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Validating Scales to Measure Undergraduate Students' Interest and Career Aspirations in Geoscience and Sedimentology

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Validating Scales to Measure Undergraduate Students' Interest and Career Aspirations in Geoscience and Sedimentology

Abstract

This full paper in the empirical research paper category presents the validity of scales to measure students' interest and career aspirations in geoscience and sedimentology (GS). High attrition rates are an ongoing concern in STEM (Science, Technology, Engineering, and Mathematics) disciplines. Previous research shows that less than 50% of the students enrolled in STEM programs graduate with a degree in their field. Given the crucial role of students' interest in determining their academic and career choices, learning experiences in STEM fields must be designed to create and sustain students' interest in the field. This paper presents the design and validation of scales to assess students' interest and career aspirations in GS. We adapted items from pre-existing instruments on STEM situational interest and career aspirations for use in the context of GS. This study is part of a larger project that comprises the development and evaluation of an educational tool to facilitate teaching sedimentology concepts. The following research question guided the study: How do the observed measures of GS interest and GS career aspirations relate to their respective underlying constructs? We surveyed two undergraduate geology courses at Texas A&M University, an R1, Hispanic-serving institution (HSI) in the southwestern United States. We administered the survey at the beginning (pre-survey) and end of the semester (post-survey) for Spring and Fall semesters of 2024 (N=151). To validate the instrument, as supported by logic and theory, confirmatory factor analysis was conducted. The GS interest model demonstrated good fit, confirming the underlying factor structure. However, the GS career aspirations model showed an inadequate fit and was respecified to include a covariance between two items reflecting content applicability and impact on goals. The respecified model showed a good fit for the data. The findings offer empirical support for the validity of the scales within the context of undergraduate geoscience courses. This study establishes a foundation for extending the instrument's use and refinement in diverse geoscience contexts, ultimately supporting the development of learning experiences that foster and sustain student interest in geoscience.

Introduction

There has been a growing emphasis on improving students' interest in Science, Technology, Engineering, and Mathematics (STEM) disciplines to counter the low recruitment and high attrition rates [1-3]. Particularly, the field of geology presents a unique challenge in fostering student interest since the concepts are difficult to visualize and there are limited opportunities for hands-on learning [4, 5]. Notably, most STEM graduates enter the workforce without firsthand experience in handling real-world problems [1, 6, 7]. Prior research has found that students show increased interest and knowledge about possible career paths by participating in active learning activities [8, 9]. Therefore, instructional approaches that emphasize active learning and hands-on experience are essential for helping students sustain interest and ultimately pursue long-term careers in STEM fields, including geoscience and sedimentology (GS) [10, 11].

To provide an accessible resource for teaching GS concepts, we designed and developed a software tool, SedimentSketch. In alignment with active learning approaches, SedimentSketch introduces students to authentic scenarios that simulate real-world problems [12]. To evaluate the effectiveness of SedimentSketch in terms of developing GS interest and career aspirations, we tailored existing instruments measuring STEM interest and STEM career aspirations to form a survey for undergraduate geoscience courses. However, as the instruments were not designed for use in undergraduate geoscience classes, this paper focuses on examining the validity of the survey in geoscience courses.

In this article, we discuss the survey adaptation process and its validation in the context of undergraduate geoscience courses. Specifically, the study addresses the research question, "How do the observed measures of GS interest and GS career aspirations relate to their respective underlying constructs?"

Related Work

SedimentSketch as an Active Learning Tool

Increasing students' interest and career aspirations in GS is critical to addressing the challenges of recruitment and retention in the field [13, 14]. Previous research shows one of the primary reasons students leave STEM fields is the perceived lack of engagement or connection to real-world applications [15]. Several sedimentology concepts, such as sediment transport, facies, and depositional environments, can be difficult to grasp without a visual or physical representation [16]. While traditional teaching strategies such as lectures and problem sets are valuable for instruction [17], active learning experiences can enhance students' interest in the material and promote long-term career aspirations in GS. Moreover, active learning interventions can play a key role in ensuring equitable academic outcomes. Intervention programs designed for personalized experiences that provide structured academic and social support can reduce gaps in achievement and retention by providing feedback and social support [18]. This demonstrated impact of personalized support suggests that SedimentSketch may be an effective approach to fostering accessibility, engagement, and hands-on learning opportunities. To assess the effectiveness of SedimentSketch in terms of enhancing students' interest and career aspirations in GS, we reviewed existing instruments designed to measure these constructs within STEM domains.

STEM Situational Interest

Situational interest is created as a response to elements in one's environment, as opposed to personal characteristics [19, 20]. The situational interest scale [21] measures situational interest in academic contexts. The authors provided evidence for the validity of the scale at the undergraduate and K-12 levels. Analysis of the scale's psychometric properties suggested that situational interest was composed of two main factors, namely, triggered situational interest and maintained situational interest. These can be conceptualized as students' feelings regarding the class activities and their perceptions regarding the class content and its usability, respectively. Furthermore, maintained situational interest is divided into two distinct dimensions: feeling and value. Based on the factor structure revised over three studies, the scale proposed by Linnenbrink-Garcia and colleagues [21] consisted of 12 items, with four items each for triggered situational interest, maintained situational interest–feeling, and maintained situational interest–value. For the current study, we only considered maintained situational interest as it represents students' interest in the content rather than the instruction. Table 1 shows sample items from the original scale [21] next to the items we adapted for the GS interest scale.

Table 1: Interest scale – sample original and adapted items

Original	Adapted
I find the math we do in class this year interesting	Things that I learn in geoscience classes interest me.
What we are studying in math class is useful for me to know	I find it useful to learn about topics in sedimentology.

STEM Career Aspirations

Career aspirations can be defined as an individual's goals or preferences related to their career [22]. By extension, STEM career aspirations are an individual's goals regarding a career in STEM. Career aspirations are distinct from interest; while career aspirations refer to career-related goals, career interest refers to an individual's "emotional disposition" towards a career [22]. When consistent over time, career aspirations are a strong predictor of educational and career choices [23].

Although career aspirations have been researched extensively, a standardized instrument for their measurement has not been established yet. Single-item measures are the most widely used measure of career aspirations [22]. Several studies have used similar single-item metrics to measure STEM career aspirations among young individuals [24-26]. With single-item measures, though, it is hard to establish construct validity because they only measure one aspect of a construct. Consequently, single-item measures are also vulnerable to measurement errors.

Noteworthy efforts to develop scales to measure career aspirations in STEM include the creation of the "scientific possible selves" instrument, which assessed middle and high school students' expectations, fears, hopes, and plans for a career in science [12, 27]. Another questionnaire was developed to measure science career aspirations among elementary school students [28, 29]. A recent scale [30] extended the questionnaire by DeWitt and colleagues [28] to create an instrument with separate career aspiration scales, each consisting of four items, for five disciplines: science, technology, mathematics, engineering, and education. Similarly, for this study, we adapted items from the scale proposed by DeWitt and colleagues [28] to measure GS career aspirations. We selected this scale because it most closely aligned with our research purpose. It is unidimensional and shows strong reliability [29]. Table 2 shows sample items from the survey [29] adapted for the GS career aspirations scale.

Table 2: Career aspirations scale - original and adapted items

Original	Adapted
I would like to work in science	I am interested in pursuing a career in geosciences.
I would like to have a job that uses science	I would choose a research project or job that requires me to work with sedimentology (e.g., core description, sedimentary rocks analysis) in the future.

We also included items in the GS career aspirations scale to assess students' awareness of the applicability of sedimentology skills and the tasks that sedimentologists perform. Prior literature indicates that knowledge of STEM fields is directly correlated with STEM career aspirations [31-35]. This link is also supported by theories of career choice. Social Cognitive Career Theory posits that learning experiences, including exposure to STEM careers, influence outcome expectations, which in turn impact career interests and goals [36]. Similarly, based on the Expectancy Value theory, knowledge of STEM fields helps students form expectations for a profession and associate task values, which directly impact their career choices [37].

Methods

Context

The software tool, SedimentSketch, was created to aid students in learning sedimentology concepts through interactive educational videos, games, and quiz-like activities [11]. SedimentSketch has been introduced at a Hispanic Serving Institution (HSI), where about 25% of the student population is Hispanic/Latinx [38]. There are documented gaps in GPA and attrition rates among different student populations in the geoscience and sedimentology (GS) fields [3, 5]. Within this setting, SedimentSketch offers students all-time access to a virtual lab that can facilitate learning of GS concepts, improving achievement outcomes for all students [11]. Combined with an active learning approach, we believe working through the real-world scenarios provided by SedimentSketch has the potential to enhance students' interest and career aspirations in GS [24, 31].

Survey Design

The survey instrument was adapted and validated using a modified version of a survey development process established in the literature [39, 40]. Figure 1 demonstrates this process.

Figure 1: Survey Instrument Development Process

In step 1, we adapted the items for the predefined constructs from existing instruments, ensuring alignment with prior literature and theory. In step 2, a team of experts reviewed the items generated in step 1 to ensure they were theoretically aligned and accurately represented the constructs being measured. The experts reviewed each item independently and described its meaning. Later, the experts discussed each item in a focus group. In the discussion, experts focused on their respective interpretations and identified the agreement on the wording and meaning of each item. After thoughtful discussion on each item and approval of each item by experts, in step 3, the survey was conducted in undergraduate geoscience courses. In step 4, the validity of the survey in the context of geoscience courses was evaluated using a Confirmatory Factor Analysis (CFA). Lastly, in step 5, the model fit was assessed, and the model was respecified accordingly.

The design of the survey was also aligned with the assessment triangle proposed by Pellegrino and colleagues [41]. The assessment triangle is a framework for designing assessments based on cognition, observation, and interpretation. The creation of the items was informed by how STEM interest and career aspirations are developed, as evidenced in theory and literature (cognition). Secondly, we used the survey as an opportunity for students to demonstrate their interest and career aspirations in GS (observation). To ensure that the measures were valid and reliable, we evaluated the survey data for validity and reliability in the context of undergraduate geoscience courses (interpretation). Being mindful of the alignment between cognition, observation, and interpretation helps ensure the design of effective assessments [41].

Scales

The GS interest scale consisted of five items adapted from the STEM situational interest scale [21]. The items were modified for use in the context of undergraduate geoscience courses. All item responses were based on a five-point Likert scale, where 1 represented "strongly disagree" and 5 represented "strongly agree". Table 3 presents the scale items and their abbreviations.

Table 3: GS interest scale

Abbreviation	Item
Geo topic interest	I am interested in learning more topics in geosciences.
Geo enjoy lab	I am enjoying doing labs in geoscience.
Geo class interest	Things that I learn in geoscience classes interest me.
Sed enjoy class	I really enjoy the content taught in the sedimentology class.
Sed utility	I find it useful to learn about topics in sedimentology.

The items for the GS career aspirations scale were adapted from a preexisting instrument designed to measure students' science career aspirations [28, 29], and prior literature. Table 4 shows the scale items and their abbreviations. All items followed a five-point Likert format from 1 to 5, denoting a scale from "strongly disagree" to "strongly agree".

Table 4: GS career aspirations scale

Abbreviation	Item
Sed impact goals	I feel that learning sedimentology would make an impact on my future goals.
Sed applicability	I know that sedimentology skills can be applied to professional and daily life.
Geo career interest	I am interested in pursuing a career in geosciences.
Sed career choice	I would choose a research project or job that requires me to work with sedimentology (e.g., core description, sedimentary rocks analysis) in the future.
Sed job knowledge	I know what sedimentologists do for their jobs.

Data Collection

The study was conducted at a large public research university in the southwestern region of the U.S.A. We surveyed students in two undergraduate Geoscience courses. Both courses covered similar concepts in sedimentology and geoscience, though the depth of coverage varied. One course provided students with an in-depth understanding of petroleum geology, catering to those interested in careers in the oil industry, with less emphasis on sedimentology. The other course was dedicated entirely to sedimentology for geology majors, preparing students for careers in geology, including energy, environmental consulting, and resource management. Data were collected at the beginning and end of the semester for two semesters (Spring and Fall 2024). Both pre-survey and post-survey data were included in the analysis.

Procedure and Analysis

The data were prepared and analyzed using the statistical software Stata, V.18.0 [42]. We found no evidence of outliers in the data. The data were assessed for missing values, and only complete sets were included in the analysis (151 observations). Descriptive statistics were examined to analyze trends in the data. We conducted pairwise Pearson correlations among the variables. Using the maximum likelihood method, we conducted a Confirmatory Factor Analysis (CFA) of the scales. A conceptual model was hypothesized and estimated for each construct. The model fit was ascertained using a combination of global fit indices, including the chi-square statistic, the root-mean-square error of approximation (RMSEA), the standardized root mean residual (SRMR), the Tucker-Lewis index, and the comparative fit index (CFI). We used the following metrics for assessing the global fit indices: RMSEA below .10 (90% confidence interval contains .06), TLI and CFI greater than .95, and SRMR less than or equal to .08 [43]. We also used AIC for model comparisons. Figure 2 shows the hypothesized models for each scale.

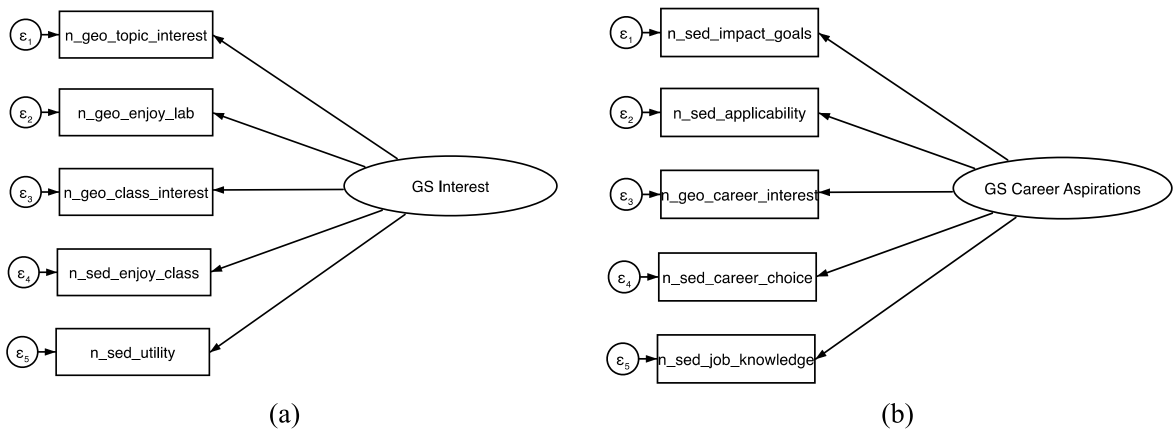

Figure 2: Hypothesized models (a) GS Interest scale (b) GS Career Aspirations Scale

The models were estimated and respecified according to the global model fit and local modification indices. Lastly, we assessed the scale and item reliability with Cronbach's alpha and McDonald's omega, using the Stata module OMEGACOEF [44]. Values above .70 are considered acceptable, and values above .90 indicate excellent reliability [45].

Findings

GS Interest Model

The results of the CFA for GS interest showed that all the indicator variables statistically significantly predicted GS interest. Table 5 lists the estimates for all indicators.

Table 5: Estimates for GS interest scale

Factor	Indicator	Estimate	SE	p	R^2	Overall R^2
GS Interest	Geo topic interest	1	constrained	<.001	.71	.93
	Geo enjoy lab	.9	.07	<.001	.67	
	Geo class interest	.96	.06	<.001	.87	
	Sed enjoy class	.84	.07	<.001	.66	
	Sed utility	.65	.07	<.001	.50	

The latent variable, GS interest, explained about 93% of the variance in the indicator variables. The global fit indices suggested that the model was a good fit. The chi-square test was not statistically significant, indicating no evidence of misfit (χ^2 (5, 146) = 7.68, p = .17). The value of RMSEA (.06) also indicated a good fit. The values of CFI (.99), TLI (.98), and SRMR (.02) also indicate a good fit. Figure 3 shows the estimated model for GS interest and the standardized factor loadings. The GS interest scale demonstrated excellent reliability based on the alpha (α = .91) and omega (ω = .91) statistics.

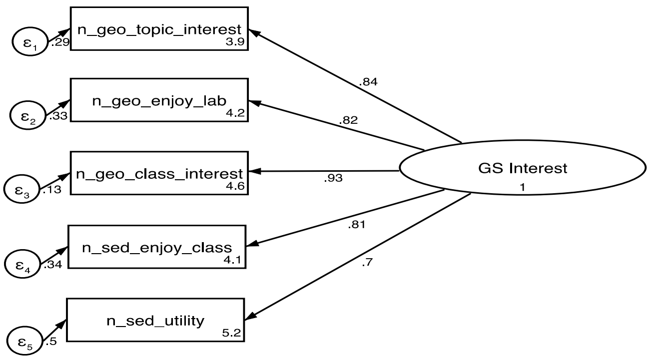

Figure 3: Estimated GS interest scale (standardized)

GS Career Aspirations Model

The hypothesized model for GS career aspirations was not an adequate fit for the data. Although all the factor loadings were statistically significant, indicating high correlations between the indicators and the latent variable, the goodness of fit indices suggested the model was mis-specified. The chi-square test was statistically significant, indicating an ill-fitting model (χ^2 (5, 146) = 82.7, p <.001). Table 6 summarizes the fit indices of the model. The values of RMSEA, SRMR, CFI, and TLI did not meet the acceptability criteria.

Table 6: Model Comparison

Model	χ^2	df	Model Comparison	$\Delta\chi^2$	Δ df	RMSEA (90% CI)	SRMR	CFI	TLI	AIC
1. Hypothesized	**82.7***	**5**				**(.26, .39)**	**.13**	**.75**	**.51**	**1927.91**
2. Respecified	**1.27**	**4**	**1 vs 2**	**81.43***	**1**	**(0, .06)**	**.02**	**1**	**1**	**1848.47**

p*<.001

Next, we analyzed the standardized covariance residuals and the modification indices to identify potential misspecification issues. Standardized covariance residuals approaching the value of three indicate possible issues of misfit. Based on the agreement between the standardized covariance residuals and modification indices, the lack of a covariance path between the error terms for items "Sed impact goals" and "Sed applicability" contributed to the misfit. The missing link also had sound theoretical support; perceptions of value and outcome expectations are known to impact career goals [36]. Therefore, we added a covariance between the error terms for items "Sed impact goals" and "Sed applicability". Figure 4 shows the respecified model with standardized estimates. The model characteristics are summarized in Table 7.

Table 7: Estimates for respecified GS career aspirations scale

Factor	**Indicator**	**Estimate**	**SE**	**p**	**R^2**	**Overall R^2**
GS Career Aspirations	Sed impact goals	1	constrained		.27	.85
	Sed applicability	1.01	.11	<.001	.27	
	Geo career interest	2.45	.40	<.001	.64	
	Sed career choice	2.37	.39	<.001	.76	
	Sed job knowledge	1.24	.25	<.001	.29	

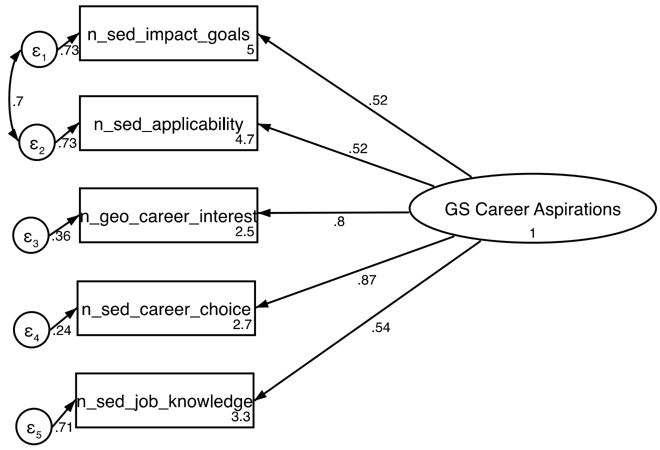

Figure 4: Respecified model of GS career aspirations (standardized)

The model fit indices showed significant improvement from model 1, as shown in Table 6. The chi-square statistic for the respecified model was not statistically significant, indicating a good fit. Values of RMSEA, SRMR, CFI, and AIC point to a near-ideal fit, as shown in Table 6. By adding a new path in the respecified model, we compromised on the parsimony of the model. Generally, parsimonious models are preferred over more complex models. However, the significance of the change in chi-square statistic shows that the hypothesized model is a significantly worse fit for the data. Therefore, the decrease in parsimony was essential to achieve a good model fit. For this reason, we prefer the respecified model over the hypothesized model for the GS career aspirations scale. Lastly, the alpha and omega values (α = .81, ω = .80) of the GS career aspirations scale showed it had good internal consistency.

Discussion

In this study, we assessed the validity of scales to measure GS (Geoscience and Sedimentology) interest and career aspirations in the context of undergraduate geoscience courses. The survey items were based on preexisting instruments and modified to fit the context of the study. There were two scales in the study, consisting of five items each. The results of two separate confirmatory factor analyses provided evidence for the validity of the survey in undergraduate geoscience courses. For the GS interest scale, the goodness of fit statistics showed that the hypothesized model was a good fit for the data. Overall, GS interest explained about 93% of the variability in the generated items. For the GS career aspirations scale, we found that the hypothesized model did not demonstrate an adequate fit. Based on standardized covariance residuals and modification indices, we respecified the model and added a covariance between the items “Sed impact goals” and “Sed applicability”. Although there was a significant correlation between the two items, it did not indicate issues with the uniqueness of the items. The respecified model demonstrated a near-ideal fit for the data, indicating that the scale was appropriate for use in geoscience courses. Both scales also showed good values for internal reliability, indicating the results were not threatened by measurement errors of the scale.

The findings of the study confirm prior knowledge regarding the components of STEM interest and STEM career aspirations. Notably, students’ affective response to content is predictive of their interest in STEM fields [20]. This relationship was found to be valid among geoscience students, highlighting the importance of positive learning experiences in inspiring and retaining student interest. Similarly, student perceptions of the utility of learning material were significantly correlated to their GS interest, as seen in Table 5. This is consistent with prior studies on interest [19] and theories of academic interest and choice [36, 37]. The career aspirations scale also aligned with prior findings. The items used as direct measures of career aspirations were significantly correlated with GS career aspirations, aligning with prior instruments [28, 30]. The significance and predictive value of the items related to career awareness resonate with Social Cognitive Career Theory [36, 46].

The findings of the study should be interpreted with some limitations. First, the validity of scales was evaluated for two undergraduate geoscience courses. The findings may not be replicated among other courses that differ in terms of students' majors and year of study, class size, or institutional context (e.g., community colleges vs. research universities). Future studies can focus on other contexts and courses. Secondly, the time limitations of the study prevented us from conducting further iterations of the validation process to strengthen the findings. Future studies can focus on examining the validity over the years or invariance examination based on varying contexts. Third, the current study did not conduct an exploratory factor analysis to assess the underlying factor structure of the scales. Although the items were derived from preexisting scales with well-defined factor structures, exploration in a new context might reveal different insights. Lastly, the goal of this study was to establish the construct validity of both scales independently. Future studies can focus on conducting relationship studies using regression and structural equation modeling, and establish the criterion validity of the scales.

Conclusion

This study provided validity evidence for a survey assessing GS interest and GS career aspirations among students in undergraduate geoscience courses. Overall, the scale was found to be reliable and valid in the context of geoscience courses. Moreover, the findings indicated that the scale is valid for use in the context of a Hispanic Serving Institution (HSI). Given the low recruitment and retention rates within geoscience [13], it is essential to have a reliable and valid measure to assess students' GS interest and career aspirations to create and evaluate effective interventions. The current study paves the way for future research to implement and evaluate the scale in multiple settings and refine the instrument, with the end goal of creating a dedicated and diverse workforce in STEM.

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