistically significant and logical factor structure.

In EFAs, statistical methods are a guide, but researchers must also make decisions based on their judgment. Determining the initial number of factors to search for in the EFA is one such example. Purely statistical methods, such as scree tests and parallel analysis, can help with this decision (Osborne, 2008; Rietveld & Van Hout, 1993). For responses to the 18 design thinking questions, the scree-test suggested extracting nine factors while the parallel analysis suggested eight. We also explored an appropriate number of factors by developing a matrix showing the correlations between each pair of questions. Clustering in this matrix showed fewer underlying factors than were suggested by the scree test and parallel analysis. Also supporting a smaller number of factors was the consideration that, in the literature, design thinking is typically defined with fewer characteristics than the scree and parallel analysis tests were recommending. Combining these considerations with statistical testing of structures ranging from nine down to three factors, a five factor structure was ultimately selected. Further description of this process is provided in the results section.

1.3 Background and methods for exploring relationships between design thinking traits and other qualities

Students' level of design thinking traits were determined by calculating a variable based on their responses to the nine design thinking questions. Numerical responses for positive indicators of design thinking were added together and numerical responses to negative indicators were subtracted from this overall value. Responses from the 4287 students who responded to all of the relevant questions were included in the regression analyses. Students with scores in the top quartile were grouped and compared with students scoring in the lower quartile.

1.3.1 Linear regression

Regression analysis was used to study relationships between design thinking traits and other characteristics. In a linear regression, observed data is used to fit a model of the relationship between a scalar dependent variable (design thinking in our case) and one or more explanatory variables (Teetor, 2011). In the regression models, the R^2 statistic represents the proportion of variance in the dependent variable that is accounted for by the sum of the explanatory variables, and is one measure of significance of fit (Coolican, 2009). For example, if a regression analysis between happiness and income yields an R^2 value of 10%, then the explanatory variables (income) are accounting for 10% of the variance in the dependent variable (happiness). In this hypothetical regression example, one would also try to control for other variables (e.g., family, friends, health) that also impact happiness.

Potentially confounding control variables were considered in this study of design thinking. Control variables were considered in order to account for students': prior performance (using an academic performance index combining reported grades and standardized test scores in science, math, and English); socioeconomic status (as measured through a common proxy - the highest level of education for their parents/guardians); gender; race; and family support (in particular, family members who contributed to their career path selection). For the regression analysis, control variables were normalized to a scale between 0 and 1 to enable comparison across variables.

After considering control variables, regression analyses were performed to determine relationships between levels of design thinking and our exploratory variables of interest: career outcome expectations, and sustainability beliefs and actions.

1.3.2 Career outcome expectations

Relationships between design thinking traits and career outcome expectations were analyzed. An outcome expectation is a belief about what will result from a course of action and differs from a goal, which is related to intentions to pursue a course of action (Lent et al., 2003). For example, a student might have a career goal to become an engineer because they have an associated outcome expectation to help solve societal problems. Outcome expectations have been found to be influential in multiple frameworks conceptualizing career choice (Lent, Brown, & Hackett, 1994; Matusovich, Streveler, & Miller, 2010; Wigfield & Eccles, 2000).

One way career outcome expectations were evaluated was through factors important to career satisfaction. The relevant question on the SaGE survey asked respondents: 'How important is the following factor for your future career satisfaction?' with the response options: making money, becoming well known, helping others, supervising others, having job security and opportunity, working with people, inventing/designing things, developing new knowledge and skills, having lots of personal and family time, having an easy job, being in an exciting environment, solving societal problems, making use of my talents and abilities, doing hands-on work, and applying math and science. Responses were provided on a 5 point anchored-scale ranging from '0 - not at all important' to '4 — very important.'

Students' sustainability-related career outcome expectations were also evaluated through a SaGE question asking: 'Which of these topics, if any, do you hope to directly address in your career? (Mark ALL that apply)' Binary response options included: energy (supply or demand); disease; poverty and distribution of wealth and resources; climate change; terrorism and war; water supply (e.g., shortages, pollution); food availability; opportunities for future generations; opportunities for women and/or minorities; and environmental degradation. These response options were drawn from Nobel Prize winner Richard Smalley's list of the ten most pressing challenges facing humanity (Smalley, 2003). Any list like this is necessarily limited, but Smalley's challenges provide response options with which students are more likely to be familiar and which span across environmental, social, and economic dimensions of sustainability. Students were asked which topics they hope to 'address,' indicating whether or not they intend to apply themselves to each issue. So, student responses were useful for identifying sustainability-related outcome expectations, as opposed to the actual level of sustainability of the students' planned actions.

1.3.3 Sustainability beliefs and actions

The relationships between students' design thinking traits and their sustainability beliefs and actions were also investigated. A series of established statements were used to measure these sustainability beliefs and actions (Clayton, 2003; Guagnano & Markee, 1995; Nisbet, Zelenski, & Murphy, 2009). For beliefs, students responded to the following statements on a 5-point Likert-scale ranging from 0 - Strongly disagree to 4 — Strongly agree:

- We can pursue sustainability without lowering our standard of living.
- I feel a responsibility to deal with environmental problems.
- I have the knowledge to understand most sustainability issues.
- I think of myself as part of nature, not separate from it.
- We should be taking stronger actions to prevent the worst effects of climate change.
- Climate change is caused by humans.

- Human ingenuity will ensure that we do not make the earth unlivable.
- Environmental problems make the future looks hopeless.
- Pursuit of sustainability will threaten jobs for people like me.
- Sustainable options typically cost more.

The series of statements measuring actions were also adapted from the established scales and chosen to represent influential sustainability options ranging from small daily choices to longer term commitments. For the following statements, students responded to the question 'How likely are you to do the following?' on a 5-point Likert-scale ranging from 0 - Not at all likely to 4 – Extremely likely:

- Put on more clothes rather than turn up the heat when I'm cold.
- Use less water when taking a shower or bath.
- Evaluate the necessity of things I buy.
- Consider the energy/carbon/ecological impact of my food choices.
- Reuse bottles for water, coffee, or other drinks.
- Choose public transportation, carpool, bicycle or walk as a means of transportation.
- Buy a product because it is environmentally friendly.
- Take sustainability related courses in my area of academic interest.
- Contribute time or money to an environmental group.
- Educate others about the importance of these or similar actions.

2 Results and analysis

Exploratory factor analyses and regression models were applied to the SaGE survey response data to further evaluate the 18 potential design thinking trait questions. Together, these statistical analyses helped eliminate misfit questions so that, ultimately, nine questions emerged as preliminary identifiers of design thinking traits. These nine questions served as the basis of a design thinking variable that was used to explore possible relationships between design thinking and other variables of interest.

2.1 Results and analysis of questions intended to identify design thinking traits

EFA was used to refine the list of 18 potential design thinking indicators. Results from an EFA showed the pattern of correlations between observed measures, in this case the 18 questions intended to identify design thinking traits. For responses to the 18 design thinking questions, the scree-test suggested extracting nine factors while the parallel analysis suggested eight. A matrix was also developed showing the correlations between each pair of questions. Clustering in this matrix pointed to fewer underlying factors than were suggested by the scree test and parallel analysis. The literature also suggested the use of fewer factors since design thinking is typically defined with fewer characteristics than the scree and parallel analysis tests were recommending. Based on

Table 1 Initial EFA[a,b] including all 18 potential design thinking questions (p = 1.01e−131)

Question (SaGE number)	*Factor*				
	1	*2*	*3*	*4*	*5*
Helping others (1c)			**0.65**		
I seek input from those with a different perspective from me (24h)	**0.86**				−0.14
I think of myself as part of nature, not separate from it (22k)		**0.65**			
I prefer to focus on details and leave the big picture to others (24a)	0.15			0.26	
I prefer to focus on the big picture and leave the details to others (24d)	0.12			0.23	0.11
I identify relationships between topics from different courses (24f)	**0.41**				0.36
I analyze projects broadly to find a solution that will have the greatest impact (24g)	**0.45**				0.44
When problems solving, I focus on the relationship between issues (24j)	**0.69**				
When problem solving, I optimize each part of a project to produce the best result (24m)	**0.41**				0.26
Solving societal problems (1l)	−0.10	0.11	**0.39**		0.19
Environmental problems make the future look hopeless (22d)	−0.14	**0.52**		0.27	−0.11
I can personally contribute to a sustainable future (22e)		**0.58**		−0.23	
Nothing I can do will make things better in other places on the planet (22h)		−0.12		**0.74**	
Inventing/designing things (1g)		0.14			0.18
I seek feedback and suggestions for personal improvement (24i)	**1.08**				−0.50
Working with people (1f)		−0.14	**0.69**		
I hope to gain general knowledge across multiple fields (24b)	**0.41**	0.15			
I often learn from my classmates (24c)	**0.43**		0.14		

[a] For all EFAs, we used maximum likelihood extraction, the preferred method for normally distributed data (Osborne, 2008). This extraction technique finds the communality values that minimize the chi square goodness of fit test.

[b] Another judgment in the EFA is the appropriate ‘rotation’ to simplify and clarify the data structure. We applied the oblique rotation method, promax, which achieves the simplest factor structure when between-factor correlation is expected. Promax rotation involves: orthogonal rotation of the matrix; production of a target matrix by raising the factor pattern/structure coefficients to an exponent greater than 2 (usually 3 or 4); and Procrustean rotation of the original matrix to a best-fit rotation with the target matrix. Factor rotation does not improve the basic aspects of the analysis but rather redistributes the variance that has been previously explained by the extracted factors, which results in better fitting solutions that are more replicable across studies (Osborne, 2008).

these considerations, and after testing the statistical significance of structures ranging from nine down to three factors, a five factor structure was ultimately selected. Table 1 shows the results of our initial EFA using five factors and all 18 questions.

When interpreting the EFA, the numbers in the columns of Table 1 are called ‘factor loadings,’ which represent the strength of the linear relationship between the factors and the measured observations for the corresponding question. For example, the question ‘I prefer to focus on details and leave the big picture to others (24a)’ loaded with factor 1 (0.15), but more closely with factor 4 (0.26). When interpreting the factor loadings, questions with loadings of 0.3 or higher were sought in alignment with recommendations by Rietveld and Van Hout (1993). Therefore the question 24a (along with questions 24d and 1g) did not load at all in this initial EFA. The bold numbers in Table 2 represent the questions that did load into factors. So, for this particular EFA, factor one includes questions 24h, 24f, 24g, 24j, 24m, 24i, 24b, and 24c; factor 2 includes questions 22k, 22d, and 22e; and so on.

Table 2 Final EFA, including nine questions to measure design thinking ($p = 0.093$)

Question (SaGE number)	*Factor*				
	1	*2*	*3*	*4*	*5*
I seek input from those with a different perspective from me (24h)	**0.69**		0.17		
I identify relationships between topics from different courses (24f)		0.11	**0.38**	0.29	
I analyze projects broadly to find a solution that will have the greatest impact (24g)			**0.84**		
when problems solving, I focus on the relationship between issues (24j)		**0.99**			
I can personally contribute to a sustainable future (22e)			0.12	0.20	**−0.30**
Nothing I can do will make things better in other places on the planet (22h)					**0.43**
I seek feedback and suggestions for personal improvement (24i)	**0.77**				
I hope to gain general knowledge across multiple fields (24b)				**0.58**	
I often learn from my classmates (24c)	0.20			**0.50**	

The goal of the EFA process is to get a sensible factor structure to emerge so that one can begin to hypothesize what underlying factors cause the questions to group. One indication that the factor structure is suitable for interpretation is when the p-value is above 0.05. The initial factor structure in Table 2 has a p-value (1.01e−131) which is well below this target, meaning that the structure does not capture sufficient detail of our dataset. Thus further improvements on the factor structure were needed.

Interpreting the EFA shown in Table 1, it appeared that many of the questions loaded according to their general survey grouping; questions from question 24 grouped together, questions from question 1 grouped together, and questions from question 22 grouped together. This clustering suggested that, with 18 questions, underlying design thinking factors were unable to overcome the fact that particular questions were purposefully written along common themes. It appeared that eliminating questions might improve the factor structure. In cases such as this, candidates for elimination are questions that loaded alone or did not load at all, meaning they did not have a factor loading of 0.3 or higher for any of the five factors. Three of the eighteen questions (Q24a, Q24d, Q1g) were therefore eliminated in the next EFA.

In an EFA which excluded these misfit questions, all of the questions loaded to one of the five factors. However, most of the questions loaded to factor one, many questions loaded with their general question grouping, and the p-value remained well below 0.05. Based on these results, the three remaining questions from question 1 were removed, as well as question 22k. The resulting structure was an improvement, but the p value remained low, many of the questions from question 24 continued to load together, and questions 24a and 24d continued to load on the lower end of the acceptable range when compared with other questions. Therefore questions 24a and 24d were dropped from the subsequent EFA, but it was not until question 24m was removed that the p-value made a significant jump. Finally, adding question 22e back

Table 3 Linear regression example of design thinking traits and selected career outcome expectations

	Design thinking question[a]								
Outcome expectation	24h	24f	24g	24j	22e	22h	24i	24b	24c
Helping others	***	*	n/s	n/s	***	(**)	***	n/s	***
Working with people	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	***
Inventing/Designing things	*	**	**	**	**	n/s	n/s	***	*
Developing new knowledge and skills	***	***	***	***	***	n/s	***	***	**
Solving societal problems	**	***	***	***	***	(*)	*	***	n/s

[a] Throughout this paper, *** = $p < 0.001$, ** = $p < 0.01$; * = $p < 0.05$; n/s = not significant.

into the analysis brought the p value to 0.093, above the 0.05 threshold, which meant that the resulting factor structure, shown in Table 2, could serve as a basis for interpretation.

2.1.1 Linear regression to complement the Exploratory Factor Analysis

Linear regression, which models the relationship between a scalar dependent variable and one or more explanatory variables, was used to complement the findings of the EFA (Teetor, 2011). Multiple linear regression analyses were run to see relationships between the design thinking traits from Table 2 and other variables from the SaGE survey that were expected to possibly correlate with design thinking. When the regression analysis showed these correlations were present, the research team had more confidence that the design thinking questions were in fact measuring a unique construct. This type of approach, combining EFA with regression analyses, is also used to refine psychological scales (Egede, 2010; Ray et al., 2006).

Table 3 shows selected results from multiple linear regression analyses that were conducted to see how indicators of design thinking correlate with career outcome expectations. As shown in Table 3, many of the design thinking items have a predictive relationship with career outcome expectations and the direction of the relationship mostly followed expectations. For example, question 22h – 'Nothing I can do will make things better in other places on the planet,' negatively correlated with a desire to find a career where they will be helping others.

Table 3 is just a summary. In all, the nine questions measuring design thinking questions were compared with 122 other variables measured through SaGE survey questions. Significant variables including parents' education, academic achievement, race, gender and citizenship were controlled for in the analyses. The regression analyses confirmed that question 22d was likely a misfit as this question correlated significantly with just 43 out of 122 variables in the regression analyses, which was more than two standard deviations below the mean number of significant items (60) for the design thinking questions we evaluated.

Table 4 Design thinking traits and related questions

Design thinking traits	Questions
Feedback Seekers - they ask questions and look for input from others to make decisions and change directions.	I seek input from those with a different perspective from me. I seek feedback and suggestions for personal improvement.
Integrative Thinking - they can analyze at a detailed and holistic level to develop novel solutions.	I analyze projects broadly to find a solution that will have the greatest impact. I identify relationships between topics from different courses.
Optimism - they don't back down from challenging problems.	I can personally contribute to a sustainable future. Nothing I can do will make things better in other places on the planet (negative).
Experimentalism - they ask questions and take new approaches to problem solving.	When problem solving, I focus on the relationships between issues.
Collaboration - they work with many different disciplines and often have experience in more than just one field.	I hope to gain general knowledge across multiple fields. I often learn from my classmates.

Our interpretation of the factor structure mapped the nine questions to five related traits of design thinking; collaboration, experimentalism, optimism, feedback-seeking, and integrative thinking. The traits, shown below in Table 4, align closely with the literature (Blizzard & Klotz, 2012; Brown, 2008; Dym et al., 2005). The underlying factor termed feedback seekers includes those who seek suggestions for personal improvement and who seek input from others with differing opinions. This factor aligns with what Brown calls empathy and with Dym et al.'s recognition of the need to work as 'part of a team in a social process.' The underlying factor referred to as integrative thinking includes those who analyze topics broadly and seek relationships between topics. Brown also identifies integrative thinking as a characteristic of design thinkers and Dym et al. emphasize that design thinkers are those who 'maintain sight of the big picture.' The optimism factor also corresponds with one of Brown's characteristics and includes those who believe they can personally contribute to a sustainable future and believe that their actions can make things better in other places on the planet. The design thinking question about problem solving and the relationships between issues was originally intended to look for integrative thinking but did not group with the other questions in this factor. Instead, this question may be more closely aligned with what Brown refers to as experimentalism and what

Dym et al. call ‘handling uncertainty and tolerating ambiguity.’ Finally, the collaboration factor includes those who often learn from their classmates and hope to gain general knowledge across multiple fields. Brown also recognizes collaboration, which Dym et al. call ‘thinking and communicating in the several languages of design.’

2.1.2 Internal consistency of the questions

Internal consistency of a set of questions is an indicator of whether these questions measure a single latent construct, which is a variable that cannot be directly observed, but is instead inferred from other variables that can be. One measure of internal consistency is Cronbach’s alpha, which can range from 0 to 1. A larger Cronbach’s alpha value indicates greater internal consistency and a value greater than 0.7 is generally considered acceptable (Peterson, 1994). In this case, since design thinking was the latent construct, a Cronbach’s alpha was calculated for the nine design thinking questions in Table 2. These nine design thinking questions yielded a Cronbach’s alpha of 0.76, a value supporting the intention for these questions to measure a single latent construct.

2.2 Results and analysis of relationships between design thinking and other qualities

The previously described control variables (to account for prior academic performance, socioeconomic status, gender, race, and family support) were individually regressed with the design thinking traits variable. Three of these control variables were correlated with the design thinking traits in a statistically significant way and were therefore included in subsequent analyses (we used $p < 0.01$ as a threshold for significance to reduce the possibility of type 1 error because we have a large data set and ran multiple tests). Academic performance and having a father contributing to selection of career path were both positively correlated with design thinking, while male gender was negatively correlated (men were less likely to score higher on the design thinking indicator). These significant control variables were included in subsequent regression analyses examining the explanatory variables of interest.

2.2.1 Career outcome expectations

Even when accounting for significant control variables, many of the broad career outcome expectations were predictive of design thinking. Significant career outcome expectations are shown in Table 5. Positively predictive outcome expectations are those with an Est. value (second column of Table 5) that is positive. Many of these outcome expectations (e.g., helping others, solving societal problems) are those needed by individuals who want to address many of the design challenges facing humanity. Two outcome expectations, supervising others and having an easy job, have negative Est. values, meaning these outcome expectations are negative predictors of design thinking; students scoring higher on the design thinking indicator were less likely to value these self-serving career factors. Combined, the career outcome

Table 5 Relationship between level of design thinking and career outcome expectations

	Est.	SE	*Sig.*
Intercept	8.46	0.70	***
Significant Controls			
Academic Performance Index	1.78	0.46	***
Father contributed to career path	0.63	0.17	***
Broad outcome expectations			
Developing new knowledge and skills	0.86	0.10	***
Making use of my talents and abilities	0.71	0.13	***
Helping others	0.69	0.11	***
Having job security and opportunity	0.61	0.13	***
Solving societal problems	0.56	0.08	***
Being in an exciting environment	0.40	0.10	***
Applying math & science	0.36	0.07	***
Inventing/designing things	0.35	0.07	***
Supervising others	−0.41	0.08	***
Having an easy job	−0.63	0.08	***
Percent Explained (from Adjusted R^2)	**19%**		

expectations shown in Table 5 account for 19% of the variance in the level of design thinking traits.

The regression analysis with design thinking and sustainability-related outcome expectations is summarized in Table 6 and demonstrates that students scoring higher on the design thinking traits scale are more likely to want to address opportunities for future generations, environmental degradation, climate change, disease, poverty, and energy. As with the positively predictive broad outcome expectations, students who wish to dedicate their careers to these sustainability challenges are those students needed to address humanity's urgent obligations. The sustainability outcome expectations shown in Table 6 accounted for 8% of the variance in the design thinking indicator.

2.2.2 Sustainability beliefs and actions

In addition to outcome expectations, the relationships between design thinking and students' sustainability beliefs and actions were also evaluated. The directional relationship of individual sustainability belief items mostly matched expectations. As shown in Table 7, positively correlated with design thinking were beliefs such as: I have a personal responsibility to deal with environmental problems; I have the knowledge to understand sustainability issues; we should be taking stronger actions to address climate change; we can pursue sustainability without lowering the standard of living; and I think of myself as part of nature. Overall, the model shown in Table 7 accounted for approximately 28% of the variance, suggesting that sustainability beliefs are predictive of design thinking among students.

The SaGE survey also asked students how likely they were to take sustainability actions. As with the sustainability beliefs, the predictive relationships for

Table 6 Relationship between level of design thinking and sustainability outcome expectations

	Est.	SE	*Sig.*
Intercept	16.46	0.29	***
Significant control variables			
Academic Performance Index	2.40	0.46	***
Father contributed to career path	0.59	0.17	***
Sustainability-related outcome expectations			
Opportunities for future generations	1.66	0.17	***
Environmental Degradation	1.49	0.31	***
Climate change	1.47	0.40	***
Disease	1.28	0.19	***
Poverty & distribution of wealth, resources	0.72	0.21	***
Energy (supply or demand)	0.64	0.23	**
Percent Explained (from Adjusted R^2)	**8%**		

Table 7 Relationship between level of design thinking and sustainability beliefs

	Est.	*SE*	*Sig.*
Intercept	10.3	0.38	***
Significant control variables			
Academic Performance Index	1.77	0.43	***
Father contributed to career path	0.7	0.16	***
Sustainability beliefs			
I feel a responsibility to deal with environmental problems	1.11	0.09	***
I have the knowledge to understand most sustainability issues	0.90	0.08	***
We should be taking stronger actions to address climate change	0.78	0.10	***
We can pursue sustainability without lowering our standard of living	0.71	0.08	***
I think of myself as part of nature, not separate from it	0.58	0.08	***
Pursuit of sustainability will threaten jobs for people like me	−0.41	0.08	***
Climate changes is caused by humans	−0.54	0.09	***
Percent Explained (from Adjusted R^2)	**28%**		

these actions matched expectations. Overall a higher design thinking traits score correlated with: conscious consumerism, such as evaluating the necessity of purchases; resource conscious behaviors, such as putting on more clothes rather than turning up the heat; and with pursuing and spreading sustainability knowledge. Counterintuitively, design thinking was a negative predictor of considering the energy or ecological impact of food choices, perhaps because this an action not well understood or not as closely identified with sustainability as some of the others. The regression model of sustainability actions shown in Table 8 accounted for 25% of the variance in the design thinking traits indicator.

One final regression was conducted using the significant variables in Tables 5–8 to determine how much of the variance in design thinking could be explained by outcome expectations, sustainability beliefs, and sustainability actions. As shown in Table 9, these variables combined account for 41% of the variation in the design thinking traits.

Table 8 Relationship between level of design thinking and sustainability actions

	Est.	*SE*	*Sig.*
Intercept	10.84	0.33	***
Significant control variables			
Academic Performance Index	1.64	0.42	***
Father contributed to career path	0.74	0.15	***
Sustainability actions			
Evaluate the necessity of things I buy	0.80	0.07	***
Reuse bottles for water, coffee, or other drinks	0.75	0.07	***
Educate others about the importance of these or similar actions	0.70	0.09	***
Put on more clothes rather than turn up the heat when I'm cold	0.65	0.07	***
Buy a product because it is environmentally friendly	0.38	0.09	***
Take sustainability related courses in my area of academic interest	0.32	0.08	***
Consider the energy/carbon/ecological impact of my food choices	−0.26	0.08	**
Percent Explained (from Adjusted R^2)	**25%**		

Table 9 Relationship between level of design thinking and outcome expectations, sustainability beliefs, and sustainability actions

	Est.	SE	*Sig.*
Intercept	3.57	0.47	***
Significant control variables			
Father contributed to career path	0.47	0.13	***
Sustainability outcome expectations, beliefs, and actions			
Opportunities for future generations (outcome expectation)	0.81	0.14	***
I have the knowledge to understand most sustainability issues (belief)	0.75	0.07	***
Developing new knowledge and skills (outcome expectation)	0.65	0.07	***
Making use of my talents and abilities (outcome expectation)	0.62	0.10	***
I feel a responsibility to deal with environmental problems (belief)	0.59	0.08	***
Evaluate the necessity of things I buy (action)	0.57	0.06	***
We can pursue sustainability without lowering our standard of living (belief)	0.55	0.07	***
Reuse bottles for water, coffee, or other drinks (action)	0.54	0.06	***
Educate others about the importance of these or similar actions	0.46	0.07	***
Helping others (outcome expectation)	0.38	0.09	***
Put on more clothes rather than turn up the heat when I'm cold (action)	0.37	0.06	***
I think of myself as part of nature, not separate from it (belief)	0.35	0.07	***
We should be taking stronger actions to address climate change (belief)	0.34	0.08	***
Being in an exciting environment (outcome expectation)	0.33	0.08	***
Human ingenuity will ensure that we do not make the earth unlivable (belief)	0.32	0.07	***
Consider the energy/carbon/ecological impact of my food choices (action)	−0.24	0.07	***
Pursuit of sustainability will threaten jobs for people like me (belief)	−0.34	0.06	***
Having an easy job (outcome expectation)	−0.37	0.06	***
Climate changes is caused by humans (belief)	−0.43	0.08	***
Percent Explained (from Adjusted R^2)	**41%**		

3 Conclusions

For the portion of this research intending to develop and refine questions to identify those with traits of design thinkers, the exploratory factor analyses and complementary regression analysis led to the statistically significant and logical factor structure shown earlier in Table 3. Traits we see include:

feedback seeking—asking questions and looking for input from others to make decisions and change directions; integrative thinking—the ability to analyze at a detailed and holistic level to develop novel solutions; optimism—the resilience to not back down from challenging problems; experimentalism—the predisposition to ask questions and take new approaches to problem solving; and collaboration—the ability to work with many different disciplines.

There is no single correct way to interpret the latent constructs which factors are measuring. The interpretation in Table 3 is our best effort based on the literature, the data, and the questions. The design thinking traits questions represent the latest of numerous iterations, and the questions will and should continue to evolve. Identifying more questions, particularly questions that further increase the reliability of the factor structure is one desirable next step. Additional questions would also improve the validity of the design thinking indicator, as more questions would then be measuring each particular construct. Another next step would be conducting a confirmatory factor analysis to test whether questions are influencing responses in a predicted way.

Bearing these qualifications in mind, these nine questions can be useful to help identify those who exhibit design thinking traits, in particular for cases like this research, where broad categorizations rather than intricate distinctions are being made. Indeed, the nine questions allowed us to begin exploring questions like: what are the characteristics of those self-identifying as design thinkers; what are their majors; what career goals and aspirations do they have; what is their demographic profile, and how do they perform in school? The findings indicate that students with more design thinking traits are more likely to possess traits that will help them respond to humanity's most urgent problems. Design thinkers are more likely to be high achieving students who desire careers where they can help others and solve societal problems. They value opportunities for growth and development in their careers. They recognize and want to address our sustainability obligations.

This preliminary understanding of who design thinkers are and what they care about can be used to create experiences to help recruit and develop them. Those with deficiencies in certain design thinking traits could receive assignments to help them develop in these areas. Strong design thinkers could be challenged with more advanced problems. One example could be environments where students engage in hands-on design to address real-world challenges. There are countless such programs at individual institutions such as Olin College's SCOPE program in which students engage in real world problems working with industry practitioners. There are also national scale examples such as Engineers without Borders through which students engage in service learning projects. Just as Engineers without Borders connects technical learning to a generation's unique orientation to service (Pryor 2007), programs that encourage design thinking could help entrench sustainability as part of the design culture in fields from architecture to planning to engineering.

In addition to confirmatory analyses and further refinement of the design thinking indicator, future research should study how levels of design thinking traits are impacted by various interventions. How do different pedagogical strategies and extracurricular activities impact students' design thinking abilities? Do the service learning programs such as EWB help develop design thinking traits? Might students stop developing design thinking traits as they undertake certain prescriptive majors, such as engineering? Are design thinkers less likely to persist in certain majors? Understanding more about these relationships would help identify programs to serve as models to engage and develop the design thinkers humanity needs.

References

Adams, R., Daly, S., Mann, L., & Dall'Alba, G. (2011). Being a professional: three lenses into design thinking, acting, and being. *Design Studies, 32*(6), 588–607.

Blizzard, J., & Klotz, L. (2012). A framework for sustainable whole systems design. *Design Studies, 33*(5), 456–479.

Blizzard, J., Klotz, L., Pradhan, A., & Dukes, M. (2012). Introducing whole-systems design to first-year engineering students with case studies. *International Journal of Sustainability in Higher Education, 13*(2), 177–196.

Brooks, F. (2010). *The Design of Design—Essays from a Computer Scientist*. NJ: Addison Wesley.

Brown, T. (2008). Design thinking. *Harvard Business Review, 86*(6), 84.

Carmel-Gilfilen, C., & Portillo, M. (2010). Developmental trajectories in design thinking: an examination of criteria. *Design Studies, 31*(1), 74–91.

Charnley, F., Lemon, M., & Evans, S. (2011). Exploring the process of whole system design. *Design Studies, 32*(2), 156–179.

Clayton, S. (2003). Environmental identity: a conceptual and an operational definition. In *Identity and the Natural Environment: The Psychological Significance of Nature* (pp. 45–65).

Coley, F., & Lemon, M. (2009). Exploring the design and perceived benefit of sustainable solutions: a review. *Journal of Engineering Design, 20*(6), 543–554.

Coolican, H. (2009). *Research Methods and Statistics in Psychology*. Routledge.

DeCoster, J. (1998). Overview of factor analysis. Retrieved 4/28/13 from. http://www.stat-help.com/notes.html.

Dorst, K. (2011). The core of design thinking and its application. *Design Studies, 32*(6), 521–532.

Dym, C. (2008). Educating engineers for a flat world. *International Journal of Engineering Education, 24*(2), 214.

Dym, C., Agogino, A., Eris, O., Frey, D., & Leifer, L. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103–120.

Egede, L. E. (2010). Development and psychometric properties of the 12-item diabetes fatalism scale. *Journal of General Internal Medicine, 25*(1), 61–66.

Goldschmidt, G., & Rodgers, P. (2011). The design thinking approaches of three different groups of designers based on self-reports. *Design Studies, 34*(4), 454–471.

Guagnano, G., & Markee, N. (1995). Regional differences in the sociodemographic determinants of environmental concern. *Population and Environment, 17*(2), 135–149.
Lent, R., Brown, S., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*(1), 79–122.
Lent, R., Brown, S., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: test of alternative social cognitive models. *Journal of Counseling Psychology, 50*(4), 458–465.
Martin, R. (2009). *The Design of Business*. Cambridge MA: Harvard Business Press.
Matusovich, H., Streveler, R., & Miller, R. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education, 99*(4), 289.
Nisbet, E., Zelenski, J., & Murphy, S. (2009). The nature relatedness scale linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior, 41*(5), 715–740.
Open University Design Group. (2014). Design thinking research symposia. Retrieved 7/9/14 from. http://design.open.ac.uk/cross/DesignThinkingResearchSymposia.htm.
Osborne, J. (2008). *Best Practices in Quantitative Methods*. Sage.
Peterson, R. (1994). A meta-analysis of Cronbach's coefficient alpha. *Journal of Consumer Research, 21*(2), 381–391.
Potvin, G., Hazari, Z., Tai, R., & Sadler, P. (2009). Unraveling bias from student evaluations of their high school science teachers. *Science Education, 93*(5), 827–845.
Ray, M., Houston, T., Yu, F., Menachemi, N., Maisiak, R., Allison, J., et al. (2006). Development and testing of a scale to assess physician attitudes about handheld computers with decision support. *Journal of the American Medical Informatics Association, 13*(5), 567–572.
Rietveld, T., & Van Hout, R. (1993). *Statistical Techniques for the Study of Language and Language Behaviour*. De Gruyter Mouton.
Rodgers, P. (2013). Articulating design thinking. *Design Studies, 34*(4).
Smalley, R. E. (2003). Top ten problems of humanity for next 50 Years. In *Energy & NanoTechnology Conference*. Rice University.
Stewart, S. (2011). Interpreting design thinking. *Design Studies, 32*(6).
Team, R. C. (2012). *R: A Language and Environment for Statistical Computing [Computer Software]*. Vienna, Austria: R Foundation for Statistical Computing.
Teetor, P. (2011). *R cookbook*. O'Reilly.
Wigfield, A., & Eccles, J. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology, 25*(1), 68–81.