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An Exploration of Sources Fostering First-year Engineering Students' Academic Well-Being in a PBL Environment

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Abstract—Contribution: This paper contributes to the literature surrounding first-year engineering students' academic well-being by proposing a conceptual framework guiding an understanding of supportive sources that foster students' academic well-being. A survey was designed and tested accordingly, and four factors that contribute to students' academic well-being were identified to inspire the improvement of a future course and curriculum design.

Background: Prior research has pointed out that students' academic well-being has a significant impact on their persistence in their current study, learning experience, academic achievement, and competence development. However, limited studies have explored first-year engineering students' academic well-being and supportive factors in the field of engineering higher education. To support engineering students to become agentic professionals, it is meaningful to pay close attention to their academic well-being and help them to become purposeful learners at an early stage of their professional development.

Research Question: 1) How can an instrument be developed and validated to characterize the sources of students' academic well-being in a PBL context? 2) What sources could foster students' academic well-being in a PBL context? Are there significant differences in age, gender, and discipline as a function of sources of academic well-being?

Methodology: With the guidance of the conceptual framework with the domains of internal and external sources, a survey was designed based on a literature review and conducted in a PBL environment. The survey's content validity, construct validity, and reliability were tested using expert review, a pilot study, exploratory factor analysis (EFA), and Cronbach's alpha.

Findings: Supportive sources fostering students' academic well-being were reported in the factors of personal values, agentic action, interactions within the learning environment, and external support. Comparisons between gender, age, and discipline verified the different impacts of the four factors on fostering academic well-being.

Keywords—Academic well-being, PBL, survey development

I. INTRODUCTION

In response to the global demands for economic, political, and social changes necessary for sustainable development, worldwide engineering educational institutes are transforming their programmes to support students' development of diverse competencies, enabling them to manage the complex reality of professional life [1]. Abundant attention has been paid within these programmes to developing students' competencies in problem-solving, communication, collaboration, and reflection, as well as transforming their thinking within a context of change. Responding to a post-pandemic learning era, students' academic well-being emerges to the attention of both academics and researchers. Referring to students' thoughts and behaviors that contribute to doing well in an educational context and students' academic life satisfaction [2,3], students' academic well-being has a significant influence on their learning experience, academic achievement, and generic competence development [4,5,6]. To increase retention and help engineering students to become agentic professionals, it is meaningful to support them to become proactive and purposeful learners from the beginning of their studies. Thus, aimed at filling in the literature gap in engineering education research, this study aims to explore how engineering students perceive the sources of their academic well-being, particularly, in the early stage of their study. The research questions of this study are: 1) How can an instrument be developed and validated to characterize the sources of students' academic well-being in a PBL context? 2) What sources could foster students' academic well-being in a PBL context? Are there significant differences in age, gender, and discipline as a function of sources of academic well-being?

II. LITERATURE REVIEW

A. Conceptualizing well-being

The notion of well-being has been conceptualized based on different philosophical traditions and various psychological theories [7-10]. In the hedonic philosophical tradition, well-being is understood as the pursuit of happiness and the presence of positive affect [7,11]. Accordingly, subjective well-being is proposed as the term to illustrate the levels of positive affect and life satisfaction [9,12]. In the eudaimonic philosophical tradition, well-being is explored in relation to the purpose of life and individual effort for personal growth [7,11,13]. Various understandings of well-being have also been examined from different theoretical perspectives. From the perspective of humanistic theories, well-being involves individuals' choices of life goals and lifestyle, which are impacted by personal values [14]. According to cognitive theories, individuals' belief systems and cognitive processes could form and foster individuals' well-being [15]. Specifically, individuals' beliefs in their abilities (self-efficacy), the feeling of having control of one's life (autonomy), and the sense of belonging to a social group (identity) were identified as fundamental psychological needs for well-being [9,15]. With various philosophical perspectives, some researchers have combined different philosophical traditions and proposed various theoretical frameworks of well-being. Keyes and Waterman developed a framework of well-being with three dimensions – emotional

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well-being, psychological well-being, and social well-being, separately referring to individuals' positive emotions, positive functional states related to values, and relations with others [7]. Each dimension of well-being contains diverse and complex components, especially psychological well-being, which encompasses six aspects - autonomy, self- acceptance, purpose of life, personal growth, relations with others, and environmental mastery [10]. Similar components of well-being were also identified by other researchers, such as Seligman's framework, which includes pleasure, engagement, relationships, meaning, and achievement as five key aspects accounting to well-being [16].

B. Conceptualizing academic well-being

Based on various frameworks of individuals' well-being proposed by psychological researchers, educational studies have paid high attention to students' well-being in their school life, which is regarded as students' academic well-being. Despite its significance to students' general well-being, academic well-being lacks a common definition, and is described as a multidimensional construct. In prior studies conducted in school settings, students' academic well-being refers to their well-being in relation to the educational context, including students' school life satisfaction and students' thoughts and behaviors that contribute to doing well in school [2,3,17]. Specifically, Hascher defined students' academic well-being as "an emotional experience characterized by the dominance of positive feelings and cognitions towards school, persons in school, and the school context." [18, p.129] Other researchers conceptualized academic well-being as a complex entity, comprised of diverse aspects, including academic self-concept, self-efficacy, learning autonomy, perceived difficulties, and school engagement [6,19]. In this study, following prior research, academic well-being refers to students' positive emotions and satisfaction with their educational choice and study environment [17], while personal values (e.g., learning autonomy and self-efficacy) and contextual elements were regarded as sources fostering students' academic well-being [20,21].

In the field of higher education, a large body of literature has examined how academic well-being is constituted and how it can be measured [22-26]. Instruments developed by psychological researchers, such as Ryff's psychological well-being scale, PERMA framework, PISA well-being scale, and Keyes et al.'s well-being scale have been adopted and tested in different learning environments [24,27-29]. Meanwhile, various self-developed frameworks and instruments were also reported by several educational researchers to measure students' well-being levels via measuring students' satisfaction with college life [22], feeling and functioning in college [23], and emotional and mental health, especially in the context of the COVID-19 pandemic [30-32]. In addition, recent literature has also explored the correlation of students' academic well-being with dropout rate, motivation, academic performance, identity, students' personalities, and demographic background [28,33-36]. Among various impact factors on students' well-being, active learning methods were regarded as supportive contextual factors [37]. Several studies have also reported that students' higher engagement in learning processes and more student–faculty interactions have a positive influence on students' well-being [5,37-39].

Although students' academic well-being has been regarded as an important indicator of students' persistence in their current study and learning outcomes, limited studies have explored engineering students' academic well-being and supportive factors in the field of engineering higher education. Several researchers have measured engineering students' well-being by investigating students' anxiety levels and mental health issues [40-41]. Marquez and Garcia reported that engineering students' aspiration to attain high grades resulted in negative psychosocial effects including higher anxiety, increased mental exertion, and low work-life balance, thereby influencing their well-being negatively [42]. Based on an exploration of psychological, social, and physical resources and their influence on students' well-being, Golsteyn and Ostafichuk also pointed out that grades, workload, the balance of academics and personal life, and students' professional competencies had a significant influence on students' well-being [43]. While these studies explored students' well-being from medical, mental health, and eudaimonic philosophical perspectives [40-41,44], understanding engineering students' academic well-being from social-cognitive and sociocultural aspects is also important. This is because well-being is not only influenced by personal feelings, but also dynamically framed by interpersonal relations, as well as contextual and institutional conditions [45-46]. To increase retention and support engineering students' professional development in learning processes, especially in the early stages of their study, more attention is needed to support students' academic well-being in engineering educational research.

C. Sources for fostering academic well-being

This study, based on an extensive literature review on well-being from diverse perspectives (e.g., psychology, socio-cognitive, etc.) and contexts (e.g., social science and education), established a conceptual framework for sources fostering students' academic well-being, thus enabling a structured understanding of these sources. Connecting socio-cognitive aspects and social-cultural emphases, the proposed framework included two domains – internal and external. Various sources in each domain are listed in Table I.

In the domain of internal sources, students' motivation, autonomy, intention, and self-efficacy were identified as supportive sources to foster students' well-being. Specifically, in the early stages of students' academic studies, their intrinsic motivation, including interests and enjoyment in engineering study, plays a key role in their willingness to enroll in engineering majors and in their curiosity to explore engineering problems, thereby influencing their academic well-being [37,39,47]. The second theme of well-being sources is students' intentions, referring to their learning goals and personal growth goals, which could contribute to individuals' well-being by providing a sense of achievement and self-functioning [15, 35,47,48]. The third theme is autonomy. While several researchers identified autonomy as a component of well-being [7], other researchers understood autonomy as a type of source to attain and foster well-being [9,48]. Autonomy contains the sense of self-determination, independence, and decision-making during learning processes [32,38]. Along with students' autonomy, self-efficacy is another vital theme of sources

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fostering students' academic well-being, which refers to students' self-confidence in their abilities to do well in their studies [48-49].

TABLE I. DESCRIPTIONS OF DOMAINS AND SOURCES

Domains	Sources	Contents
Internal sources	Motivation	- Interest in engineering studies - Interest in solving problems - Enjoyment of learning
	Intention	- Learning goals - Personal growth goals
	Autonomy	- Willingness to complete tasks - Self-determination for learning - Control over learning processes
	Self-efficacy	- Confidence in professional competencies - Belief in ability to complete learning tasks
External sources	Interactions with peers	- Identifying and sharing learning goals - Trusting relationships with teammates - Quality inter-group interactions - Respect and care for others
	Interactions with professionals	- Quality interactions with faculty - Quality interactions with the professional community
	Interactions with others	- Feeling socially integrated - Quality interactions with family and friends - Cared for and supported by others
	Learning Environment	- Availability of learning resources - Performance evaluation - Infrastructure support

The domain of external sources that foster students' well-being breaks down into four key areas, including interactions with peers, supervisors, professionals, and others (family and friends), as well as the characteristics of the learning environment. Firstly, it contains sources from interactions with peers, including conducting teamwork and collaborative learning, sharing learning goals, making sense of learning experiences together, building trusting relationships, and respecting each other [45,49,50]. Secondly, interactions with educational faculty and professionals are also pointed out as sources that foster students' academic well-being [38,51]. Higher frequency and quality of interactions with faculty and other professionals have positive influence on students' learning experiences and outcomes [38,52]. With constructive feedback as well as effective communication with instructors and wider professional communities, students could identify role models, and gain positive feelings of institutional acceptance, which contribute to their academic well-being [30,38,53]. In addition to interactions with professionals, relations with other people, family and friends could also influence students' well-being in their university life [24]. Last but not least, the learning environment where students are situated in is a significant and fundamental source of students' academic well-being, including the availability of learning resources, infrastructure support, fair performance evaluation methods, and an atmosphere of mutual trust [22,30,39].

With the support of such a conceptual framework, a survey instrument was designed and tested for the examination of the different sources of students' academic well-being. The validation and reliability of the instrument were tested in an educational environment in which Problem and Project Based Learning approaches (PBL) are adopted over decades at a systemic level. Participants of the validation study were first-year engineering students, experiencing the initial stage (first semester) of their college life. The study results are reported and discussed with reflection on the instrument implementation and recommendations on pedagogical practices for supporting engineering students' well-being.

III. METHODS

A. Research Context and Participants

This study was conducted at a leading Danish higher engineering educational institution, where PBL has been used as the core learning approach for the curriculum design of both undergraduate and graduate engineering programmes. Projects are organized into semesters with 15 European Credit Transfer System (ECTS) credits. In this context, students are required to gain other 15 ECTS credits for courses, which are designed to equip students with the professional knowledge and skills needed to finish the projects. In this PBL practice, students are expected to become at the center of the learning process; identify project topics, solve real-world problems, communicate, and interact with engineering communities (industry, companies, clients, etc.) [54]. During these learning processes, engineering faculty are expected to take the role of facilitators who do not teach professional knowledge directly but show students professional ways to learn knowledge and solve problems [55]. The implementation of PBL at the curriculum level has received positive feedback from the industry, evidenced by empirical research on the effectiveness and benefits of PBL practice on training career-ready engineers with comprehensive competencies [55].

Within this context, the survey in this study was distributed online through a software named SurveyXACT to 728 first-year engineering students at Aalborg University in the first semester of the academic years 2022 – 2023. A total of 258 students gave consent and answered the survey. With a response rate of 34.89%, 254 students provided effective responses.

TABLE II. PARTICIPANT INFORMATION

Variables	Categories	N
Gender	Male	174
	Female	76
	Other	2
	Prefer not to say	2
Age	< 18	1
	18 – 21	139
	21 – 24	78
	24 – 27	22
	> 27	14
Discipline	Mechanical Engineering (ME)	33
	Computer Science and Engineering (CSE)	69
	Energy Engineering (EE)	35
	Civil Engineering (CE)	49
	Architecture (AR)	68
Total		254

B. Survey Development

With the guidance of the conceptual framework, items were designed in the internal and external domains. This survey was tested via expert review and a pilot study. After studying in the PBL environment for 2-3 months and experiencing a pilot project in teams, participants were asked to indicate the extent to which the diverse sources supported their academic well-being. Based on the definitions of academic well-being from the literature, a brief elaboration of this term was given to participants in the beginning of the survey. Then, the following

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question was asked: "Based on your personal learning experience, to what extent have the following aspects supported your academic well-being?", and participants were required to rate the following statements on a four-point descriptive Likert scale (from 1 – no support to 4 – strong support).

C. Validity

Content validity was used to evaluate the extent to which the statements within the survey reflected the sources fostering students' academic well-being. Six experts in PBL or well-being research were invited to review all the items for inclusion in the survey. Then, a pilot study was conducted among 22 first-year engineering students, aimed to collect students' understanding of sources fostering their well-being and their feedback on the statements. Several items were revised based on experts' and students' comments and suggestions. After the expert review and the pilot study, one item was deleted because of overlap, and two items related to interactions with family and friends were added.

Construct validity was examined via exploratory factor analysis (EFA), which is an important tool to evaluate the structural validity of a survey in the early stages of survey development [56]. The EFA was conducted in SPSS with 254 cases, aimed to "identify the underlying dimensions of a domain of functioning, as assessed by a particular measuring instrument" [56]. The Kaiser-Meyer-Olkin (KMO) value and chi-square value in Bartlett's test of sphericity were utilized as criteria to examine if the data were suitable for EFA. The value of KMO was 0.888, and the result of the Bartlett test of sphericity was significant ($p < 0.001$). Principal components with an eigenvalue greater than 1.00 was adopted as the criteria, which identified four factors. A varimax rotation and a cutoff score for the factor loadings of 0.4 were utilized in this exploratory factor analysis [57]. Seven items were deleted because they did not load on any factor. Two items related to communication with professional communities and collaboration with people from diverse backgrounds were also not strongly related to any factor. A possible reason might be that first-year engineering students have not had many opportunities to communicate with people from diverse backgrounds and professional communities. One item – "I hang out with my friends outside academic work" was excluded because it might not be connected to students' academic well-being from students' perspectives. Four items related to students' individual values towards their abilities, learning resources and assessment methods were not strongly related to the current four factors in this survey. However, even though these seven items were not loaded to any factors, it does not mean they are not important. Polishing of statements and further testing are needed for the validation of this survey.

As shown in Table III, eight items were loaded on factor one, personal values; seven items were loaded on factor two, agentic actions; ten items were loaded on factor three, interactions within the learning environment; and the last factor, external support, included five items. Among all items, two items were found to be related to two factors, including item 15 and item 23. In these cases, prior literature has suggested diverse justification methods, including considering the highest loading value and the content of the item, as well as the guidance of theories [58-59]. In this study, item 15 was considered to be included in factor two since it is related to students' actions to finish learning tasks. The content of item 23 involved both agentic actions and interactions within the learning environment. With a focus on teamwork and a higher value for factor three, it was categorized into the dimension of interactions within the learning environment.

TABLE III. FACTOR LOADINGS BASED ON EFA (N = 254)

No	Items	Factor Loadings			
		1	2	3	4
	Factor 1 – Personal values				
1	I find my current study interesting.	.673			
2	I enjoy learning about the topics in my study.	.662			
3	I am motivated to go into further depth about certain topics.	.656			
4	I aspire to achieve a good career through my academic work.	.649			
5	I choose my study program following my interest.	.637			
6	I am responsible for my own learning process.	.604			
7	I make contributions to the team.	.507			
8	I expect to develop professional competencies through my study.	.503			
	Factor 2 - Agentic actions				
9	I monitor my academic growth towards my goals.		.696		
10	I can solve difficult academic problems.		.690		
11	I set up goals for my academic success.		.642		
12	I can manage my time well.		.622		
13	I make decisions following what I think is important for my academic success.		.572		
14	I challenge myself to reach my full (academic) potential.		.559		
15	I can accomplish academic tasks.	.504	.471		
	Factor 3 – Interactions within the learning environment				
16	I communicate with my peers efficiently.			.769	
17	I express my opinions comfortably in group discussions.			.706	
18	I develop teamwork strategies together with my peers.			.694	
19	I reflect with my peers on our progress towards common goals.			.683	
20	I experience mutual trust in my study context.			.626	
21	I feel comfortable in the physical environment where I study.			.624	
22	I feel treated fairly in my study context.			.610	
23	I believe I can complete tasks in a team.	.448		.519	
24	I share common learning goals with my peers.			.501	
25	I know what is expected of me in my study context.			.409	
	Factor 4 – External support				
26	I seek ongoing feedback from my instructors/supervisors.				.601
27	I share many aspects of my academic life with my family.				.543
28	I seek advice from my instructors/supervisors when I face problems with my academic work.				.751
29	I communicate efficiently with my instructors/supervisors.				.639
30	I talk to my friends about problems with academic work.				.612
	Deleted Items				
31	I have access to needed resources (e.g., literature, databases, software, library services, etc.) in my studies.				
32	I work hard without considering my grades				
33	I think the current assessments are a reflection of my performance.				
34	I communicate with professional communities (e.g., industry, companies). associations).				
35	I enjoy working with people from diverse backgrounds.				
36	I am able to manage stress related to academic work (e.g., stay calm during exams, work towards deadlines, etc.).				
37	I hang out with my friends outside academic work.				

D. Reliability

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The internal consistency analysis was examined by calculating Cronbach's alpha, a value of which is considered acceptable when it is equal to or greater than 0.7 [58]. The Cronbach's alpha coefficients for the factors and the survey were 0.868 (personal values), 0.824 (agentic actions), 0.808 (interactions within the learning environment), 0.789 (external support), and 0.905 (total survey), which means that the reliability of the survey is acceptable (>0.70).

IV. Results

This section illustrates participants' perspectives of the sources fostering their academic well-being in a PBL environment. Comparisons and differences between genders, ages, and disciplines, were also reported.

A. Descriptive Statistics

The descriptive information of the four factors is shown in Table IV. Out of all factors, factor one – personal values, has the highest mean value (Mean = 3.458, SD = 0.436) as the supportive sources for students' academic well-being, followed by factor three – interactions within the learning environment (Mean = 3.194, SD = 0.501) and factor two – agentic actions (Mean = 2.899, SD = 0.542). Factor four – external support has the lowest mean value (Mean = 2.804, SD = 0.586).

TABLE IV. Means and Standard Deviations of Factors (N = 254)

Factor	Mean	Std. deviation	Std. error of mean	No. of items	Cronbach's alpha
F1	3.458	.436	.027	10	0.868
F2	2.899	.542	.034	8	0.824
F3	3.194	.501	.031	7	0.808
F4	2.804	.586	.037	5	0.789
Total				30	0.905

Table V reports the initial results of this survey. In the dimension of personal values, the item "I aspire to achieve a good career through my academic work" was highlighted by students as the most supportive source for fostering their academic well-being (Mean = 3.650), followed by the item "I expect to develop professional competencies through my study" (Mean = 3.638). Other internal sources related to students' learning autonomy, interest in engineering, and other intrinsic motivation were also found to support students' academic well-being in a PBL context.

In the dimension of agentic actions, the most supportive source for students' academic well-being was "I can accomplish academic tasks" (Mean = 3.220), followed by the item – "I make decisions following what I think is important for my academic success" (Mean = 3.181). Other actions, including challenging oneself, solving academic problems, setting up learning goals, and managing time were also reported helpful to support students' academic well-being. The item with the lowest level of contribution in this dimension was "I monitor my academic growth towards my goals" (Mean = 2.622).

In the third dimension, interactions within the learning environment, the item with the highest mean value was "I believe I can complete tasks in a team" (Mean = 3.441), followed by "I feel treated fairly in my study context" (Mean = 3.374), "I feel comfortable in the physical environment where I study" (Mean = 3.323), and "I express my opinions comfortably in group discussions" (Mean = 3.299). Participants also pointed out that mutual trust in their study context supported their academic well-being (Mean = 3.181). Other sources, such as reflecting on learning experience with peers, sharing learning goals, developing teamwork strategies, and engaging in efficient communication, were identified as supportive experiences for fostering students' academic well-being. By contrast, the item with the lowest level of support was "I know what is expected of me in my study context" (Mean = 2.941), perhaps because many first-year students have not thought about the expectation of their roles and performance within the learning environment and professional communities.

TABLE V. Means and Standard Deviations of Items (N=254)

Items	Mean	Std. Error	Std. Deviation	Variance
Factor 1 – Personal values				
I aspire to achieve a good career through my academic work.	3.650	.037	.582	.339
I expect to develop professional competencies through my study.	3.638	.035	.565	.319
I am responsible for my own learning process.	3.472	.041	.651	.424
I find my current study interesting.	3.441	.043	.679	.461
I make contributions to the team.	3.406	.044	.698	.487
I choose my study program following my interest.	3.358	.043	.678	.460
I enjoy learning about the topics in my study.	3.354	.040	.635	.404
I am motivated to go into further depth about certain topics.	3.346	.045	.715	.512
Factor 2 – Agentic actions				
I can accomplish academic tasks.	3.220	.041	.646	.418
I make decisions following what I think is important for my academic success.	3.181	.046	.738	.544
I challenge myself to reach my full (academic) potential.	2.996	.047	.741	.549
I can solve difficult academic problems.	2.787	.049	.776	.603
I set up goals for my academic success.	2.780	.056	.893	.797
I can manage my time well.	2.709	.056	.899	.808
I monitor my academic growth towards my goals.	2.622	.053	.838	.702
Factor 3 – Interactions within the learning environment				
I believe I can complete tasks in a team.	3.441	.043	.685	.469
I feel treated fairly in my study context.	3.374	.045	.710	.504
I feel comfortable in the physical environment where I study.	3.323	.047	.743	.551
I express my opinions comfortably in group discussions.	3.299	.050	.798	.637
I experience mutual trust in my study context.	3.181	.039	.628	.394
I reflect with my peers on our progress towards common goals.	3.169	.048	.764	.584
I share common learning goals with my peers.	3.075	.043	.693	.481
I develop teamwork strategies together with my peers.	3.067	.049	.785	.616
I communicate with my peers efficiently.	3.067	.051	.815	.663
I know what is expected of me in my study context.	2.941	.048	.770	.593
Factor 4 – External support				
I seek advice from my instructors/supervisors when I face problems with my academic work.	2.941	.051	.820	.672
I communicate efficiently with my instructors/supervisors.	2.929	.049	.777	.604
I seek ongoing feedback from my instructors/supervisors.	2.854	.053	.838	.702
I talk to my friends about problems with academic work.	2.854	.059	.944	.892
I share many aspects of my academic life with my family.	2.441	.062	.991	.983

In the dimension of external support, which was regarded as

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the least supportive factor, the highest-ranked item was related to advice from participants' instructors/supervisors (Mean = 2.941), followed by efficient communication (Mean = 2.929) and ongoing feedback from (Mean = 2.854) instructors/supervisors. Some students also regarded that talking to friends about problems with academic work had a positive and supportive role in their academic well-being. However, communication with family about academic work was regarded as the lowest supportive source for participants' academic well-being. According to engineering students' feedback and comments on this survey, most of them seldom talked about their engineering study with their family members, unless their family members also worked in engineering fields. Thus, most participants chose "Not applicable" and "No support" for this item.

B. Analysis of Demographic Variables

Comparisons between gender, age, and discipline were conducted through independent sample t-test and ANOVA for every factor. The results are reported in this section. In terms of gender differences, shown in Table VI, a significant difference (p = 0.006) was found in factor three – interactions within the learning environment. Compared to men, women engineering students reported higher contributions from interactions with peers and teamwork to foster their academic well-being, which is consistent with findings from prior studies that found teamwork to be more attractive to women, who have better learning experiences and are more productive and effective in teams [60-62]. No significant differences between females and males in the other three factors were found.

TABLE VI. GENDER VARIATION (N = 254)

Factor	Gender	Mean	SD	SEM	T	df	Sig. (2-tailed)
1	Male	3.447	.476	.036	-.659	195.306	.511
	Female	3.482	.341	.039			
2	Male	2.917	.527	.040	.685	248	.494
	Female	2.867	.558	.064			
3	Male	3.253	.508	.039	2.800	248	.006
	Female	3.063	.455	.052			
4	Male	2.792	.596	.045	-.664	248	.507
	Female	2.845	.534	.061			
Total	Male	3.149	.414	.031	1.190	185.326	.236
	Female	3.093	.315	.036			

TABLE VII. ANOVA BASED ON DISCIPLINE (N = 254)

Factor	Discipline	Mean	SD	SEM	F	Sig. (2-tailed)
1	ME	3.557	.287	.050	2.040	.089
	CSE	3.536	.387	.047		
	EE	3.321	.567	.096		
	CE	3.434	.368	.053		
	AR	3.419	.495	.060		
2	ME	2.939	.466	.081	.829	.508
	CSE	2.859	.541	.065		
	EE	3.012	.634	.107		
	CE	2.939	.504	.072		
	AR	2.834	.554	.067		
3	ME	3.330	.435	.076	3.915	.004
	CSE	3.275	.447	.054		
	EE	3.209	.555	.094		
	CE	3.245	.495	.071		
	AR	3.000	.518	.063		
4	ME	2.806	.537	.094	.907	.460
	CSE	2.783	.563	.068		
	EE	2.771	.627	.106		
	CE	2.710	.579	.083		
	AR	2.909	.615	.075		

ME – Mechanical Engineering (N = 33); CSE – Computer Science and Engineering (N = 69); EE – Energy Engineering (N = 35); CE – Civil Engineering (N = 49); AR – Architecture (N = 68)

TABLE VIII. COMPARISON OF ACADEMIC DISCIPLINE FOR FACTOR 3 (N = 254)

Discipline		Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
ME	CSE	.055	.104	.597	-.149	.259
	EE	.122	.119	.307	-.113	.356
	CE	.085	.110	.440	-.132	.303
	AR	.330	.104	.002	.125	.535
CSE	EE	.067	.102	.512	-.134	.267
	CE	.030	.092	.740	-.150	.211
	AR	.275	.084	.001	.110	.440
EE	CE	-.036	.108	.738	-.250	.177
	AR	.209	.102	.042	.008	.409
CE	AR	.245	.092	.008	.064	.426

Similar results were found among groups at different age levels (< 18, 18-21, 21-24, 24-27, > 27). Age level was not found to be significantly associated with any of the factors. Rather than age level, students' learning experiences may be influencing their perspectives on the sources supporting their academic well-being.

Comparisons between disciplines were also conducted using ANOVA, shown in Table VII. There was no significant difference between students who majored in different engineering disciplines in relation to factor one, two, and four. However, in the dimension of interactions within the learning environment, the results indicated a significant difference between disciplines (p = 0.004). Specifically, Table VIII shows that students from Architecture reported that teamwork and in-group communication made less contributions to their academic well-being than students from mechanical engineering, computer science and engineering, energy engineering, and civil engineering.

V. DISCUSSION

This study examined the perspectives of first-year engineering students on the supportive sources of their academic well-being in a PBL environment. A survey was designed and validated via EFA, which identified four factors. The loading results of the EFA suggested a logic that was close to the original design of the survey, based on the conceptual framework developed from an extensive literature review. The proposed conceptual framework contained two domains – internal and external sources. The first two factors – personal values and agentic actions, belonged to the domain of internal sources, and factors 3 and 4 belonged to the domain of external sources. Nonetheless, several items loaded on different factors than the original design. Specifically, item 17 – "I express my opinions comfortably in group discussions" was originally included in the autonomy dimension, which is in the domain of internal sources, yet it loaded on factor 3 pertaining to interactions within the learning environment. This item originally reflected students taking actions based on their own values, which is an important component of autonomy, however, these actions happened in the process of group discussions, causing students to link this item to interactions with peers. Item 20 – "I experience mutual trust in my study context", previously categorized as external support, was also found to be related to the factor of interactions within the learning environment. In a PBL environment, mutual trust is

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mainly built upon teamwork and interactions with peers and facilitators, thus, students might see this element as an inherent attribute of teamwork and a component of good interactions with peers. They needed to create mutual trust by themselves instead of depending on external support provided by the learning environment. Item 23 – "I believe I can complete tasks in a team", originally from the theme of self-efficacy in the domain of internal sources, was placed in the factor of interactions within the learning environment since this item also contains peer interactions and teamwork, and participants might have linked this item to teamwork processes. Moreover, items related to the study environment (items 20, 21, 22, 25) were expected to load on a separate factor, which showed sources from the physical learning context, but they loaded on factor 3, together with items related to interactions with peers. The possible reason is that teamwork and collaborative learning are basic principles for a PBL context [54]. The study environment mainly consisted of interactions with peers and collaborative learning in PBL, thus, participants might have connected peer interactions with the study environment, which led to items from these two aspects loading together.

Through quantitative data analysis, diverse sources loaded in four factors were reported. In the domain of internal sources, participants rated higher scores on factor 1 – personal values than factor 2 – agentic actions, which supports the finding that individuals' intrinsic motivations and goals play a key role on the attainment of well-being according to the self-determination theory [9]. In the domain of external sources, participants in this study rated higher contributions of interactions with peers to their academic well-being than interactions with others, such as professionals, family, and friends. As mentioned before, in a PBL environment, students are expected to conduct self-directed learning and collaborative learning, leading to interactions with peers becoming the main component of their study life. Meanwhile, since participants in this study were first-year engineering students, they had limited opportunities to interact with other engineering professionals, such as industry, companies, real clients, and so on. The contribution of professionals was limited, but the results might be different for students at different educational levels.

While these four factors had different impacts on students' academic well-being, the outcomes of this study highlighted the interrelatedness and inseparability of factors within each domain and the ongoing interaction between internal and external sources, as illustrated in Fig. 1. In the domain of internal sources, personal values play a key role in the choices and actions students take in their learning processes, while their agentic actions and experiences also form and influence personal values [63]. These internal sources could influence students' choice and utilization of external sources [64], thereby influencing their learning experiences and attainment of academic well-being [21]. Students' internal sources, including their goals, values, and performance, could influence the ways they work with peers and seek external support from a broader environment. On the other hand, the external sources also form and influence the internal sources, since students' personal values are always context bound, and their experiences, decision-making, and sense-making processes are always related to their interpretation of relations and sources offered by the learning context [65]. Thus, by identifying four factors supporting students' academic well-being, this study recognizes the interplay between internal and external sources and suggests further exploration of interrelatedness of factors in future studies.

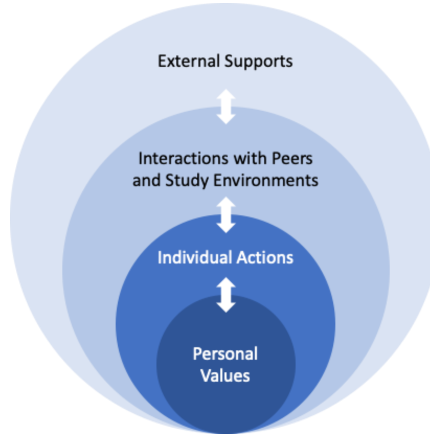

Fig. 1. The connections between factors

In terms of the comparison between student groups, female engineering students placed higher value on the contribution of teamwork and interactions with peers on their academic well-being than male students, which is consistent with prior studies [60-61]. Compared to males, female engineering students have been found to have higher willingness to conduct collaborative learning and assess themselves with higher communication and teamwork skills, as well as higher efficiency in collaborative learning [64, 66]. These findings might explain why teamwork and interactions with peers contributed more to female engineering students' academic well-being. In addition to gender differences, students from architecture placed lower value on the contributions of interactions with peers to their well-being than students from the other four engineering disciplines. The possible reason might be related to their identity. As future engineers, students from architecture tend to identify themselves as designers [67], who might have strong autonomy over their designs and projects, and place less value on the contributions of teamwork and interactions with peers. In sum, sources for fostering academic well-being could be different for diverse student groups, and academic well-being itself does not develop entirely naturally. For engineering students, it is important to set personal learning goals, have the self-awareness to develop their self-efficacy and learning autonomy, and take action to achieve their goals. Meanwhile, educators need to be aware of the interplay between students' personal values and their learning preferences, and support the sources of students' academic well-being within the learning environment [38]. For educational institutions, when designing the curriculum and creating learning contexts, in addition to learning objectives, more attention on students' academic well-being is needed. While various sources might have been in place in the learning environment, the attainment of well-being does not take place automatically. Policy support for fostering students' academic well-being and the facilitation of the identified sources in the learning environment are needed.

This study has several limitations. First, this study was conducted in the context where PBL has been implemented at the curriculum level. Although PBL elements were not emphasized in this survey, so far, the development and validation of the survey were only conducted in this PBL environment. This might lead to different perspectives among students regarding the sources contributing to their academic well-being, thus limiting the generalization of the survey to other learning environments. Further validations are needed to explore the possibility of potential implementation of this survey, by involving diverse data sources and learning environments in different institutions or countries. Second, this study only focused on first-year engineering students, who just entered university and need more time to be exposed to different learning contexts, accumulate various learning experiences, and develop their personal values such as self-efficacy, autonomy, and identity. Future studies could involve students at different educational levels or adopt a longitudinal method to track the changes in students' perspectives of sources contributing to their academic well-being at different stages of their programmes. The third limitation is that this study only illustrated an initial comparison between student groups. Although significant differences between gender and discipline were reported, this study has not fully explored the reasons for these differences. Further statistical comparison of differences between student groups and explanation of the statistical results based on qualitative data are needed in future research.

VII. Conclusion

This study investigated students' perspectives on the sources that contributed to their academic well-being. The study contributes to the literature surrounding first-year engineering students' academic well-being by proposing a conceptual framework guiding an understanding of supportive sources that foster students' academic well-being. With guidance from the proposed conceptual framework, a preliminary survey was designed and validated in a systemic PBL context, which is ready to be used as an analytical tool to explore the influence of diverse sources to support students' academic well-being. Four factors were confirmed, including personal values, agentic actions, interactions within the learning environment, and external support. Meanwhile, comparisons between gender and disciplines were conducted, and initial findings were reported.

This research is still in an explorative stage. Further validation of the survey will be conducted in diverse social cultural groups (e.g., senior students, other study environments, and societal contexts). Meanwhile, this study calls for more attention to students' academic well-being in engineering educational research. Future comparative studies are needed for explanations of the statistical results and a better understanding of the influences of various sources on students' academic well-being.

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