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Understanding and Enhancing Student Engagement: Measuring Resources, Self-Assessment and Constructive Engagement In 1st-Year Engineering Courses

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Abstract

This complete research paper aims to develop a reliable and valid scale for assessing resources, self-assessment, and constructive engagement in 1st year engineering courses. As engineering education evolves to meet the demands of the 21st century, educators are increasingly focusing on creating more interactive and engaging environments for their students. The Engineering+ program at Oregon State University exemplifies this approach by combining traditional lectures with small-group studios and socially relevant projects. Previous research indicates that students' engagement correlates directly with academic progress. This is especially relevant in the Engineering+ setting, where students are in the process of choosing their majors and planning their futures. Students take three courses on varying topics to explore their interests and practice fundamental engineering skills during their first year. Therefore, enhancing student engagement in these courses not only aids in a deeper understanding of the offered materials but also facilitates social interactions that can inform better decision-making for their futures." This study aims to develop a reliable and valid scale for assessing Resources, Self-Assessment, and Constructive Engagement in Engineering+ courses. The decision to measure these particular constructs is based on an in-depth qualitative study to understand how and why students engage in their engineering courses. Established procedures were implemented for scale development, including construct definition, item pool generation, measurement format, a comprehensive overview of the item pools, and scale validation procedures. An item pool was created based on a comprehensive review of previous literature. The survey was administered, and 1634 responses were collected. This paper reports on the processes and findings of the scale development. Regarding the scale's validity, multiple iterations of the survey were implemented to gather supporting evidence. Exploratory and confirmatory factor analyses confirmed the scale's factor structure, substantiating five key factors related to our three main ideas: Educator Availability, External Resources, and Student Connectivity are based on Resources, Course knowledge, which covers constructive engagement, and Self-Assessment. These factors align closely with the unique pedagogical approach of the Engineering+ program and our qualitative study, fostering engagement and development. This study contributes to the existing body of research by providing a validated tool for assessing important constructs related to engagement in Engineering courses, thereby enabling educators to gain valuable insights to inform effective instructional strategies.

Introduction

The importance of student engagement in the first year of engineering education cannot be understated, as it plays a critical role in fostering students' engagement [1]. Ohland [2] discusses the complexities of engagement and its influence on student perseverance and satisfaction within the engineering discipline. The study presents evidence for the imperative of integrative educational practices that are sensitive to the challenges unique to early engineering education.

These findings underscore the importance of tailored educational strategies and support mechanisms that cater to the unique challenges faced by novice engineering students. These findings advocate for a pedagogical shift towards reinforcing engagement to enhance the educational landscape for emerging engineering professionals [1], [2].

Investigating factors related to engagement and related factors in the first year of engineering education is critical due to its positive influence on student performance, persistence, and goal orientation, which are essential for meeting the demands for high-quality engineers in the global market [3], [4], [5]. Understanding engagement, particularly among underrepresented groups, is vital for increasing diversity within the field, as it can inform interventions aimed at improving retention and satisfaction in engineering disciplines [5]. Engaged students are more likely to excel academically and remain in their chosen field, contributing to a competitive workforce [6]. The importance of social engagement in this context cannot be overstated. As Tinto suggested, involvement and integration within the academic life of college significantly enhance the likelihood of student persistence [7]. He elucidated that in order to increase student retention in first-year students, there is a need to incorporate early social and academic communities and groups. His emphasis on early integration underlines the critical role of social engagement, particularly in the formative first year. Recognizing the significance of social engagement for first-year students, it becomes imperative to delve deeper into understanding the dynamics of this engagement and its impact on student persistence and success [7], [8]. Investigating how social connections, interactions, and collaborations within academic settings influence the freshman experience can provide valuable insights. In the crucial first year of engineering education, truly understanding and fostering student engagement is key to supporting student success. At this early stage, students are making important decisions about their majors and mapping out their future careers. Despite the recognized importance of student engagement in educational success, there remains a gap in our understanding of the nuances of student engagement, particularly among first-year engineering students. This period is a critical juncture in a student's academic journey, a time when they are navigating through the complexities of their coursework while also making pivotal decisions about their future career paths. Bridging this gap in understanding is not just about enhancing academic outcomes; it's about supporting students as they lay the groundwork for their professional lives.

Our study aims to create a detailed scale that measures resources, self-assessment, and constructive engagement among first-year engineering students. This tool isn't just about numbers; it's about getting a deeper insight into how students interact and think and how these factors influence their engagement in the academic journey. By formulating precise definitions and methodologies for these concepts, our objective is to equip educators with essential insights that enable the implementation of impactful strategies that could improve student engagement and success. These strategies are aimed at fostering engagement within learning contexts, thereby significantly elevating the quality of student learning experiences in the initial year of engineering education.

Literature Review

The constructs under investigation in our study are the result of a comprehensive qualitative inductive research project focused on related factors to student engagement. This research aimed to delve into the dynamics of how and why students engage with their engineering courses. Through in-depth interviews and analysis, we sought to capture the essence of student engagement from the perspectives of those immersed in the learning environment. The insights gained from this qualitative exploration informed the initial design of our survey [9], guiding us in identifying and selecting the specific constructs to measure. This qualitative foundation ensures that the constructs we are examining are rooted in the actual experiences and challenges faced by engineering students. This alignment between empirical findings and survey design is crucial for the development and validation of an instrument that accurately captures the nuances of student engagement in engineering education.

Theoretical Frameworks

This section describes our constructs and how they relate to broader ideas from the literature. In this research, we are focusing on three principal ideas: Resources, Self-Assessment, and Constructive Engagement. The constructs we have selected for our study are linked to these core concepts. Educator Availability, External Resources, and Student Connectivity pertain to the theme of resources, highlighting the various supports, social interactions, and tools available to students. Course Knowledge is associated with constructive engagement, addressing how students interact with and construct meaning from the course material. Lastly, Self-Assessment relates directly to students' ability to evaluate their own understanding and progress. Through these constructs, our research aims to dissect and understand the multifaceted nature of student engagement in engineering education, providing insights into how resources, self-evaluation, and active involvement in learning processes contribute to student's academic experiences and outcomes. Each construct has been carefully chosen and defined to capture the multifaceted nature of student engagement in first-year engineering courses. Building on the theoretical frameworks we discussed earlier, it's important to note how each construct within our instrument is aligned with specific dimensions of student engagement in first-year engineering courses.

Constructive Engagement

Course Knowledge, reflecting the dimension of constructive engagement, is grounded in the constructive aspect of Chi's ICAP theory [10]. Michelene Chi's ICAP framework categorizes student cognitive engagement into four distinct levels based on their interaction with learning material: Interactive, Constructive, Active, and Passive. This model suggests that as students move from passive engagement, where they merely receive information, to more active forms of engagement, where they engage with the material through activities such as summarizing or questioning, their understanding of the content deepens. At the highest levels of engagement, constructive and interactive, students not only engage with the material by generating new ideas or solutions but also collaborate with peers, further enhancing their comprehension and retention of knowledge [10]. The ICAP theory posits that students' understanding and ability to internalize course content improve as they engage more actively and constructively in their learning processes [10]. Measuring student constructive engagement based on Chi’s ICAP framework can provide researchers with data on how much students have been actively involved in their learning experiences.

Engagement in the educational context is a multifaceted construct that researchers have attempted to define in a comprehensive manner. It is often construed as specific student behaviors within a learning environment, reflecting their level of investment in the learning process [11], [12].

Cognitive engagement is a form of engagement characterized by the depth of psychological commitment students apply to their learning journey. It goes beyond mere participation in class activities; it's about how deeply students process information, understand concepts, and engage with the material at a meaningful level [13]. For first-year students, this concept is particularly important as it relates to their ability to adapt to new academic challenges and environments. [14]. At the core of cognitive engagement is a genuine interest in the subject matter. This intrinsic nature of cognitive engagement makes it a complex attribute to measure, as it is not directly observable. Instead of relying on overt indicators, gauging cognitive engagement demands more subtle and deliberate methods. Indicators such as a student's proficiency in assimilating new data with pre-existing knowledge, different methods of gathering knowledge, or their perseverance in confronting demanding academic challenges can serve as proxies for cognitive engagement [15]. This emphasizes the need for innovative measurement tools to accurately capture the related factors to the depth of students' engagement in the learning process [13], [16].

Resources

Educator Availability, Student Connectivity, and External Resources constitute the components of the Resources construct, one of the primary ideas underpinning our research. These components are intimately connected to the social aspects of student engagement. According to Lin, social engagement can be defined as the dynamic process by which individuals participate in a web of relationships and activities within their social network, leveraging the collective resources and norms that facilitate cooperation and mutual benefit [17]. Embedded resources within the context of social engagement refer to the intangible assets that are accessible through one's social networks and relationships. These resources encompass a wide range of benefits and supports that are integral to the fabric of social interactions, including information, influence, and support [17]. Information refers to the knowledge and insights that can be gained through social connections, offering individuals a competitive advantage in various contexts. Influence encompasses the power one can exert within their network, facilitating the achievement of personal or collective goals. Support represents the emotional, financial, or practical assistance available through social ties, which can be crucial in times of need. Embedded resources are thus critical components of social capital, highlighting the value of social networks in providing access to resources that significantly enhance individual and collective capabilities and opportunities [17], [18], [19].

Nan Lin emphasizes that embedded resources within a social network structure become accessible through individual connections. These resources, deeply ingrained within the network's fabric, facilitate various forms of social engagement that individuals can mobilize for personal, social, or professional advancement. Lin's perspective on social capital posits that the value derived from a network is not merely in the connections themselves but in the quality and depth of the resources these connections enable individuals to access and utilize [17], [20].

In the context of educational environments, including the relationships between students and between students and instructors, this conceptualization underscores the importance of creating strong, interconnected networks. Such networks can significantly enhance learning experiences by providing access to vital information, positive influence, fostering social credentials, and deepening personal relationships. These embedded resources can enrich the educational process, making it more engaging, effective, and responsive to students' needs [17], [20], [21]. Lin's theoretical framework underscores the significance of connectedness as a fundamental aspect of social engagement. He posits that the essence of relationships, particularly through resources, plays a pivotal role in enhancing students' educational experiences. This concept influences the caliber of interactions and the exchange of embedded resources within a social network, emphasizing the critical role of social connections in educational contexts [21]. Educator Availability and Student Connectivity are directly associated with the social dimension of engagement. These factors focus on the accessibility of instructors and TAs and the connections and interactions among students, highlighting the importance of social networks and support systems in the educational experience. External Resources investigates how students utilize resources beyond the classroom.

The study "Students' Engagement in First-year University" by Krause and Coates offers a comprehensive analysis of student engagement during the first year of university. The paper introduces seven calibrated scales of student engagement developed from a large-scale study of undergraduate students in Australia. These scales explore various facets of engagement, including self-managed, peer, and student-staff interactions. The study underlines the need for a broader understanding of engagement as a multifaceted process and advocates for robust theorization that integrates both quantitative and qualitative measures. It emphasizes the importance of student involvement in activities that foster high-quality learning outcomes, echoing the perspectives of scholars like Astin and Pace. The study's findings underscore the dynamic interplay between students and institutional activities and conditions, shaping the nature and degree of student learning and development. This research contributes to understanding contemporary student engagement, particularly within the context of the first year of university study, highlighting the imperative for ongoing research and the development of institutional policies that support an enriching student experience [22].

Self-Assessment

Research demonstrates that metacognitive skills, such as self-assessment, play an important role in enhancing students' cognitive engagement and learning outcomes. Metacognition, which involves awareness and control over one's cognitive processes, has been shown to influence problem-solving abilities and academic performance across various educational settings. Mayer (1998) underscores the interplay between cognitive and metacognitive in solving problems, highlighting how these skills collectively contribute to successful academic endeavors [23]. Veenman (2013) elaborates on the assessment of metacognitive skills in computerized learning environments, suggesting that metacognitive activities can be inferred from learner behavior, thereby offering insights into students' cognitive engagement [24]. Furthermore, Schraw (1998) discusses instructional strategies aimed at fostering metacognitive awareness, suggesting that such strategies can significantly improve learning outcomes by promoting self-regulation and reflective thinking [25]. Students can enhance their learning experience by setting clear educational objectives, tracking their advancement, and adopting more effective study techniques. Wolters, Pintrich, and Karabenick (2005) conducted a review of research related to the Motivated Strategies for Learning Questionnaire (MSLQ) and found evidence of a link between metacognitive awareness and cognitive engagement. This connection underscores the importance of metacognitive practices in fostering deeper engagement with learning material [26].

The study "Understanding First-Year Students’ Transition to University" by Alasdair Blair examines the transition experiences of first-year university students and their engagement with academic expectations, assessment, and feedback. Conducted with 51 first-year students from a UK university, the study reveals mixed feelings among students regarding their adjustment to university life. While most students found workloads and the nature of assessment in line with their expectations, they expressed dissatisfaction with the support provided, particularly in terms of contact time with tutors and feedback on performance. The research uncovers a gap between students' understanding of academic expectations and the clarity of communication from tutors regarding assignment requirements. Despite knowing where to seek academic support, many students felt that tutors were not fully aware of their academic progress, and there was a lack of opportunities for discussion and feedback. The study emphasizes the need for a more supportive academic environment in the first year, suggesting that targeted feedback and increased tutor contact could significantly enhance the student transition experience [27].

These examples underscore the importance of the constructs to student engagement and success. Together, these constructs offer a comprehensive view of the multifaceted nature of student engagement, encompassing related elements critical for student engagement and success in engineering education.

Site and Participants

This study was conducted within the context of the Engineering+ program at Oregon State University, an innovative first-year engineering curriculum designed to engage students in hands-on projects, major exploration, and skill development. The Engineering+ program aims to provide students with a dynamic learning environment that fosters collaboration, real-world problem-solving, and exposure to various engineering disciplines. The Engineering+ curriculum is specifically tailored to the needs and experiences of first-year engineering students. The program recognizes the importance of engaging students early in their academic journey and provides a supportive environment that encourages exploration, collaboration, and skill development. By focusing on first-year students, the program acknowledges the critical role that early experiences play in shaping students' academic and professional trajectories. The program employs a unique pedagogical approach that combines traditional lectures with hands-on, project-based learning experiences. During their first year, Engineering+ students enroll in a three-term sequence of courses (ENGR 100, ENGR 102, and ENGR 103) that explore the intersections of engineering, society, and the environment. The Engineering+ program is committed to promoting diversity, equity, and inclusion in engineering education. The program recognizes the importance of creating an inclusive learning environment that values diverse perspectives and experiences. By embracing diversity and promoting inclusivity, the Engineering+ program aims to attract and retain a broad range of students, ensuring that the study's findings are relevant to a diverse population of first-year engineering students.

The survey instrument developed in this study was administered to students enrolled in Engineering+ courses at Oregon State University. The sampling method employed in this study can be described as a voluntary sample. Students in the Engineering+ courses were invited to participate in the survey, but their participation was not mandatory. This approach resulted in a sample of students who chose to participate in the study. After excluding incomplete responses, a total of 1,634 valid responses were collected. The program's innovative curriculum, commitment to hands-on learning, and focus on diversity and inclusion make it an ideal setting for examining factors that contribute to student engagement in the critical first year of engineering education.

Methodology and Results

In this section, we outline the development of our instrument for student resources, self-assessment, and constructive engagement in engineering+ courses. This instrument is a continuation of an ongoing project focusing on key factors that facilitate students' social, behavioral, and cognitive participation in their courses. In this study, our approach draws upon the foundational work of Devellis [28] and McCoach [15], who specialize in crafting measurement instruments within educational frameworks. McCoach suggests that while direct measurement of these constructs may not be feasible, they exhibit a "causal relationship" with observable metrics, aiding in the detection of underlying constructs [15, p. 35]. Devellis proposed an eight-step process tailored for developing scales that are adaptable to various contexts. Recognizing the versatility of Devellis's method and its specific relevance to different settings, we adopt his eight-step process for our purposes. We will explain how we applied each of these steps in the formation of our instrument aimed at measuring student social and cognitive engagement in engineering+ courses.

Step 1: Define clearly what you want to measure

In the development of our current scale, we built upon the foundational framework established in our previous research. As outlined by Devellis, our initial step was to thoroughly understand the relevant concepts and constructs, a process underpinned by a comprehensive literature review and qualitative data collection. This foundational work, documented in our prior study, involved conducting 33 interviews with students enrolled in STEM courses. These discussions were instrumental in pinpointing key constructs pivotal for enhancing students' resources, self-assessment, and constructive engagement in STEM environments [9]. Qualitative data can help in the initial stage of scale development. This type of data offers in-depth and comprehensive insights, aiding researchers in grasping the subtleties of a construct [28]. For the current scale, we have undertaken a rigorous revision and adaptation process to align more closely with the unique context and requirements of first-year engineering education. This involved carefully recalibrating the questionnaire items, ensuring they resonate with the specific learning dynamics and course structures characteristic of first-year engineering programs. The revised scale aims not only to reflect the foundational principles of student engagement as delineated in our previous research but also to address the nuanced needs and challenges students face in the nascent stages of their engineering education journey. The constructs selected for inclusion in the new scale are Course Knowledge, Educator Availability, External Resources, Student Connectivity, and Self-Assessment.

Steps 2,3,4: Generate an item pool, Determine the format for measurement, and have the initial item pool reviewed by experts

In Step 2 of DeVellis's framework, the focus is on creating a broad collection of potential questions, also known as an item pool, that pertains to the identified constructs of interest. This involves drafting a diverse set of items that comprehensively cover the dimensions and nuances of each construct, ensuring a thorough representation in the measurement tool. The generated items are designed to capture the varied aspects of the constructs, aiming for a wide-ranging yet relevant selection that can accurately reflect the constructs' complexity. This step is crucial for establishing a solid foundation for the subsequent development and refinement of the measurement instrument [28]. Step 3 discusses selecting the response format for the items, ensuring alignment with Step 2 for appropriate item formulation. Based on [9], [27] we implemented a 5-point Likert scale for the development of this scale. The development of these items was informed by a comprehensive literature review, theoretical frameworks, and findings from qualitative interviews. Forty-eight items were generated, drawing on the ICAP and Lin's theoretical models, tailored for a first-year engineering course context. Step 4 involved an expert review of the item pool by experts in engineering education to confirm the scale's content validity. Following this, the instrument was refined to consist of twenty-seven items.

Step 5: Consider the inclusion of validation items.

In Step 5, the process emphasizes the integration of validation items into the instrument. This involves incorporating at least one item per construct from a previously validated scale, according to the literature and existing metrics. The purpose is to mitigate the effects of extraneous factors unrelated to the construct within the new instrument, thereby bolstering its validity. This strategic inclusion serves as a benchmark, ensuring each construct is grounded in established research and measurement practices [28]. For each construct, we incorporated a minimum of one item from a widely recognized scale to substantiate the instrument's validity [10].

Step 6 and 7: Administer items to a development sample, and Evaluate the items

We subsequently administered the survey, which we had developed, across engineering courses tailored for first-year students. After excluding incomplete responses to prevent listwise deletion, the total number of valid responses amounted to 1,634. The collected sample was divided into two halves to facilitate both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). This division was planned to ensure that the demographic characteristics, including class size, gender, and others, were evenly distributed across both subsets. This approach, recommended by DeVellis, serves a dual purpose: EFA allows for the identification and exploration of underlying factor structures without preconceived hypotheses, while CFA is used to test and confirm the factor structure suggested by EFA. Splitting the data in this manner provides a robust methodology for validating the scale's construct validity, ensuring that the analysis is both comprehensive and reliable [28]. In Step 7, we conducted the EFA and CFA to ensure the evidence of validity.

Exploratory factor analysis

Following the guidelines of Thompson [29] and Costello [30], we conducted an exploratory factor analysis (EFA) on half of our collected dataset. This analysis was performed using JASP 0.18.2, employing the minimum residual factoring method for extraction and selecting the oblimin promax rotation to permit correlations among the extracted factors. In line with the Kaiser criterion, which recommends retaining factors with eigenvalues over one [31], our analysis shown in Table 1 aimed to extract the appropriate number of factors based on this. The scree plot (Figure 1) indicated the need for five distinct factors.

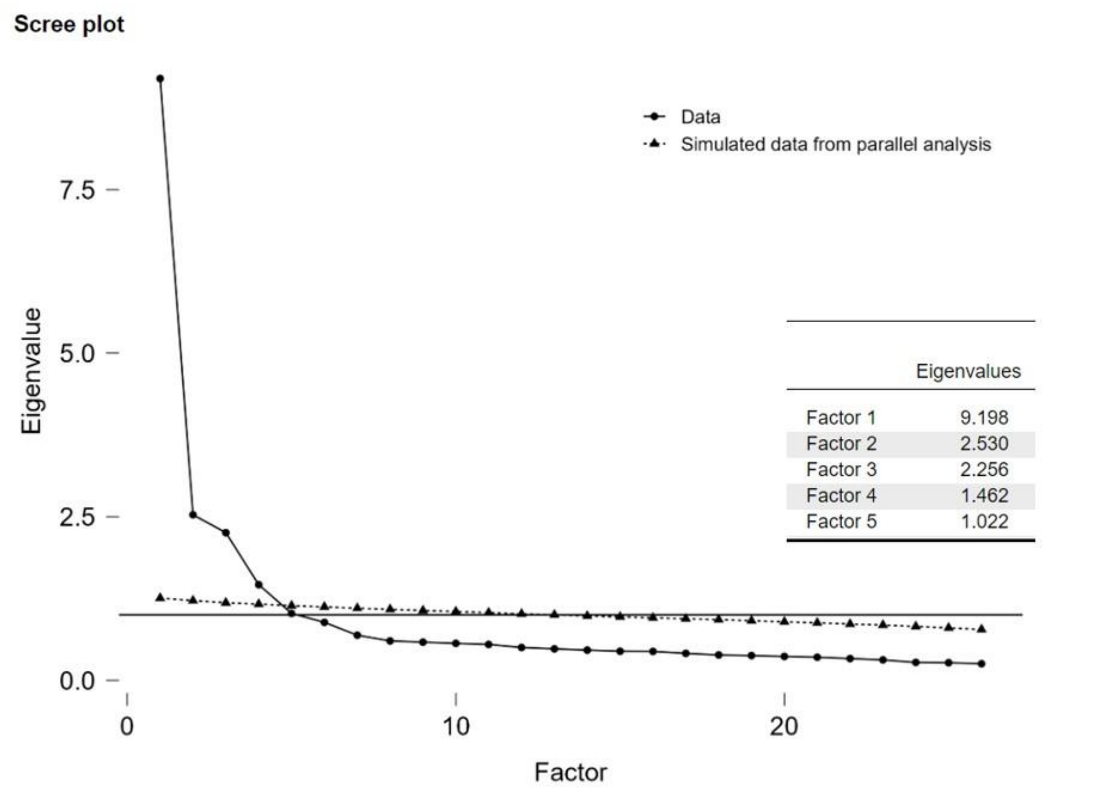

Figure 1: EFA Scree Plot and Eigenvalues

Factor loadings ranged from 0.470 to 0.897, indicating varying degrees of association with the respective factors. Uniqueness values, which measure the variance in each variable not explained by the factors, suggested that while the factors accounted for a significant portion of the variance, individual items also retained unique contributions. All factor loadings (Table 1) were higher than 0.3, which is the minimum suggested by Hair et al. [32]. Furthermore, Bartlett's Test of Sphericity (Table 2) was conducted to assess the appropriateness of factor analysis for our dataset. The test yielded a chi-square value of 6543.875 and a p-value of less than 0.001, indicating that the correlation matrix was not an identity matrix and suggesting that the data were suitable for factor analysis. Together, these analyses provide a robust foundation for identifying key dimensions of engagement and tailoring educational strategies to enhance student experiences in first year engineering courses.

Table 1: EFA Results

Factor Loadings						
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Uniqueness**
EA5	0.81					0.325
EA3	0.785					0.361
EA2	0.778					0.392
EA1	0.739					0.354
SA3		0.79				0.292
SA4		0.761				0.332
SA1		0.64				0.439
SA2		0.531				0.485
SC2			0.897			0.226
SC1			0.829			0.323
SC4			0.579			0.539
SC5			0.554			0.549
CK2				0.88		0.264
CK3				0.678		0.464
CK1				0.567		0.542
CK4				0.47		0.462
EXR1					0.825	0.324
EXR2					0.772	0.43
EXR3					0.662	0.472

Note. Applied rotation method is oblimin.

Table 2: Bartlett's Test

Bartlett's Test

X^2	df	p
6543.875	171.000	< .001

Chi-squared Test

	Value	df	p
Model	239.638	86	< .001

Confirmatory Factor Analysis

Following the exploratory factor analysis (EFA), we proceeded to perform a confirmatory factor analysis (CFA) on the second half of the dataset to validate the EFA findings. This step is in line with the recommendations of Brown [33], who notes that CFAs are effective for confirming the structure of factors and how individual items relate to those factors in surveys. We utilized the statistical software R and JASP version 0.18.2 for the CFA. According to Ding, Velicer, and Harlow (1995), while CFAs can be conducted with smaller sample sizes, having a sample size of at least 200 is generally recommended to ensure the analysis has sufficient power and yields reliable results [34]. Given these guidelines, our dataset, comprising 1,634 responses, was well above the recommended minimum, ensuring that our confirmatory factor analysis (CFA) had more than sufficient power and provided reliable solutions.

In Table 3, the factor loadings range from 0.707 to 0.879, which are substantial, indicating that the indicators are good representatives of their respective latent constructs. Specifically, the factor loading values suggest that the indicators have a strong relationship with the constructs they are intended to measure. High factor loadings imply that the construct explains a large portion of the indicator's variance. The standard errors are low (ranging from 0.011 to 0.023), which indicates a high level of precision in the factor loading estimates. Lower standard errors contribute to more reliable factor loading estimates. This statistically significant result ($p < .001$) suggests that the factor loadings are significantly different from zero, reinforcing the relevance of the indicators in measuring their respective constructs. These results suggest a well-fitting model with strong factor loadings, high precision, and statistical significance, indicating that the constructs are well-defined and the indicators effectively represent them. Table 4 shows that the significant p-value for the factor model suggests a good fit between the model and the observed data, substantially improving upon the baseline model. The reduction in the Chi-square value when moving from the baseline to the factor model suggests that the factor structure hypothesized in the CFA closely aligns with the underlying patterns in the dataset.

Table 3: CFA Factor Loadings

Factor	Indicator	Estimate	Std. Error	z-value	p	95% Confidence Interval	
						Lower	Upper
Educator Availability	EA5	0.79	0.012	63.71	< .001	0.766	0.815
	EA3	0.827	0.012	66.55	< .001	0.803	0.852
	EA2	0.86	0.012	74.31	< .001	0.838	0.883
	EA1	0.861	0.011	76.55	< .001	0.839	0.883
Self-Assessment	SA3	0.779	0.012	66.47	< .001	0.756	0.802
	SA4	0.86	0.011	76.08	< .001	0.838	0.883
	SA1	0.853	0.011	77.8	< .001	0.831	0.874
	SA2	0.827	0.011	75.44	< .001	0.806	0.849
Student Connectivity	SC2	0.867	0.016	53.66	< .001	0.835	0.899
	SC1	0.803	0.016	50.8	< .001	0.772	0.834
	SC4	0.877	0.018	49.67	< .001	0.842	0.911
	SC5	0.707	0.018	39.05	< .001	0.671	0.742
Course Knowledge	CK2	0.777	0.011	68.5	< .001	0.754	0.799
	CK3	0.878	0.011	80.2	< .001	0.857	0.9
	CK1	0.831	0.011	73.84	< .001	0.809	0.853
	CK4	0.827	0.011	73.5	< .001	0.805	0.849
External Resources	EXR1	0.772	0.021	37.15	< .001	0.731	0.813
	EXR2	0.794	0.021	37.52	< .001	0.753	0.836
	EXR3	0.879	0.023	37.94	< .001	0.834	0.924

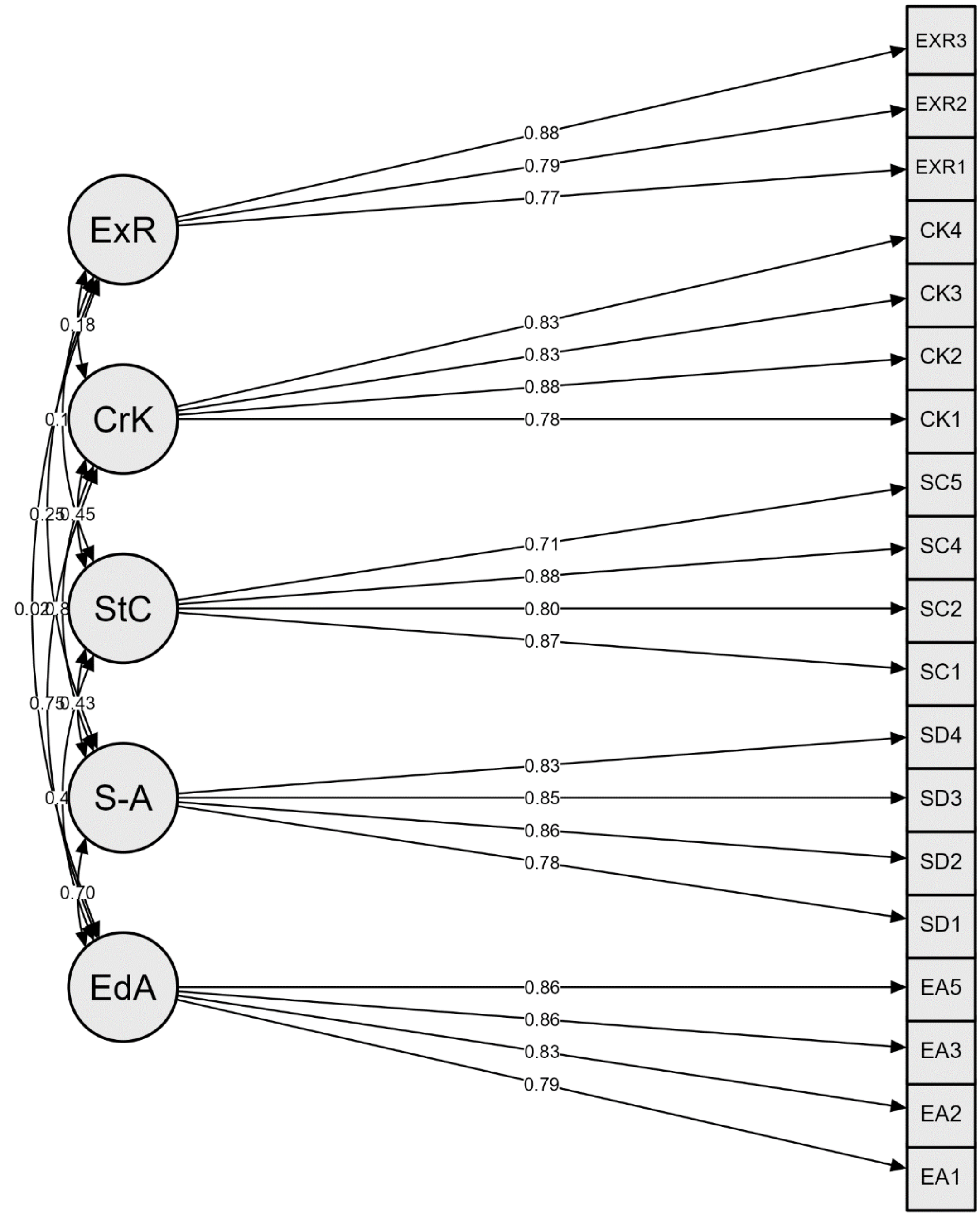

Figure 2: CFA Model Plot

Table 4: Chi-square Test

Chi-square test

Model	X^2	df	p
Baseline model	16974.608	171	
Factor model	700.241	142	< .001

Note. The estimator is DWLS and the test statistic is scaled.shifted because there are categorical variables in the data. You may consider changing the standard error method to 'robust'.

Step 8: Optimize scale length

In Step 8, we need to modify the scale length to improve the scale reliability. Devellis notes that achieving this involves finding a balance within the "benefit of a larger number of items increasing reliability with fewer number of items minimizing the burden on the participant [12, p. 13]." Following the expert review, we discovered that a shorter survey is crucial for practical use, as participants are more inclined to complete a shorter and more manageable survey. This approach aligns with other scale development studies that highlight the importance of creating shorter surveys to ensure that a large number of students can easily comprehend and complete them. Consequently, we decided to remove eight items from the survey. [9], [12], [35]. Table 5 shows the questions that were designed in this process.

Table 5: Survey Questions

Factor	Questions
Educator Availability	The instructor/teaching assistant is available to answer questions when I need help.
	I can get a hold of the instructor/teaching assistant when I need help.
	When I have a question about assignments, I can get them answered.
	When I am struggling in this course, I can get help.
Self-Assessment	I ask myself questions to see if I understand what I am learning in this course.
	I check to see if I understand the things I am trying to learn.
	If I get confused about something in this course, I go back and try to figure it out.
	If I don’t understand something in this course, I go back and try to learn it again.
Student Connectivity	I know other students in this course.
	I have friends in this course.
	I communicate with other students in this course.
	I spend time studying with other students in this course.
Course Knowledge	I connect ideas and concepts directly taught in this course to things I already know.

	I think of how I can apply concepts from this course to ideas outside this course.
	I will be able to use what I learn in this course in other courses.
	I understand the material in this class by making connections between multiple course activities.
External Resources	I need additional resources other than those provided to be successful in this course.
	I need to look things up on the internet to be successful in this course.
	I have to use resources/help outside the course to be successful.

Results and Future Work

In this study, we detailed the creation and validation of an emergent instrument to assess resources, self-assessment, and constructive engagement among first-year engineering students. Leveraging DeVellis' guidelines, we crafted our scale and further enhanced its reliability and validity through confirmatory factor analysis (CFA). This tool gauges five ideas that students reported as relevant and essential in our qualitative research. The development of this scale is poised to serve both researchers and educators within the realm of first-year engineering education, offering a resource to deepen understanding of related factors to student engagement. It is envisioned that educators can apply insights from this instrument to refine their online course offerings, fostering a more engaging and effective learning environment. Looking ahead, the scope of this scale could be broadened to encompass additional factors and constructs, such as student effort, sense of belonging, feedback mechanisms, and other critical dimensions. Expanding the scale in this manner would not only enrich its comprehensiveness but also enhance its applicability, enabling a more nuanced exploration of the factors influencing student engagement and success in engineering education.

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