Validation of a Survey for Graduate Teaching Assistants: Translating Theory to Practice

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Abstract

Background Graduate teaching assistants (GTAs) play important roles in undergraduate education. The improvement of GTAs' teaching skills relies on effective formative and summative feedback about their teaching. An absence of robust, theory-driven feedback tools can limit the scope and the usefulness of feedback to GTAs.

Purpose This article focuses on the validation of a student survey that provides pedagogical feedback to GTAs. This survey's development was guided by the How People Learn (HPL) framework. Consisting of four dimensions (knowledge-centeredness, learner-centeredness, assessment-centeredness, and community-centeredness), this framework has been used to empirically assess GTA teaching and student learning, especially in engineering.

Method The survey was validated using exploratory factor analysis (EFA) with prior external content validity checks. We used EFA to identify distinct factors in the survey. The analyses informed item development on the final survey that operationalized the dimensions of the HPL framework.

Results We produced a 29-item survey informed by the HPL framework. Three distinct factors were identified in the survey structure after two rounds of EFA. These factors represent an individual dimension or a hybrid of dimensions of the HPL framework.

Conclusion This article describes the development of a survey that is ready for use by engineering GTAs to solicit feedback from students. From survey results, GTAs may obtain HPL-based teaching profiles that translate theory to practice. Implications for practice are also provided to facilitate the implementation of the survey, to improve the effectiveness of GTA teaching, and to enhance engineering student learning.

Keywords How People Learn; graduate teaching assistants; survey validation

Introduction

The significance of providing training and opportunities for teaching to graduate students has been emphasized by multiple researchers (Ambrose & Bridges, 2010; Feldon et al., 2011). Such findings are significant, since approximately half of the doctoral students who indicated definite post-graduation employment commitments in the United States will have academic jobs at two- or four-year colleges (National Science Foundation, 2009). Although pedagogical training for graduate students enhances instruction in undergraduate education, actual teaching has been identified as positively related to the enhancement of their research skills (Feldon et al., 2011). Graduate students who do both research and teaching demonstrate greater improvements in writing testable hypotheses and designing experiments than graduate students who do research alone.

Considering the positive impacts of teaching for graduate students, multiple formats of programs or workshops have been launched to enrich graduate students' teaching experience and to improve their teaching. Teaching centers or faculty preparation programs have been established on college campuses to assist graduate students progress from novice to expert teachers (DeNeef, 2002; Richards, Velasquez, & Payne, 2012; Zhu, Lynch & Cox, 2012). Serving as teaching assistants is the major way graduate students gain teaching experience and put into practice what they learn. It is a way for them to be mentored for their future roles as faculty members (Lambert & Tice, 1993). Graduate teaching assistants (GTAs) have also taken on important roles in undergraduate education, especially in science, technology, engineering, and mathematics (STEM) education, by leading laboratory sessions, grading homework or exams, and teaching in large introductory courses (Occupational Information Network, 2013).

Many GTAs will remain in academia after graduation; therefore, the training and preparation of GTAs are essential to their students' learning and to the pedagogical development of future faculty. Preparation for, and feedback about their teaching contributes to GTAs' self-efficacy (Prieto & Meyers, 1999; Park, 2004). Feedback can be provided in various ways, including by student surveys, GTA self-reflection, or classroom observation (Cox & Cordray, 2008).

Considering the need for effective feedback to GTAs and the usefulness of Bransford, Brown, and Cocking's (1999) How People Learn (HPL) framework in improving students' learning, this article reports the development of a survey guided by the HPL framework. Using two rounds of data collection, we report the overall validation process using exploratory factor analysis (EFA) for an HPL-based student survey among over 2000 first-year engineering students. This survey is an essential component of the Global Real-time Assessment Tool for Teaching Enhancement (G-RATE), a multidimensional instrument that incorporates qualitative and quantitative measures to evaluate teaching within instructors' classrooms (Cox et al., 2011). Combining prior work in content validation (Cox, Zhu, London, Hahn, & Ahn, 2012) and on the basis of previous qualitative work about the pedagogical understanding of GTA teaching in first-year engineering labs (Zhu et al., 2010), we report final items that will be included in the student survey. Collective survey results will provide a profile of GTA teaching practices framed in the context of the HPL framework. We also offer suggestions about ways to apply this survey in GTA training to improve their teaching skills.

Literature Review

The need to provide GTAs with effective training and feedback has been stressed by multiple researchers (Luft et al., 2004; Prieto, Yamokoski, & Meyers 2007; Cox et al. 2010). Early research efforts about TA training focused more on testing a training method or technique rather than emphasizing the theoretical approach that guides TA training (Nyquist, Abbott, & Wulff, 1989). However, to provide systematic training, it is necessary to incorporate best teaching and learning theories into training practices.

So far, only a few efforts have focused on using theory to guide GTA training. Prieto, Yamokoski, and Meyers (2007) adopted self-efficacy theory to address the relationship between GTAs' self-efficacy toward teaching and their prior training and supervision. On the basis of a series of studies, they found prior training and supervision to be positively related to GTAs' increased self-efficacy, which in turn, improves their teaching effectiveness (Meyers & Prieto, 2000; Prieto, 1999).

Given the importance of ongoing supervision and feedback, it is imperative to offer a variety of useful feedback, in both formative and summative formats, to GTAs as they progress in their teaching. Currently, feedback to GTAs is delivered by means of student questionnaires (Black & Kaplan, 1997; Cordray, Pion, Harris, & Norris, 2003; Seymour et al., 2005), classroom observation (Harris & Cox, 2003; Cox & Cordray, 2008), and peer evaluation (Robinson, 2000). Such various tools offer timely feedback to GTAs from many perspectives.

Because student surveys provide large-scale responses from students in a timely manner, they have been widely adopted by researchers and practitioners (Black & Kaplan, 1997; Cordray et al. 2003; Prieto, Yamokoski, & Meyers, 2007). These surveys probe various aspects of GTA instruction, such as communication skills (Black & Kaplan, 1997) and pedagogical content knowledge (Bond-Robinson & Rodriques, 2005). Missing from these current surveys, however, is an application of a guiding theoretical framework to understand overall GTA teaching practices in a more systematic manner. Moreover, the use of surveys in giving teaching feedback requires appropriate interpretation of their results (Marincovich, 1998). Using theories that have proven effective in teaching and learning to guide the survey development may facilitate the interpretation of student responses.

Theoretical Perspective

Teaching and learning theories are needed for framing evaluation and training GTAs about pedagogical practices. Bransford, Brown, and Cocking's (1999) How People Learn (HPL) framework provides a model for how classroom teaching can be accessed in four dimensions to establish a learning environment favorable for teaching and learning. Researchers have applied this framework to the design of learning modules and courses in a variety of disciplines, particularly bioengineering at institutions within the National Science Foundation-funded Vanderbilt-Northwestern-Texas-Harvard/MIT Engineering Research Center for Bioengineering Educational Technologies (VaNTH) (VaNTH Web site, 2013).Although research has demonstrated the effectiveness of the HPL framework in improving student learning (Cordray, Harris, & Klein, 2009) and has focused on its use by faculty (Cox & Harris, 2010), limited efforts have been made to explore how the HPL framework might provide timely feedback to graduate students in their professional development.

There are four dimensions of the HPL framework:

Knowledge-centeredness refers to an instructor's focusing on students' understanding of course materials and their abilities to apply academic content across contexts. This dimension goes beyond students' memorization of information to their understanding of when to apply this knowledge accurately across contexts.

Learner-centeredness refers to an instructor's considering students' individual backgrounds and experiences. In a learner-centered classroom, instructors tailor their instruction to align with the students in the class.

> **Assessment-centeredness** refers to an instructor's providing students formative feedback (short-term feedback that provides a check of student understanding and is often not associated with a grade) and summative feedback (feedback that often assesses a student's deeper understanding of course content and is associated with formal course grades) to encourage and to guide their development. Assessment-centered environments allow students and instructors to learn from each other in an effort to revise teaching practices and content.
>
> **Community-centeredness** relates to the group interactions that occur inside or outside of a class environment among students and instructors; learning may occur among all members in the course.

Although presented theoretically as four distinct dimensions, these dimensions have strong interactions with each other, and teaching practices often reflect more than one HPL dimension.

The HPL framework has been adopted at various educational levels to create learning modules and is effective in improving student learning (Cordray et al., 2003; Pandy et al., 2004; Birol et al. 2006; Roselli & Brophy, 2006, Linsenmeier et al., 2008). Cordray, Harris, and Klein (2009) performed a meta-analysis of a series of experimental and quasi-experimental studies with instructional innovations that were designed and implemented in the context of the HPL framework and an instruction cycle known as the STAR (Software Technology for Action and Reflection) Legacy Cycle. They summarized the effectiveness of 33 learning modules in bioengineering and concluded "moderate to large effects" for the adoption of HPL-based materials in learning modules in which researchers used experimental or quasi-experimental designs (between 50% and 70%). These findings suggest the usefulness of the HPL framework in improving students' learning performance.

In addition to being applied to creating learning modules, the HPL framework has been used to provide feedback for teaching and learning. For example, Cordray et al. (2003) constructed an Experiences in and Benefits from this Course (EBC) survey, which was developed to determine the representation of the HPL elements of courses that implemented HPL-based practices versus traditional courses that did not use HPL-based materials and activities. Using the EBC, Cordray et al. (2003) demonstrated a significant difference of the presence of HPL elements in HPL-oriented courses and lecture-based courses. The HPL framework has also been used to guide the classroom observation process. Cox and Cordray (2008) developed a set of HPL indexes to distinguish instructional practices based on the HPL principles from those did not. Although few studies have used the HPL framework to assess teaching and prove feedback, studies demonstrate the potential usefulness of the HPL framework in guiding feedback processes. Therefore, it is promising to develop and validate instruments, such as surveys, to provide feedback in the context of the HPL framework.

Methods

Content Validation of the Survey

The survey described in this article is intended to provide direct feedback to engineering GTAs from items representing the four HPL framework dimensions. The survey, which contains 36 items with seven negatively worded items added for internal validity checks, originated from one-on-one, in-depth interviews in which researchers explored GTAs' understanding of their teaching in engineering labs and engineering professors' expectations for graduate student teaching in undergraduate courses (Zhu et al., 2010). The items were developed from practical instances where GTAs applied HPL dimensions in their teaching.

To evaluate to what extent each student survey item represented elements of the HPL framework and to identify which dimensions were represented in each survey item, we asked seven experts familiar with the HPL framework to rate the survey (Cox et al., 2012) and rate how well each survey item reflects each dimension of the HPL framework in a four-point Likert scale (1 = not at all, 2 = only a little, 3 = somewhat, and 4 = a great deal). We compiled experts' rating in each dimension for each survey item. For each dimension, when the experts' agreement level reached 70% or higher, we determined that that dimension was represented in that survey item. These ratings helped us establish the survey's content validity. This survey, with minor editorial changes, was also distributed to engineering undergraduates in the first round of data collection. Additional details about this data collection and analysis are presented in following sections.

Study Context

The context of the study is a first-year engineering course that is required of most first-year engineering students. This course introduces these students to the engineering profession, engineering problem-solving tools, and engineering disciplines. It uses multidisciplinary materials and open-ended learning activities. The course develops students' problem-solving, teamwork, communication, and other professional skills by introducing them to the engineering design process, engaging them in generating innovative ideas, and using quantitative tools to address engineering problems. It includes both class sessions and laboratory sessions (with approximately 120 students enrolled in a class). One professor often leads the class session while a GTA is responsible for leading the lab session. In the lab session, GTAs start with 20 to 30 minutes' review of the major course content followed by student group work. GTAs are also expected to hold office hours and to grade student homework and projects.

Data Collection

Two rounds of survey data were collected. The first round occurred in fall 2010 and was distributed online to approximately 1500 first-year engineering students at a Midwestern university. We obtained complete responses from 1298 students. After the first round, researchers performed exploratory factor analysis on the dataset, revised the survey instrument, and distributed the survey the following year. For the second round, the survey was distributed to about 1000 first-year engineering students at the same university in fall 2011. We obtained complete responses from 994 students. After collecting the data, we performed another exploratory factor analysis.

The Web address to the online survey was distributed by the professors in weekly course slides. Appropriate IRB procedures were followed for this study, and students were informed of the voluntary nature of participation (i.e., completion of the online survey did not have any impact on course grade). No incentives were offered to participants.

Data Analysis

Exploratory factor analysis (EFA) In this study, we used exploratory factor analysis (EFA) to understand the structure of the survey. Results from the EFA were compared to prior results from content experts' ratings of the survey (Cox et al., 2012). The goal of EFA is to "identify the underlying dimensions of a domain of functioning, as assessed by a particular measuring instrument" (Floyd & Widaman, 1995, p. 286). EFA is an essential tool in the early stage of instrument development because it allows assessment of construct validity.

In the survey instrument, item responses are not continuous variables but ordered categorical measures (on a four-point Likert scale, 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree, and "not applicable"). Since they are neither continuous nor have normal distribution, the traditional maximum likelihood (ML) estimation or generalized least square (GLS) estimation methods may produce inaccurate estimates (Bollena & Barb, 1981; West, Finch, & Curran, 1995). Thus, we used weighted least square with mean and variance correction estimator (WLSMV; Muthén & Muthén, 2010). The WLSMV is a robust estimator that uses polychoric correlations to accurately estimate parameters in factor analysis (Flora & Curran, 2004). Our sample size of over 200 is adequate enough for the WLSMV approach (Flora & Curran, 2004).

Since this model has a large sample size and categorical indicators, fit indices produced by Mplus software – root mean square error of approximation (RMSEA), root mean square residual (RMSR), and comparative fit index (CFI) – were used to assess the model fit. To demonstrate RMSEA as a measure of good fit, Hu and Bentler (1999) suggest a cutoff close to 0.06 and an RMSR less than 0.08, and a CFI larger than 0.9. The chi-square/degree-of-freedom statistic was not used to assess model fit because of its oversensitivity to a large sample size.

Many procedures are available for rotation. An oblique rotation (Promax) was chosen because it allows for correlation between factors and a simple structure (Kline, 2002, p. 65). An orthogonal solution may not be appropriate in this situation because the independence of the factors may not be maintained. There is a strong overlap among the four dimensions of the HPL framework. Therefore, correlations may exist among potential factors.

To decide the number of factors to keep, the widely used scree-plot solution was first employed for visual inspection and then followed by the criterion that each statistically viable solution should be psychological meaningful. Similar scree plots were produced for both rounds of result analysis. In each case, a clear single factor was strongly suggested along with reasonable second and third factors.

Results

First-round survey results On the basis of the first-round survey responses from the first-year engineering students, EFA was applied to examine the structure of the survey (29 items with negatively worded items excluded). A three-factor model was identified as the most statistically acceptable model on the basis of the principle of eigenvalues greater than or equal to one and the model fit indices (including RMSEA and RMSR). The eigenvalues of the first three factors are either larger than one or close to one. Moreover, RMSEA = 0.057, RMSR = 0.023, and CFI = 0.984 indicate a good model fit. Six items had cross loadings to two factors, and they are listed under both factors in Table 1.

Factor One seems to have a strong representation of knowledge-centered items, Factor Two primarily represents learner-centered items, and Factor Three represents a hybrid of multiple HPL dimensions. Eleven items loaded to Factor One. Five out of the 11 items in this factor represent the knowledge-centered dimension according to prior content analysis results (Table 1; Cox et al., 2012). Factor Two seems to represent the learner-centered dimension of the HPL framework, since all items except one reflect the learner-centered dimension according to the ratings of content experts (Table 1). The last factor seems to be a hybrid factor, in which 15 items are loaded. Eleven out of

Table 1 Item Mapping for Different Factors (first-round exploratory factor analysis results)

Items	Factor loading 1	2	3	Experts' rating[a]
Factor One (In the lab session and on other occasions, my GTA . . .)				
1 Encouraged me to work with my team	**0.710**	0.215	−0.091	C
2 Emphasized learning new skills	**0.689**	0.109	0.158	K
3 Encouraged the students to learn from each other	**0.617**	0.188	0.106	C
4 Helped me understand the key concepts	**0.566**	0.282	0.173	K
5 Shared skills I can use after finishing this course	**0.536**	0.154	0.268	K
6 Made me feel comfortable when I communicated with him/her	**0.528**	**0.402**	0.004	L
7 Explained how to address specific problems	**0.511**	0.143	0.301	K
8 Was patient with me when I struggled while learning engineering concepts	**0.495**	0.180	0.312	L
9 Understood that I may learn differently from my peers	**0.489**	−0.031	**0.475**	L
10 Asked questions to make me think	**0.479**	0.006	**0.426**	KA
11 Made sure I understood the tasks I completed	**0.424**	0.130	0.392	LA
Factor Two (In the lab session and on other occasions, my GTA . . .)				
1 Helped my team when we needed assistance	0.180	**0.761**	−0.029	LC
2 Accommodated my individual needs when necessary	0.149	**0.653**	0.140	L
3 Was approachable	0.308	**0.606**	−0.015	LC[b]
4 Guided me to answers	0.184	**0.527**	0.254	L
5 Kept me motivated to continue learning	0.034	**0.464**	**0.488**	L
6 Provided detailed comments on my work	0.070	**0.443**	0.380	A
7 Related the content of the course to a big picture	0.141	**0.415**	**0.410**	KL
8 Facilitated my communications with professors	0.098	**0.410**	**0.449**	L
9 Made me feel comfortable when I communicated with him/her	**0.528**	**0.402**	0.004	L
Factor Three (In the lab session and on other occasions, my GTA . . .)				
1 Noticed when I was improving in the class	−0.031	0.071	**0.839**	L
2 Cared about my transition from high school to college	0.020	0.152	**0.729**	LC[b]
3 Noticed my misunderstanding of a concept	0.276	−0.128	**0.719**	KLA
4 Gave me a chance to share my thoughts on his/her teaching	0.040	0.314	**0.552**	LC[b]
5 Translated theoretical knowledge into practical skills	0.022	0.399	**0.543**	K
6 Confirmed that the majority of the class understood a concept before introducing new material	0.324	0.023	**0.531**	na
7 Shared his/her own practical experience	0.294	0.064	**0.522**	K
8 Realized that learning engineering concepts can be tough	0.115	0.272	**0.490**	L
9 Kept me motivated to continue learning	0.034	**0.464**	**0.488**	L
10 Understood that I may learn differently from my peers	**0.489**	−0.031	**0.475**	L
11 Facilitated my communications with professors	0.098	**0.410**	**0.449**	L
12 Applied knowledge to everyday situations	0.397	0.122	**0.433**	KL
13 Asked questions to make me think	**0.479**	0.006	**0.426**	KA
14 Was sensitive to my concerns about my grades in this course	0.345	0.117	**0.422**	L
15 Related the content of the course to a big picture	0.141	**0.415**	**0.410**	KL

Abbreviations: K = Knowledge-centered; L = Learner-centered; A = Assessment-centered; C = Community-centered; na = not applicable
Note: Factor loading coefficients that are larger than 0.4 are shown in bold.
[a]The listed HPL dimensions in Experts' rating column have the percentage of agreement higher than 70%.
[b]These items have 42.9% agreement on learner-centered and community-centeredness, respectively.

15 survey items reflect the learner-centered (L) dimension; six items reflect the knowledge-centered (K) dimension; two items reflect the community-centered (C) dimension; and two items reflect the assessment-centered (A) dimension (Table 1). It is possible that there could be another factor that represents learner-centeredness embedded within Factor Three given the large number of items that seem to reflect learner-centered aspects. Alternatively, the hybrid factor could also result from the close correlations among the four dimensions of the HPL framework. Overall, by using EFA, we can demonstrate the survey has at least two relatively distinct factors (knowledge-centeredness and learner-centeredness). Nonetheless, because some of the items that represent the knowledge-centeredness dimension are also present in Factor Three, it is somewhat difficult to distinguish clearly between the knowledge-centered elements within Factors One and Three.

EFA provided us with information to help explore the latent constructs of the survey; EFA findings were then compared with content experts' ratings of the same items. Knowledge-centered items were strongly represented in Factor One, although some of the community-centered items also had strong representations in Factor One (Items 1 and 3, with factor loading coefficients of 0.710 and 0.617, respectively). The representation of community-centeredness, however, was not very strong due to the small number of community-centered items on the original survey. Learner-centeredness seems to be relatively prominent in the factor structure of the survey because nearly all the items that were loaded in Factor Two represented the learner-centered dimension. Assessment-centeredness was less observable in the EFA, which is possibly due to the limited number of assessment-centered items present in the initial survey.

Second-round survey results On the basis of the factor analysis result from the first round and feedback from an instructional team (including the coordinators, some professors, and GTAs from the course in which the survey was administered initially), we made major modification to the survey's first version in three ways: (1) increasing the representation of the assessment- and community-centered dimensions by adding additional items reflecting these dimensions, (2) decreasing the representation of learner-centered items by rewording current items that represent this dimension, and (3) deleting survey items that did not clearly reflect HPL dimensions on the basis of the external expert rating results. We also made minor editorial changes to clarify the meaning of some items. The revised version has 30 items (excluding the negatively worded items).

After these changes, we collected 994 responses using the revised (or second) survey. We analyzed their responses using another round of EFA and the same estimator (WLSMV). Again, a three-factor model was identified as the most statistically acceptable model on the basis of the principle of eigenvalues greater than or equal to one and the parameters for a good model fit (including RMSEA and RMSR). The eigenvalues of the first three factors are either larger than one or close to one. Moreover, the model fit parameters indicate a good model fit (RMSEA = 0.059, RMSR = 0.026, CFI = 0.984).

Factor One primarily represents a hybrid of knowledge-centered and community-centered items; Factor Two primarily represents learner-centered items; and Factor Three represents assessment-centered items. As shown in Table 2, 14 items load to Factor One, which represents a hybrid of knowledge- and community-centeredness. Thirteen out of

14 items reflect knowledge- or community-centered dimensions. Eight items load to Factor Two, which seems to reflect learner-centeredness. Six out of eight items reflect this dimension. Eight items load to Factor Three. Three items in this factor were added to enhance assessment-centeredness in the survey.

Several items showed changes in their factor loading after the wording changes in the survey. For example, Item 8 in Factor One was "Understand that I may learn differently from my peers" before the revision and was originally mapped as a learner-centered item. Because of the change of wording (to "Acknowledged the diverse learning styles of students in the class"), the item now loads on Factor One instead of Factor Two, representing less designation as a learner-centered item.

Similar changes are observed in other items. For example, Item 2 under Factor Three before the revision was "Noticed when I was improving in the class," which was originally defined as a learner-centered item. Now, because of the change to "Acknowledged when I was improving in the class," the revised item now represents the assessment-centered dimension. It is loaded to Factor Three, which seems to reflect mostly assessment-centeredness. Furthermore, Item 3 under Factor Three was worded originally as "Was sensitive to my concerns about my grades in this course" and was identified as a learner-centered item. The change to "Addressed my concerns about my grades in this course" represented a more active on the part of the GTA by emphasizing that the GTA gave feedback or addressed concerns. This deliberate focus on assessment-centeredness is confirmed given this item's new loading to Factor Three.

In addition to these changes in factor loading after the revision of the original survey, we observed that the item "Acknowledged my misunderstanding of a concept" cross-loaded on Factor One (knowledge- and community-centeredness) and Factor Three (assessment-centeredness). This item was also identified as representing multiple dimensions (knowledge-, learner-, and assessment-centeredness) from the content experts' rating. Therefore, it makes sense that this item loaded to both factors.

Our original goal was to design an assessment tool that would reflect the four dimensions of the HPL framework. Three distinctive factors were identified in the second round. With the second version of the survey, all four dimensions of the HPL framework were represented in the survey structure on the basis of the EFA results. Although the How People Learn framework presents four dimensions, community-centeredness seems to be a dimension that overlaps with the other three dimensions. Therefore, it is reasonable that in the EFA results community-centered items load with items in other dimensions instead of standing out as a single factor. Nonetheless, we do not exclude the possibility of having a community-centeredness factor in a future revised version of a similar survey. In summary, compared with the first iteration of the survey, the second version of the survey was significantly improved in terms of the factor structure. Moreover, prior experts' ratings of survey items' representation of each HPL dimension also provide additional validity of the second version, which would be potentially useful for wider applications among a larger survey population.

Teaching Profiles

On the basis of the second version of the HPL survey and the three factors identified from the EFA (Table 2), we analyzed the survey data from the students. Students were asked to rate their instructors on a four-point Likert scale (1 = strongly disagree,

Table 2 Item Mapping for Different Factors
(second round exploratory factor analysis results)

Items	Factor loading 1	2	3	Experts' rating[b]	New items' HPL dimensions[c]
Factor One: Knowledge- and community-centeredness (In the lab session and on other occasions, my GTA . . .)					
1 Fostered a collaborative learning environment	**0.791**	0.173	−0.064	–	C
2 Encouraged me to work interactively with my team	**0.715**	0.203	−0.094	C	–
3 Emphasized learning new skills	**0.689**	0.088	0.150	K	
4 Shared skills I can apply in the future	**0.611**	0.141	0.170	K	
5 Encouraged the students to learn from each other in class	**0.610**	0.227	0.016	C	
6 Encouraged a nonthreatening environment where students could ask questions or comment about academic content	**0.610**	0.270	−0.020	–	C
7 Asked questions to make me think	**0.602**	0.056	0.223	KA	
8 Acknowledged the diverse learning styles of students in the class[a]	**0.591**	0.085	0.204	–	
9 Applied knowledge to everyday situations	**0.577**	0.165	0.219	KL	
10 Shared his/her own practical experience	**0.568**	−0.086	0.356	K	
11 Explained how to solve specific problems	**0.515**	0.147	0.247	K	
12 Helped me understand key course concepts	**0.499**	0.279	0.221	K	
13 Related the content of the course to a big picture	**0.425**	0.323	0.158	KL	
14 Acknowledged my misunderstanding of a concept	**0.409**	−0.059	**0.530**	KLA	
Factor Two: Learner-centeredness (In the lab session and on other occasions, my GTA . . .)					
1 Helped my team when we needed assistance	0.128	**0.795**	−0.001	LC	
2 Addressed my individual needs or concerns	0.175	**0.555**	0.232	L	
3 Provided responses that guided me in problem solving	0.343	**0.527**	0.112	L	
4 Motivated me to continue learning	0.198	**0.502**	0.278	L	
5 Translated theoretical knowledge into practical skills	0.214	**0.498**	0.237	K	
6 Facilitated my communications with professors or other course staff	0.190	**0.482**	0.273	L	
7 Provided verbal feedback about my progress	0.163	**0.454**	0.304	–	A
8 Acknowledged that learning engineering concepts can be challenging at times	0.366	**0.430**	0.059	L	
Factor Three: Assessment-centeredness (In the lab session and on other occasions, my GTA . . .)					
1 Provided written critiques about my progress	−0.179	0.225	**0.878**	–	A
2 Acknowledged when I was improving in the class[a]	0.098	0.146	**0.686**	–	
3 Addressed my concerns about my grades in this course[a]	0.313	−0.068	**0.618**	–	
4 Provided written critiques to my team about our progress on course deliverables	0.052	0.274	**0.567**	–	A

Table 2 (continued)

Items	Factor loading 1	Factor loading 2	Factor loading 3	Experts' rating[b]	New items' HPL dimensions[c]
5 Acknowledged my misunderstanding of a concept	**0.409**	−0.059	**0.530**	KLA	
6 Confirmed that I understood the tasks I completed	0.348	0.126	**0.496**	LA	
7 Confirmed that the majority of the class understood a concept before introducing new material	0.395	0.035	**0.452**	na	
8 Provided verbal feedback to my team about our progress on course deliverables	0.302	0.218	**0.408**	–	A

Abbreviations: K = Knowledge-centered; L = Learner-centered; A = Assessment-centered; C = Community-centered; na = not applicable.
Note: Factor loading coefficients that are larger than 0.4 are shown in bold.
Item "Communicated effectively with me" has no loading larger than 0.4 and was therefore not included in the table.
[a]Items that have major changes in wording from the first version of the survey.
[b]The listed HPL dimensions in Experts' rating column have agreement higher than 70%.
[c]For new items added in the second version of the survey, the dimension provided in this column is designed and defined by the research team, not by external experts.

2 = disagree, 3 = agree, and 4 = strongly agree). A "not applicable" option was also available. Responses to the items can be summed to obtain the total response. Individual teaching profiles, which represent GTAs' pedagogical strengths and represent the extent to which GTAs demonstrate elements of the HPL framework, can be generated for each GTA on the basis of survey output from students about their GTA's teaching over the course of the semester.

Sample data used to produce teaching profiles are presented in Tables 3 and 4. Table 3 gives data for the different profiles of three GTAs' teaching for Factor Three. The table gives the percentages of students' responses to the eight survey items in Factor Three, which represents the assessment-centered dimension of the HPL framework.

Table 4 gives the percentages of students' responses to assessment-centered items for GTA B. The data demonstrate the extent to which the 97 students in the GTA B's course agreed that he/she performed each of the survey items in Factor Three. From these items, the strength of this GTA is that the GTA provided written critiques to teams about their progress on course deliverables. An area of possible improvement for this GTA is acknowledgment of student improvement in the course.

These tables are examples of how this feedback might also be used formatively to identify ways that GTAs can enhance their undergraduate teaching. Although only sample pedagogical data for Factor Three are presented, profiles for each of the three factors and for the items within each factor could be generated. By reviewing students' responses to different items, potential strengths and weaknesses for each GTA's instruction can be identified. These types of representation may also be used as teaching profiles at various moments of a semester for one GTA during pre- and postpedagogical training.

Discussion

This article reports the validation process for a survey that allows students to assess their GTAs' teaching in the context of the HPL framework. By means of the exploration of factors within the survey, we found a three-factor structure after two rounds of EFA. We identified clear factors of learner-centeredness and assessment-centeredness as well as a hybrid factor of knowledge-centeredness and community-centeredness. The presence of these factors is compared with prior results from content experts familiar with the HPL framework. This process suggests the usefulness of EFA in understanding the structure of the HPL survey. Also, with the survey and the three identified factors, we generated sample GTA teaching profiles that provide a way for GTAs to reflect on ways to improve their teaching.

Guided by the HPL framework, we translated the HPL framework into practice using a large set of quantitative data. As discussed in the literature review, the HPL framework has proved its usefulness in guiding the development of courses and learning modules (Cordray, Harris, & Klein, 2009). Current studies using the HPL framework for feedback have shown its potential effectiveness for formative and summative assessment (Cordray et al., 2003; Cox & Cordray, 2008; Cox et al., 2011). This article fills a gap in current research by providing a valid HPL-oriented feedback tool for engineering GTAs and adds to the assessment and evaluation of teaching and learning in engineering courses as described below.

First, considering the usefulness and the frequent adoption of the HPL framework in engineering education, a survey and teaching profiles developed in the HPL context allow GTAs to obtain students' perspectives in the context of the HPL framework and to reflect formatively or summatively on their teaching, thereby facilitating the successful implementation of this framework.

Second, some instructional methods in engineering courses, such as team-based learning, often demand advanced pedagogical skills from the professors and GTAs to coordinate and to facilitate team activities (Felder, Brent, & Prince, 2011). The current survey was designed on the basis of the HPL framework, which strongly supports the establishment of a collaborative community in which students can learn from each other. With this emphasis on a collaborative community in its design, this survey can provide direct feedback about GTAs' teaching and therefore could enhance the practice of team-based learning.

Third, the survey was tested for GTAs of a large engineering course. Many of their functions, including leading lab sessions, organizing group activities, and guiding students through problem-solving processes, can overlap with the functions of engineering professors. Therefore, with slight modification in a few survey items, this survey could potentially have

Table 3 Percentage Agreement for Students' Responses to Assessment-Centered Items in Factor Three for Three GTAs' Teaching

	Strongly disagree	Disagree	Agree	Strongly agree	Not applicable
GTA A ($n = 72$)	7.5%	26.9%	43.9%	16.5%	5.4%
GTA B ($n = 97$)	6.3%	22.7%	49.9%	14.4%	6.7%
GTA C ($n = 104$)	1.6%	12.9%	53.7%	27.9%	4.0%

Table 4 Percentage of Students' Responses to Assessment-Centered Items in Factor Three for GTA B ($n = 97$, eight questions)

Question	Strongly disagree	Disagree	Agree	Strongly agree	Not applicable
Provided written critiques to my team about our progress on course deliverables	3.1%	9.3%	60.8%	25.8%	1.0%
Provided written critiques about my progress	6.2%	27.8%	48.5%	13.4%	4.1%
Provided verbal feedback to my team about our progress on course deliverables	8.2%	23.7%	49.5%	16.5%	2.1%
Acknowledged when I was improving in the class	11.3%	28.9%	38.1%	11.3%	10.3%
Confirmed that I understood the tasks I completed	5.2%	18.6%	51.5%	15.5%	9.3%
Addressed my concerns about my grades in this course	9.3%	26.8%	46.4%	8.2%	9.3%
Confirmed that the majority of the class understood a concept before introducing new material	2.1%	27.8%	51.5%	16.5%	2.1%
Acknowledged my misunderstanding of a concept	5.2%	18.6%	52.6%	8.2%	15.5%

a broader impact if tested in more engineering courses and additional professors and student populations.

In addition to providing feedback from students' perspectives, it is imperative to incorporate multiple perspectives and measures in an effort to provide timely and effective teaching feedback to GTAs. For this reason, we propose the following ways that the survey and profiles can be used to provide feedback and to improve GTAs' teaching skills and confidence.

Use this survey along with training sessions, course, and learning modules on pedagogy in the context of a specific discipline After GTAs receive students' feedback through the teaching profile, it is important they have some level of understanding about the fundamentals of pedagogy so that the feedback is useful and they can make adjustments to their teaching. As Shuman (1987) pointed out, a teacher's knowledge base should include multiple categories, such as content knowledge, general pedagogical knowledge, pedagogical content knowledge, and other knowledge about learners, educational contexts, and educational goals. Within these different knowledge categories, pedagogical content knowledge represents the "blending of content and pedagogy" and can "distinguish the understanding of the content specialist from that of the pedagogue" (p. 8).

Most GTAs received systematic and rigorous training in the content knowledge and technical skills of their disciplines. Similar to this training process, the development of pedagogical content knowledge also requires systematic investment and close apprenticeship from seasoned faculty members (Robinson, 2000). Developing pedagogical content knowledge requires a deep understanding in both disciplinary content knowledge and pedagogical theories and practices. A systematic introduction to a variety of pedagogical theories and current best practices in teaching and learning will expose GTAs to a variety of practical tools and

Table 5 Sample Reflective Questions for Graduate Teaching Assistants

How People Learn dimension	Sample reflective questions
Knowledge-centered	Please provide specific examples of things you did to help students learn new skills and understand key concepts. Please provide specific examples of things you did to emphasize the importance of learning skills that can be used after finishing this course. Please provide specific examples of things you did to show that the course content can be applied outside of the classroom.
Learner-centered	Please provide specific examples of things you did to accommodate the personal needs of an individual student. Please describe how you determined whether a student was improving or not.
Assessment-centered	Please provide specific examples of things you have learned from your students and the specific ways in which you obtained feedback from your students. Please describe the methods you used in class to make sure your students understand the concepts that you are teaching.
Community-centered	Please provide specific examples of the things you did to encourage students to learn from one another.

guidance in curriculum design, assessment and evaluation, and classroom management so that they can make meaningful adjustments to their teaching practices.

Use this survey along with classroom observations The results of the survey and the teaching profile provide perspectives of GTAs' teaching from students. Although this survey is one part of an HPL-based multidimensional tool to provide feedback to instructors (Cox et al., 2011), classroom observations by peers or experts (e.g., seasoned faculty familiar with pedagogical content knowledge about the course or staff from an institution's center for teaching and learning) also might be performed in conjunction with the survey to give GTAs insight about enhancing their teaching and to provide a more holistic view of their teaching. GTAs also might use HPL-based observation tools such as the VaNTH observation system (VOS; Harris & Cox, 2003; Cox & Cordray, 2008) or the Global Real-time Assessment Tool for Teaching Enhancement (G-RATE; Cox et al., 2011). Both the VOS's and the G-RATE's classroom observation portions collect data in code strings representing interactions that occur between instructors and students. Cox and Cordray (2008) have demonstrated the ability of such HPL-based observation tools to distinguish HPL-type teaching from traditional, non-HPL teaching.

Use this survey along with self-reflective questions for GTAs Reflective thinking and action are essential in the professional development from novice to expert (Butler, 1996; Jolly, 1999). Several researchers (Benner, 1984; Butler, 1996) discussed this process in terms of five specific stages: novice, advanced beginner, competent, proficient, and expert. GTAs, as novices in teaching, can benefit from engaging in a guided reflective process. Use of this survey along with reflective prompts will allow GTAs to reflect in depth how they are engaging with their students and how they can develop practical strategies in translating the theory into daily teaching tasks and practices. Sample GTA reflection questions framed within the context of the HPL framework are given in Table 5.

Conclusion

We developed and validated a survey, an essential part of a multidimensional assessment tool, G-RATE, which can be used to provide feedback from multiple perspectives, including students, observers, and GTAs (Cox et al., 2011). To date, literature reports that learning activities such as collaborative learning and group activities are beneficial to undergraduate engineering students (Springer, Stanne, & Donovan 1999), but details linking such activities to real-time classroom teaching and learning are needed. In response to this need, research in this direction will add value to what researchers know about the pedagogical experiences of GTAs and professors in diverse environments. Using teaching profiles generated on the basis of students survey results, student course outcomes (e.g., course grades and deliverables), and other profiles based on class observation data generated by peers or seasoned teachers, one will be able to explore pedagogical elements that align with course outcomes. Moreover, the data collected from wider student and instructor populations will afford an analysis of the pedagogical practices (framed within the context of the HPL framework) identified across disciplines and instructors of different levels of expertise. Results from such studies will help stakeholders to enhance the learning experiences of undergraduate engineering students in various courses and to understand how feedback might be used to enhance teaching in undergraduate engineering courses.

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