Measuring University Students' Science Communication Efficacy in Middle and High Schools

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Abstract

Self-efficacy is a person's belief in one's capabilities to organize and execute the courses of action required to produce certain attainments and it is task-specific or subject-specific. Generalized self-efficacy or confidence measures have been made with the common use of five-point scales with anchoring descriptors, but many of the self-efficacy studies are criticized for their invalidity. This study focuses on university students' self-efficacy in science communication. In this study, science communication efficacy is defined as university students' beliefs in their capabilities to help middle and high school students understand science. Specifically, we intend to develop a standardized instrument for measuring university students' self-efficacy in communicating science to K-12 students. The specific research questions are: 1. What is the validity evidence for supporting the use of the measurement instrument to measure university students' self-efficacy in communicating science to K-12 students? 2. What is the reliability evidence for supporting the use of the measurement instrument to measure university students' self-efficacy in communicating science to K-12 students? The development of the science communication efficacy instrument follows a construct modeling approach, starting with a clearly defined construct, operationalized by progress variables. Assessment tasks are then derived from the defined progress variables, and data collected from pilot-testing and field-testing are used to examine the fit between the progress variables and data using Rasch modeling. The final revised instrument contains 20 items with four response categories to describe respondents' levels of self-efficacy in communicating science. The results have revealed that the revised self-efficacy instrument is well-targeted at the STEM students. Measures from this instrument are reasonably valid and reliable, thus are appropriate for assessing university STEM students' science communication self-efficacy.

Measuring University Students' Science Communication Efficacy in Middle and High Schools

Introduction

In the US, there is a long history of involving university students in K-12 science education. A good example is the NSF funding program called Graduate STEM (Science, Technology, Engineering and Mathematics) Fellows in K-12 Education (GK-12). Through interactions with teachers and students in K-12 schools, graduate STEM fellows improve their science communication and teaching skills while enriching STEM content and instruction for their K-12 partners. Over the years, the idea of GK-12 has been expanded to placing university students (graduate and undergraduate) in K-12 classrooms in order for them to learn science communication, teaching skills, leadership, teamwork, and civic engagement. This form of university student learning has also been called service learning.

There has been well-established evidence on the benefits of placing university students in K-12 classrooms. For example, teachers involved in the GK-12 program have reported increased STEM content knowledge (e.g., Gamse et al., 2010); a use of more effective pedagogical techniques (Gamse et al., 2010; Huziak-Clark et al., 2007), greater access to STEM resources (Gamse et al., 2010; Moskal et al., 2007), to name just a few. For K-12 students, in a recent evaluation of the GK-12 program (Abt Associates, 2010), a majority of teachers indicated that the GK-12 program had positive effects on their K-12 students' STEM knowledge and skills. STEM students working in K-12 classrooms have reported gains as well. In another recent evaluation of the GK-12 program (NSF, 2010), a majority of current and former graduate students indicated that their GK-12 experience benefited their ability to conduct various activities requiring communication, teaching, and teamwork skills. A majority of their college faculty advisors also concurred that the GK-12 program helps their students develop skills in these areas.

While the benefits of GK-12 and similar service learning programs have been reported as described above, measurement of university students' gains using standardized measurement instruments is still lacking. Our study intends to fill this gap. It focuses on university students' self-efficacy in science communication.

Literature review

Self-efficacy Theory

According to Bandura, self-efficacy is a person's belief in one's capabilities to organize and execute the courses of action required to produce certain attainments (Bandura, 1997). Bandura stated that people will not attempt to do things if they do not believe they can produce certain results. In other words, self-efficacy can affect the initiation of behavior, the amount of effort expended and the persistence of behavior in spite of challenges and negative experiences (Bandura, 1977). Other researchers reached the same conclusion. Self-efficacy can affect one's cognitive, motivational and affective processes (Jones, 2012). Pajares (1996) argued that a person's self-efficacy will determine how the person approaches tasks and responds to set-backs, in addition to that it also can determine what the person will do with the skills and knowledge he/she has. Salas (2009) also stated that the more students succeed, the more they believe they can succeed (self-efficacy), and therefore, the more they do succeed.

Self-efficacy is a context-specific rather than a stable characteristic trait. It is therefore thought to have a direct effect on performance in specific contexts. Self-efficacy judgment varies based on the level of skill and perseverance required to achieve a given task in a given context (Bandura, 1997; Dellinger et al, 2008; Tschannen-Moran et al., 1998; Woolfolk & Burke, 2005). Ormrod (2004) pointed out that, while self-efficacy is similar to self-concept or self-esteem, an important distinction for self-efficacy is that it is domain, task, or situation specific. Examples provided by Salas (2009) is that a teacher may have a strong sense of self-efficacy in teaching mathematics, while weaker self-efficacy in teaching English; or a student may have high self-efficacy when performing mathematics skills, but a low self-efficacy in language arts. Self-efficacy is related to perceived specific abilities rather than generalized self-beliefs (Gaffney, 2011). Bursal and Yigit (2012) proposed that self-efficacy beliefs should be extended to specific subject areas since they are context and subject matter dependent.

Over the past decades, many scholars have studied self-efficacy in educational settings; they have found a great influence of self-efficacy on teaching and learning processes (Armor et al., 1976; Ashton, 1984; Ashton & Webb, 1986; Bursal & Yigit, 2012; Gibson and Dembo, 1984; Guskey & Passaro, 1994; Humphries et al, 2012; Roll-Peterson, 2008; Schunk, 1989; Shim & Ryan, 2005; Soodak & Podell, 1993; Soodak & Podell, 1996; Tschannen-Moran et al., 1998; Woolfolk Hoy & Davis, 2006). Bandura (1994) pointed out that educational activities can influence a person’s self-efficacy and, therefore, that these activities should utilize methods which can increase self-efficacy. Jones (2012) found that self-efficacy can be developed through some experiences. For example, when one sees that someone like himself/herself succeeds following sustained effort, he/she will believe he/she can succeed too. Other research studies have demonstrated that when training for a specific skill, high self-efficacy is positively correlated with performance (Bandura, 1997; Block et al., 2013; Gist et al., 1989; Pajares, 1996). Dellinger et al. proposed that self-efficacy be represented in a causal model of interactions among self and society, internal personal factors, and the external environment as reciprocating factors. They argued that internal personal factors (cognitive, affective and biological events) and the external environment influence behaviors, while the environment is impacted by behaviors and personal factors, and personal factors are impacted by behaviors and the environment (Dellinger et al., 2008).

Measuring Self-efficacy In Educational Realms

Generalized self-efficacy or confidence measures have been made with the common use of five-point scales with anchoring descriptors (Berridge et al. 2007; Clark et al., 2004; Day et al., 2007; Riboh et al., 2007; Sherer et al., 1982). For example, in the measurement of teacher efficacy in two Rand Corporation assessments of educational programs (Humphries, 2012), researchers used two Likert-scaled items to assess teacher self-efficacy “When it comes right down to it, a teacher really can’t do much, because most of a student’s motivation and performance depends on his or her home environment;” and “If I try really hard, I can get through to even the most difficult or unmotivated students.” (Armor et al.,1976; Berman et al., 1977). Ashton et al. also used two items from the Rand studies, along with interviews and classroom observations, to explore the relationship between teacher efficacy and student achievement, and they identified differences among the teachers of different levels of self-efficacy, and found that workplace factors can influence teaching self-efficacy (Ashton, 1984; Ashton et al., 1983) .

Recently, more teacher self-efficacy scales have been developed with more items to assess teacher self-efficacy in different domain (DeChenne & Enochs, 2010; Dellinger et al., 2008; Tschannen-Moran & Hoy, 2001). One of the most widely used and regarded teacher self-efficacy scales is the Teacher Efficacy Scale developed by Gibson and Dembo (1984), which was based on the Rand study items but utilized the framework of self-efficacy from social cognitive theory (Bandura, 1986). The scale with 16 items consisted of two constructs: self-efficacy and outcome expectancy (Roberts& Henson, 2000). For a long time, the Teacher Efficacy Scale and its variations have been the dominant means for assessing teaching efficacy (Henson, 2002; Klassen et al., 2011; Tschannen-Moran et al., 1998). Other relevant scales include the Responsibility for Student Achievement (Guskey, 1981), the Teacher Locus of Control (Rose & Medway, 1981), and the Webb Scale (Ashton et al., 1982). Although the Teacher Efficacy Scale had been long considered as the standard for measuring self-efficacy, more scholars have questioned this scale. For example, some scholars argued that the scale has some theoretical and psychometric problems which may invalidate the results (Brouwers & Tomic, 2003; Coladarci & Fink, 1995; Deemer & Minke, 1999; Dellinger, 2005; Denzine, Cooney et al., 2005; Guskey & Passaro, 1994; Tschannen-Moran et al., 1998).

Some studies have attempted to develop new measurement tools in order to address the problems, such as the Ohio State Teacher Efficacy Scale (Tschannen-Moran & Hoy, 2001). The Ohio State Teacher Efficacy Scale includes items that reflect the multidimensional nature of teaching by including specific teaching tasks within several domains of functioning that were important to a group of teachers participating in item development (Dellinger et al., 2008). However, there are still debates on this scale. For example, in Roberts and Hensons' (2000) study, they argued that "although the eigenvalues seem to also support a one-factor solution, the question arises again concerning the utility of an instrument that cannot explain at least 60% (original instrument explained 35.8%) of the variance in the inter-item matrix of associations." (Roberts & Henson, 2000).

With many of the self-efficacy studies being criticized for their invalidity, more and more researchers put increasing emphasis on the validity and reliability of the instruments. Some underline that the development of an instrument should be a rigorous process involving conceptual analysis of the domain of functioning, drafting and piloting the instrument, and statistical analysis of results including factor analysis and internal consistency reliability (Shea & Fortna, 2002). Many researchers use confirmatory factor analysis to develop teacher self-efficacy scales. Roberts and Henson (2000) developed a new self-efficacy instrument with confirmatory factor analysis to confirm the hypothesis that science teacher self-efficacy exists in two constructs: teaching efficacy and knowledge efficacy. Dellinger et al (2008) described a new measure of teacher self-efficacy beliefs using a principal components analysis with a varimax rotation and then a confirmatory factor analysis using structural equation modeling. Humphries et al (2012) developed a 35-item, 7-factor Physical Education Teaching Efficacy Scale.

Science Communication

Science communication has risen globally in importance in recent years (Bowater & Yeoman, 2012). Science communication is cross-disciplinary, involving communication, psychology, education, philosophy, policy and sociology, as well as the 'traditional' sciences such as natural, physical and computational science (Burns et al., 2003; Mulder, Longnecker, & Davis, 2008). Despite of its importance, science communication has no standard definition. Bryant (2003) defines science communication as processes by which the culture and knowledge of science are absorbed into the culture of the wider community. Gilbert and Stocklmayer define science communication as a “purposive intervention by a driving actor or a group of driving actors to alter the present state of the relationship between sciences and society toward their desired state” (Gilbert & Stocklmayer, 2012, p. 9). Science communication involves following aspects: Awareness including familiarity with new aspects of science; Enjoyment or other affective response; Interest as evidence by voluntary involvement with science or its communication; Opinions, the forming, reforming, or confirming of science-related attitudes; Understanding of science, its content, processes, and social factors (Burns et al., 2003).

Early models of science communication were based on the Shannon-Weavers one-way model of communication as shown in Figure 1 (Shannon & Weaver, 1949). According to this model, science communication is linear; its aim is for a source to transmit a message to a “receiver” without distortion. The notable one-way “deficit model” of science communication is a variation of the Shannon-Weavers model with the assumption that the audience is thought to be somehow deficient in knowledge of science, thus must be corrected (Ziman, 1991, 1992). The deficit model depicts communication as a one-way flow from science to its public and implies a passive public (Gross, 1994).

The one-way model of science communication fails to take into consideration of more complex communication activities, such as feedback from the receiver to the sender (Bowater & Yeoman, 2012). Bryant (2003) stated that many scientists hold theidea that knowledge flows like water down a pipe, i.e., from one brain to another without undergoing change. Gilbert and Stocklmayer (2012) argue that the message about science to be sent always needs to be modified and different receivers may decode the same message in different ways according to their own understandings and thoughts. People learn best when facts and theories have meaning in their personal lives (Kahlor & Stout, 2009).

Currently, more sophisticated two-way models that consider constant feedback in both coding and decoding processes are available (Gilbert et al., 2012). As in the example shown in Figure 2, which was developed by Wood (2003), communication is regarded as both interactive and two-way. A contextual model depicts communication as a two-way flow between science and its public and implies an active public; it’s central focus is not the state of science, but the situation of the public (Gross, 1994).

Specifically for science communication in schools, Bowater and Yeoman (2012) propose that a school science communication event should be more structured, fit within a timetabled lesson, and accept that not all kids will be interested in or want to do what have been planned. They suggest that one should ensure that he or she tailors the information to suit the school audience and build upon their existing knowledge. They suggest some steps for people who is planning a school science communication event, such as “think about your audience”; “decide on the subject matter, the aim and objective(s) and how you will deliver it”; and “check the National Curriculum” (Bowater& Yeoman, 2012).

To summarize, self-efficacy refers to “people’s judgments of their capabilities to organize and execute courses of action required to attain designed types of performances” (Bandura, 1986, p. 391) and it is task-specific or subject-specific. Communication is essentially as much a matter of listening as it is of talking and, to be effective, each party must have some understanding of the other: “To be effective with any audience, communication must be an interactive process…" (Stocklmayer et. al., 2001, p. 3). In order to engage the audience, science communicators must identify audience's preconceptions or alternative conceptions of science. Science communication is not just about knowledge and understanding; it also depends as much on the interests and concerns of the audience as on those of the scientists or others in positions of social authority (Lewenstein, 1995). The process of participation and engagement in science is a contextual one (Falk & Storksdieck, 2005). Accordingly, in this study science communication efficacy was defined as university students' beliefs in their capabilities to help middle and high school students understand science. Specifically, we intend to develop a standardized instrument for measuring university students' self-efficacy in communicating science to K-12 students. The specific research questions are:

1. What is the validity evidence for supporting the use of the measurement instrument to measure university students' self-efficacy in communicating science to K-12 students?
2. What is the reliability evidence for supporting the use of the measurement instrument to measure university students' self-efficacy in communicating science to K-12 students?

Method

Participants

Participants were university students, most of them in STEM fields, who were part of a NSF-funded project that assigned university graduate and undergraduate students to middle and high school classrooms to work with students and teachers in science. For this sample, 49.4% of the participants were undergraduate students and 1.1% of them were Master’ s student, and 20.7% of them were PhD students. Eighty-seven students completed the pilot instrument after they had completed at least one semester placement in middle and high schools from 2011-2013. Seventeen additional students completed the revised instrument after they had completed their placement in local middle and high schools in Dec. 2013.

Procedure

The development of the science communication efficacy instrument followed a construct modeling approach (Wilson, 2003; 2005). The construct modeling approach to developing a measurement instrument starts with a clearly defined construct, which “precipitates an idea or a concept that is the theoretical object of our interest in the respondent…” (Wilson, 2005, p. 5), operationalized by progress variables. Assessment tasks are then derived from the defined progress variables, and data collected from pilot-testing and field-testing are used to examine the fit between the progress variables and data using Rasch modeling (Bond & Fox, 2007; Liu, 2010).

We defined the construct of science communication self-efficacy to be the university students’ beliefs in their capabilities to help middle and high school students understand science. The progress variable of self-efficacy was conceptualized as consisting of the following levels of capabilities: understanding students, developing science content, and explaining the content.

We used a Likert-scale (Likert, 1932) type question format. Using response scales to collect attitude data has a long history in science education. For each Likert-scale item, respondents are asked to specify their levels of agreement to a given statement, usually expressed in a format such as: strongly disagree, disagree, neutral, agree, strongly agree (Bond & Fox, 2007). The pilot measurement instrument contained 20 items with five response categories to describe respondents’ levels of self-efficacy in communicating science. Response categories were coded as 1 through 5 in an ordinal scale: 1—Nothing, 2—Very Little, 3—Some Influence, 4—Quite a Bit, and 5—A Great Deal. The items related to three major aspects of the progress variable on science communication to middle and high school students: understanding students, developing science content, and explain the content.

Data Analysis

Students responses to the 20-item pilot measurement instrument were then analyzed using the rating scale Rasch model (Andrich, 1978). Rasch measurement has been increasingly used in a wide variety of disciplines in the past 30 years (Liu & Boone, 2006), and is becoming the convention for developing quality measurement instruments in all social sciences (Royal et al., 2010). Unlike most other statistical models which are applied to data, Rasch models impose requirements upon data (Royal, et al., 2010). Advantages of using Rasch measurement are that, when there is good model-data-fit, measures produced by the instrument are interval. Interval scale measures have precise measurement errors for both individual items and subjects, and allow for inferential statistical analyses to be conducted with more power.

Winsteps computer program (Linacre, 2011) was used to conduct the analysis. Linacre's eight rating scale analysis guidelines (2002) were used to decide item quality.

Pilot-study

Item and person separation and reliability of the pilot instrument

Based on the analysis of the pilot instrument, item separation was 3.33 (reliability=0.92) and person separation was 2.56 (reliability =0.87), both were acceptable. The mean of the infit mean squares (MNSQ) at 1.01 and the outfit mean squares (MNSQ) at 0.99 were very close to the expected value of one. The mean infit ZSTD and outfit ZSTD were both inside the conventionally acceptable range of -2 to + 2.

The Wright map of items and subjects showed that students’ self-efficacy had a wide range of variation, but most items gathered along the middle to lower end of the subjects’ communication efficacy range. However, no item was available for higher science communication efficacy subjects, and only one student fell below the 20 items. A gap existed between two items with seven students in that gap. The above findings suggestged that the items of pilot instrument as a whole were relatively easy for those respondents, thus there was a need for addition of more difficult items for higher efficacy students.

Fit statistics for items

The mean square residual (MNSQ) and the standardized mean square residual (ZSTD) are typically used as the fit indicators to examine how well each item accords with the Rasch unidimensional model. Item MNSQ has an expected value of 1.0 and a range from zero to infinity. Based on Linacre’s suggestion (Linacre, 2010), items fit the model when their MNSQs fall within the range of 0.6 to 1.4 (for rating scale); a fit value below 0.6 (overfit) indicates that the item fits better than expected and can be a hint to item redundancy; a fit value above 1.4 (underfit) might be an indicator for multidimensionality (Vehren et al., 2013). ZSTD values are within the range of -2 to +2 (Liu, 2010) when there is a good fit; a positive z-residual indicates that responses are worse than expected; a negative z-residual indicates that responses are better than expected (Bradley et al., 2010).

Inspection of the fit statistics for all pilot 20 items, 17 of the 20 items had infit and outfit MNSQs within the acceptable range of 0.6 to 1.4, with exceptions of item 2 (infit MNSQ =0.47 and outfit MNSQ=0.49), item 5 (infit MNSQ=1.43 and outfit MNSQ=1.51), and item 19 (infit MNSQ=1.44 and outfit MNSQ=1.45) .

Item-measure correlation

Item-measure correlation (point-measure correlation/PTMEA) indicates how the item contributes to the item difficulty (Liu, 2010). According to Wolfe and Smith (2006), "item-measure correlations should be positive, indicating that the scores on the item are positively correlated with the average score on the remaining items. Negative item-measure correlations indicate negatively polarized items that were not reverse scored. Near zero item-measure correlations indicate that the item is either extremely easy or difficult to answer correctly or to endorse or that the item may not measure the construct in the same manner as the remaining items" (Wolfe & Smith, 2006, p. 206).

None of the 20 items had a zero or negative point-measure correlation (PTMEA); all of the point-measure correlations (PTMEA) had values ranging from 0.25 to 0.73, which indicated that all of the 20 items contributed to the measurement of students' science communication efficacy.

Rating scale category structure

The item category frequencies had a good spread, meeting the expectations (Linacre, 2002;Wolfe & Smith, 2006). The measure for category 1 was -2.80, meaning that the average agreeability estimate for persons answering 1 across all items was -2.80 logits. For categories of 2, 3, 4, 5, the category agreeability estimate was -1.30 logits, -0.13 logits, 1.25 logits, and 3.10 logits, respectively, meeting the requirement of the rating scale design, which was increasing monotonically with category.

Linacre (2002) recommended that step calibrations should increase by at least 0.81 logits for a 5-point scale to show distinction between categories (Wolfe & Smith, 2006). The step calibration of the 20 items increased monotonically by 0.51 logits, 1.30 logits, and 1.37 logits; however, the difference between category 2 and 3 (0.5 logits) was too small. This issue was also reflected in probability curves. Probability curves of good rating scales show that each hill stands alone, as hills blending in with other hills indicate that respondents may have a hard time to endorse among the categories (Royal, et al., 2010). Specifically, the category 2 ("very little") and category 3 ("some influence) were too close for respondents to differentiate; they needed to be combined.

Item and Instrument Revisions

Based on the Rasch analysis results of the pilot-study instrument, a number of improvements were made to the instruments. Specifically, in order to accurately measure the self-communication self-efficacy of persons with the highest ability level, we added four new items: new item 17 ("Explain a difficult science concept to students"), new item 18 ("Explain current research to teachers"), new item 19 ("Facilitate student learning in museums "), new item 20 ("Explain science to parents").

Four pilot items had similar measures: -0.41 logits ("understand middle and high school students' science background knowledge"), -0.43 logits ("understand middle and high school students' interest in science"), -0.34 logits ("Understand middle and high school students' social and cultural backgrounds"), -0.53 logits ("Understand middle and high school students' attention span"), respectively, and two of them, "Understand middle and high school students' social and cultural backgrounds"(PTMEA=0.32) and "Understand middle and high school students' attention span"(PTMEA=0.25) had low PTMEA correlation. These two items were removed from the instrument. We also removed item "Lead small group activities/discussions with students after school or during weekends" and item "Tutor students after school or during weekends" because they both did not fit the model well and both pertained to "weekends" activities that were not central to the measured construct. We also collapsed the rating scale categories from five to four. The new categories became: 1—Little, 2—Some, 3—Quite a bit, and 4—A Great Deal.

Field-testing

The revised instrument included again 20 items. They were responded by 17 students. Responses by the 17 students were combined with the responses by the 87 students from the pilot study by the following recoding: 1 was coded as 1, 2 and 3 were coded as 2, 4 as 3, and 5 as 4. The combined responses were then submitted to Rasch analysis again. The findings reported next are based on this analysis.

Results

Figure 3 presents the Wright map of the revised instrument. We can see that students' self-efficacy had a wider range of variation from -2.33 logits to 5.92 logits, while the revised item measures ranged from -0.68 logits to 0.84 logits. The first two most difficult items (item 20, item 19) were the new items (1.23 logits, 1.12 logits), and item 17 (0.39 logits) and item 18 (0.60 logits) were both above the mean of the items, indicating that the four new items were relatively difficult items just as intended. However, there was still one gap located near two standard deviations from the mean of the items; fifteen students had a lower self-efficacy than any item could assess. Another gap existed at the top of the continuum, where 14 higher self-efficacy students were in that gap.

Table 1 presents fit statistics for the final 20 items in the revised instrument. We can see that, infit MNSQs ranged from 0.65 to 1.29 whereas the outfit MNSQs ranged from 0.69 to 1.31; both were regarded as being acceptable. Infit ZSTDs and outfit ZSTDs all ranged from -2.0 to +2.0 with the exception of item 2 (infit ZSTD= -3.0 and outfit ZSTD=-2.5), item 6 (infit ZSTD=1.8 and outfit ZSTD= 2.2). All the items exhibited strong positive point-measure correlations (PTMEA) ranging from 0.50 to 0.70.

Table 2 presents the category structure statistics. As shown in Table 2, with four categories instead of five, each category count satisfied the criterion for minimum counts of 10 observations (Linacre, 2002). The average category measures were ordered and increased monotonically from -1.01 logits to 1.60 logits. The outfit MNSQ ranged from 0.96 logits to 1.02 logits, indicating expected category usage (Linacre, 2002). In addition, the category threshold calibrations increased monotonically with categories and the distances were all more than 1.1 logits, meeting the guidelines given by Linacre (2004). Inspecting the category probability curves (see Figure 4), we see that each category represented a distinct region of the underlying construct, thus, collapsing category 1 and 2 had indeed improved our rating scale diagnostics.

Figure 5 presents the dimensionality map based on PCA (principal component analysis). PCA was applied to standardized residuals to identify possible dimensions existing in the scale (Oon & Subramaniam, 2011). A variance greater than or equal to 50% for the Rasch dimension can be regarded as evidence that the scale is unidimensional (Linacre, 2011), and scale unidimensionality can be assumed if the second dimension (first contrast) has the strength of less than 3 items (in terms of eigenvalues) and the unexplained variance by the first contrast is less than 5% (Oon, & Subramaniam, 2011). Measures resulted from the revised measurement accounted for 43.9% of total variance, though 4% higher than pilot measurement, yet still below the expected norm. Besides, the second dimension had an eigenvalue of 3.2 and accounted for 9% (previously it was 3.5 and 10.2%) of the variance, indicating that unidimensionality of items was still not ideal. From Figure 5, we see that items A, B, C, D, a, b (corresponding to items 11, 10, 14, 9, 4, 5) had the largest contrast loadings (>0.50), suggesting that they might measure an additional dimension. Table 3 presents the summary statistics related to reliability. It can be seen in the table that the person separation index was 2.77, with an equivalent Cronbach's reliability coefficient (α value) of 0.88. Item separation index was 2.94, and its corresponding Cronbach's α value was 0.90, indicating reliable item and person estimation. Further, Rasch measurement produces an SEM as an additional measure of reliability for each individual person and item measure. Persons and items with measures closer to their means have smaller SEMs than those further from the means. As shown in Table 3, SEM values for persons and items were small, ranging from 0.14 to 0.33.

Conclusion

Validity

According to Liu and Boone (2006), "if assessment data fit the Rasch model well, then there is evidence to claim that the originally hypothesized dimension or construct exists, and is assessed by the instrument, thus providing evidence for content and construct validity." (Liu & Boone, 2006, p. 6). Based on the above presented findings, overall items fit the Rasch model well, suggesting that measures based on this revised instrument are valid. Given the nature of Rasch measurement, when items fit the Rasch model, there is evidence for the construct validity of the measures.

Unidimensionality

From the results presented above, unidimensionality of the instrument requires further improvement. Specifically, items 4, 5, 9, 10, 11, and 14 need to be reconsidered. We tried to remove those six items; the variance accounted for did not improve much and was still below 50%. Although it is common in the literature involving Rasch analysis that reported variance accounted for by Rasch measures based on PCA is less than 50% (Cervellione et al., 2009; Fischer et al., 2005; Higgins, 2007; Oon & Subramaniam, 2011), and our variance accounted for (43.9%) by Rasch measures in this study is not unusual, further improvement to the instrument to improve unidimensionality is needed.

In conclusion, the results suggest that the revised self-efficacy instrument with the new 20-items is well-targeted at the STEM students. Measures from this instrument are reasonably valid and reliable, thus are appropriate for assessing university STEM students' science communication self-efficacy.

Table 1

The Revised Item Statements and Statistics

Item	Statement	Infit		Outfit		Measure	PTMEA
		MNSQ	ZSTD	MNSQ	ZSTD		
1	Understand middle and high school students' science background knowledge	0.81	-1.5	0.82	-1.3	-0.54	0.61
2	Understand middle and high school students' interest in science	0.65	-3.0	0.69	-2.5	-0.54	0.62
3	Understand middle and high school students' cognitive abilities	0.94	-0.5	1.02	0.2	-0.20	0.50
4	Decide what science topics are appropriate to students	0.94	-0.4	0.97	-0.2	-0.11	0.60
5	Decide how much science content is appropriate to students	1.12	1.0	1.19	1.4	0.33	0.50
6	Help teachers find relevant resources (e.g., science activities)	1.25	1.8	1.31	2.2	-0.15	0.57
7	Develop science labs	1.24	1.8	1.21	1.6	0.42	0.65
8	Develop out-of-school science learning activities	1.12	1.0	1.08	0.6	0.73	0.62
9	Assist teachers in teaching lessons	1.17	1.3	1.18	1.3	-0.70	0.56
10	Assist teachers in conducting labs	1.08	0.6	1.10	0.7	-0.97	0.61
11	Teach science labs to students	0.97	-0.2	-0.93	-0.5	-0.34	0.68
12	Facilitate out-of-school science learning activities	0.88	-0.9	0.87	-1.0	0.66	0.69
13	Lead small group activities/discussions with students in class	1.14	1.1	1.09	0.7	-0.71	0.55
14	Demonstrate scientific content, procedures, tools, or techniques to students	0.92	-0.6	0.87	-0.9	-0.68	0.65
15	Teach lessons or give lectures to students in class	0.90	-0.8	0.90	-0.7	-0.09	0.70
16	Explain a difficult science concept to students	0.77	-1.9	0.76	-1.9	-0.45	0.69
17	Relate current research to K-12 curriculum	1.07	0.3	1.03	0.2	0.39	0.64
18	Explain current research to teachers	1.04	0.2	0.97	0.0	0.60	0.65
19	Facilitate student learning in museums	1.29	1.0	1.20	0.7	1.12	0.66
20	Explain science to parents	1.23	0.8	1.29	1.0	1.23	0.60

variance explained by measures = 43.9%   unexplained variance (total) = 56.1%

Table 2
Summary of Rating Scale

Rating Scale Category	Observed Count	Observed%	Average Measure	Outfit MNSQ	Step Calibrations
1=None	203	12	-1.01	1.02	NONE
2=Some	482	28	-0.17	0.96	-1.46
3=Quite a bit	631	36	0.58	1.05	-0.07
4=A great deal	420	24	1.60	1.00	1.53

Table 3
Summary Output for All Test Items

			Infit		Outfit	
PERSON	MEASURE	SEM	MNSQ	ZSTD	MNSQ	ZSTD
MEAN	0.29	0.18	1.01	-0.2	1.00	-0.2
SD	1.26	0.08	0.55	1.7	0.53	1.7
Person separation= 2.77 (reliability=0 .88) Item separation =2.94 (reliability=0 .90)						

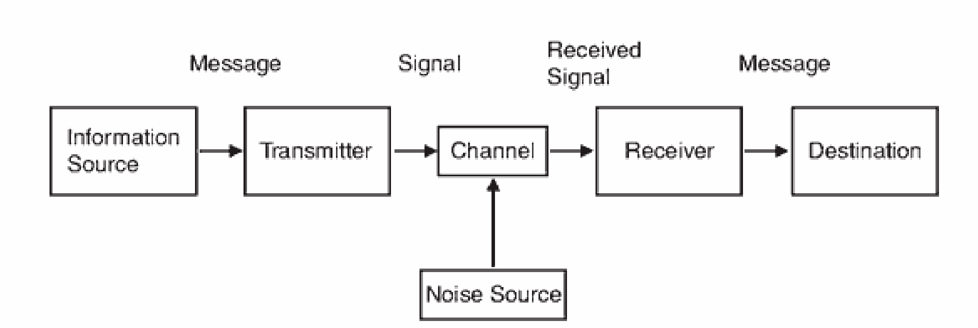


Figure 1. Shannon-Weavers one-way model (Shannon&Weaver, 1949)

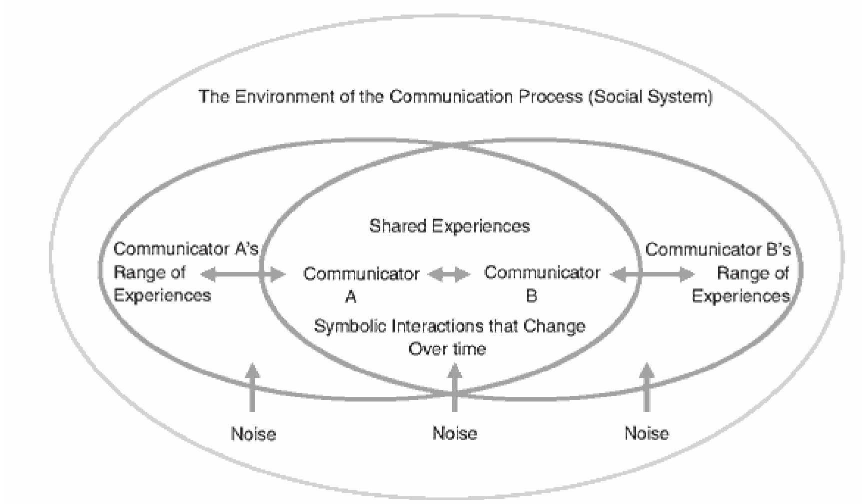
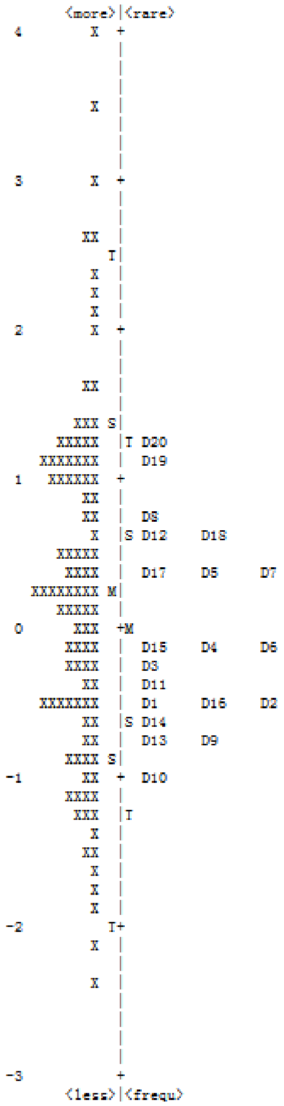


Figure 2. Transaction model of communication from Wood, 2003 (adapted by Bowater & Yeoman, 2012)



```
          <more>|<rare>
    4        X  +
                |
                |
                |
             X  |
                |
                |
                |
    3        X  +
                |
                |
            XX  |
               T|
             X  |
             X  |
             X  |
    2        X  +
                |
                |
            XX  |
                |
           XXX S|
         XXXXX  |T D20
       XXXXXXX  |  D19
    1   XXXXXX  +
            XX  |
            XX  |  D8
             X  |S D12    D18
         XXXXX  |
          XXXX  |  D17    D5     D7
      XXXXXXXX M|
         XXXXX  |
    0      XXX  +M
          XXXX  |  D15    D4     D6
          XXXX  |  D3
            XX  |  D11
       XXXXXXX  |  D1     D16    D2
            XX  |S D14
            XX  |  D13    D9
          XXXX S|
   -1       XX  +  D10
          XXXX  |
           XXX  |T
             X  |
            XX  |
             X  |
             X  |
             X  |
   -2          T+
             X  |
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             X  |
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                |
   -3           +
          <less>|<frequ>
```
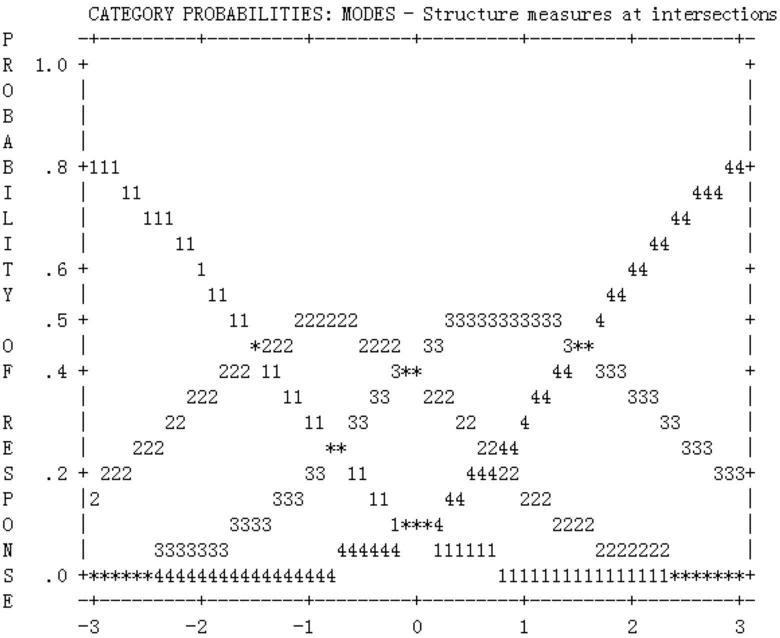
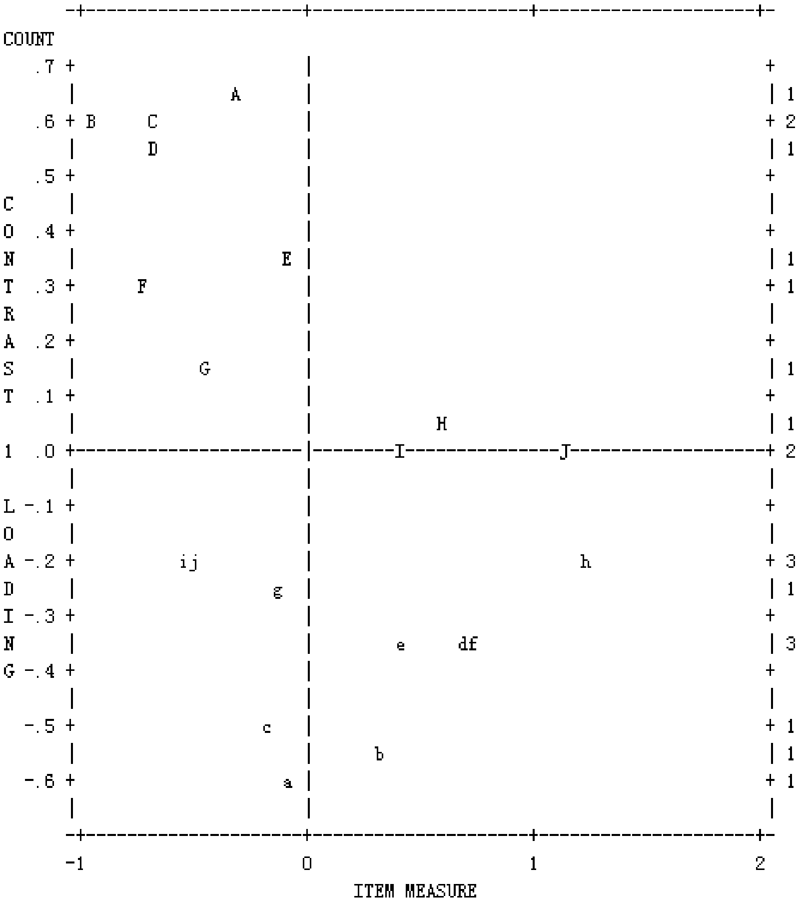

Figure 3. Wright Map of Person-Item distribution



```
        CATEGORY PROBABILITIES: MODES - Structure measures at intersections
P      -+---------+---------+---------+---------+---------+---------+-
R  1.0 +                                                             +
O      |                                                             |
B      |                                                             |
A      |                                                             |
B   .8 +111                                                        44+
I      |   11                                                   444  |
L      |     111                                              44     |
I      |        11                                          44       |
T   .6 +          1                                       44         +
Y      |           11                                   44           |
    .5 +             11    222222        3333333333    4             +
O      |               *222      2222  33           3**              |
F   .4 +            222 11          3**            44  333           +
       |         222      11      33   222       44       333        |
R      |       22           11  33        22    4            33      |
E      |    222               **            2244               333   |
S   .2 + 222                33  11         44422                  333+
P      |2               333      11     44     222                  |
O      |             3333           1***4          2222              |
N      |      3333333          444444   111111         2222222       |
S   .0 +******44444444444444444               1111111111111111*******+
E      -+---------+---------+---------+---------+---------+---------+-
       -3        -2        -1         0         1         2         3
```

Figure 4. Category structure probabilities curves



```
      -+---------------------+---------------------+---------------------+-
COUNT
   .7 +                      |                                            +
      |               A      |                                            | 1
   .6 + B     C              |                                            + 2
      |       D              |                                            | 1
   .5 +                      |                                            +
C     |                      |                                            |
O  .4 +                      |                                            +
N     |                    E |                                            | 1
T  .3 +      F               |                                            + 1
R     |                      |                                            |
A  .2 +                      |                                            +
S     |            G         |                                            | 1
T  .1 +                      |                                            +
      |                      |            H                               | 1
1  .0 +----------------------|--------I---------------J-------------------+ 2
      |                      |                                            |
L -.1 +                      |                                            +
O     |                      |                                            |
A -.2 +          ij          |                          h                 + 3
D     |                   g  |                                            | 1
I -.3 +                      |                                            +
N     |                      |        e     df                            | 3
G -.4 +                      |                                            +
      |                      |                                            |
  -.5 +                  c   |                                            + 1
      |                      |      b                                     | 1
  -.6 +                    a |                                            + 1
      |                      |                                            |
      -+---------------------+---------------------+---------------------+-
      -1                     0                     1                     2
                                 ITEM MEASURE
```

Figure 5. Factor analysis of residuals

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