Influencing program satisfaction for undergraduate students

in STEM areas:

The impact of interdisciplinary features, disciplinary connectedness, faculty support, and examination difficulty

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Abstract: Ensuring program satisfaction for undergraduate students in the areas of science, technology, engineering and mathematics (STEM) matters in student retention and education quality improvement. This study explores how four rarely examined variables support from faculty members, interdisciplinary features of STEM program courses, discipli*nary connectedness of STEM program core courses,* and *examination difficulty* impact Chinese STEM undergraduates' *program satisfaction*. With data from 619 Chinese STEM undergraduates, structural equation modeling shows that *course satisfaction* partially mediates the impact of *support from faculty members* on *program satisfaction*, while fully mediating that of *interdisciplinary features of STEM program courses* and *disciplinary connectedness of STEM program core courses* on *program satisfaction*. *Examination difficulty* exerts no significant impact on *program satisfaction* neither directly nor indirectly. S*upport from faculty members* impact *course satisfaction* significantly stronger for junior and senior students than for freshmen and sophomores, while *interdisciplinary features of STEM program courses* impact *course satisfaction* stronger for freshmen and sophomores than for juniors and seniors. The study ends with practical implications for the higher education reform in relevant areas.

Keywords: undergraduate STEM students; program satisfaction; higher education; interdisciplinary and disciplinary features; faculty support, examination difficulty

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1. Introduction

Delivering student-centered educational experiences at scale have been strongly called to reform STEM programs in various countries such as the UK, Australia, Singapore and the Netherlands (Graham 2018). Such a call results from reported students' dissatisfaction with their educational experiences provided by their registering programs in teaching, courses, learning environment, assessment methods, etc., which in time leads to student attrition in STEM fields that besets governments, industries and academic communities (Association of American Universities, 2017; Chen, 2013; Holdren et al., 2013). Increasing student satisfaction among many other goals has therefore taken a strong hold among university administrators as a means to implement student-centered educational idea (Elliott and Shin 2002), in that satisfaction involves students' evaluative responses to educational effectiveness (Juillerat and Schreiner 1996), the extent to which educational aspirations are met (Elliott and Shin 2002), the achieved value of education as a product (Grace et al. 2012), and students' motivation for further learning (Yeoh et al. 2017). As a program involves expectations of students in comprehensive terms including competence, potentiality, adaptability, skills and knowledge acquisition (CSU 2016), it is critical to identify factors influencing program

satisfaction of STEM undergraduates who are the future workforces driving economic competitiveness.

This study aims to use STEM-program undergraduates in China as samples to shed light on the topic of program satisfaction of global concern for two reasons. Firstly, as a later-comer to scientific and technological forefronts, China has been constantly benchmarking the quality of its STEM graduates with international standards. That explains why China prepared ten years to join Washington Accord (WA), an internationally recognised agreement on engineering graduate attributes, to render its university-level STEM education substantially equivalent to international standards (Zhuang and Xu 2018). The recent 'New Engineering Education' (NEE) launched by China's Ministry of Education (MOE) in 2017, a nation-wide STEM-program-reform initiative, in fact absorbs numerous state-of-the-art international ideas on educational development such as cross-disciplinary education, student-centered education, and synergetic education. For instance, 'strengthening interdisciplinarity and connectedness among subjects and courses' (MOE, 2017) is especially emphasised in NEE against the broader backdrop of dramatic cross-disciplinary technological breakthroughs in the global industry sector. As such, an exploration of students' program satisfaction in China unravels how internationally agreed ideas originating from the West come into play in a non-Western context.

Secondly, China's STEM education reform measures addressing relatively unique shortfalls of the country's higher education system (i.e. demotivating assessments, insufficient faculty support to students) can also provide implications for the world regarding how program quality is affected. For example, China's recent emphasis on tightening academic standards to improve undergraduates' learning and educational effectiveness in strong terms derives from the long-standing criticism that its education system exerts overpressure on secondary school students while is too soft with undergraduates (Yan, 2018).

Baosheng Chen, China's Minister of Education, even joked on such a phenomenon as 'life-burying secondary schools and entertaining universities' which later went viral online. This Chinese phenomenon, quite the opposite of educational practices in Western countries, has been perceived as a fundamental barrier that prevents China from producing technologically innovative talents as Western countries do (Zhao 2014). These vernacular characteristics militate against the program quality but have drawn relatively rare attention from the international academic community.

As such, this study attempts to examine the relationships between STEM students' program satisfaction and five particular aspects: interdisciplinary features of STEM program core courses, disciplinary connectedness of STEM program core courses, faculty support to students, examination difficulty, and course satisfaction. The first two aspects are in line with the aforementioned globally recognised ideas of STEM education reforms in providing more interdisciplinary learning experiences and strengthening course quality, while the third and fourth aspects are more of China-specific educational barriers that pinion student learning. The last aspect, course, is also included for analysis as course constitutes a basic part for any university programs. Conceptually, these few aspects fit into Schwab's (1973) identification of four essentials of education: 'learner', 'teacher' (faculty support to students involves both teacher and learner), 'milieu' (whether examination motivates student learning) and 'subject matter' (interdisciplinary and connected features of STEM courses). Prior to the analysis of their relationships, relevant literature is firstly reviewed.

2. Literature Review and Hypotheses Development

2.1 Faculty's support and student learning

When it comes to STEM students' learning, faculty members are identified as crucial stakeholders in ensuring learning excellence because of STEM subjects' demanding nature in

and of itself (Holdren et al., 2013; Ortiz & Sriraman, 2015). Students need various types of faculty scaffoldings to keep learning such as supportive learning environment and high expectations (Allan, Clarke, and Jopling 2009), competition-oriented and interest-igniting projects (Crawley et al., 2014), and close connections to and monitoring of student learning beyond classrooms (Tam, Heng, and Jiang 2009). Student satisfaction is reported to rise when faculty show genuine concerns beyond basic course requirements (Husband 2013), and the attrition likelihood becomes less if students feel positive about their instructors in terms of providing support (Xu, 2015).

The rationale derives from the socio-cultural perspective of learning that effective learning happens through socially supported interactions which benefit the development of learners' intrinsic motivation, expertise, metacognitive skills and sense of self (National Research Council 2003). Regardless of objective resource constraints such as class size or student/faculty ratio in many universities, substantive connections between faculty members and students beyond classrooms are called for to facilitate student learning (Tam, Heng, and Jiang 2009). In Chinese higher education sector, some faculty members are viewed as careless outsiders of improvement in teaching and learning due to the current evaluation system that prioritises research(Huang, Pang, and Yu 2018), which leads to the goal displacement for higher education(Zou, Du, and Rasmussen 2012). Concurrently, there are student complaints about their instructors' disappearances once classes are finished (Ye 2011). As such, the Chinese Engineering Education Accreditation Association added 'faculty support to students' to the overall indicators that evaluate engineering program accreditation in 2017, requiring engineering faculty members to provide counseling to students in addition to classroom teaching(Zhuang and Xu 2018). Overwhelmingly, the enormous energy and temporal resources STEM students have to spend on STEM subjects accentuates the need for students to obtain extra-curricular support from their faculty(Case 2015). Given the above

association between faculty support and student learning, as well as measures facilitating change in Chinese STEM programs, our first hypothesis is established as:

H1a. Support from faculty members (SFFM) significantly predicts STEM undergraduates' program satisfaction (PS).

2.2 STEM attributes and student learning

Regarding disciplinary features, interdisciplinarity constitutes the basic nature of STEM subjects (Al Salami, Makela, and de Miranda 2017; Henderson et al. 2008). STEM subjects deal with real-world problems complexly underpinned by multiple disciplines(Leshner and Scherer 2018), thus demanding interplay and intersection among heuristics and epistemologies (National Academies of Sciences, Engineering and Medicine 2018). Compared with other fields, STEM problems in stronger terms 'require people from different disciplines to come together and solve them' (STEM Innovation Task Force 2015, 17). As coordinating different conventional disciplinary courses and increasing interdisciplinary elements is key to developing an integrated engineering curriculum (Crawley et al. 2014), STEM education requires instructors to make meaningful connections between various academic areas when designing and teaching courses.

As such, not only interdisciplinary training is stressed in STEM programs across countries (National Academies of Sciences, Engineering and Medicine 2018), but a concurrent approach to integrating design and manufacturing of products, supporting responsiveness and lifecycle reliability based on interdisciplinary collaboration is sonorously called (Davim 2012). Worldwide STEM graduates are expected to apply knowledge of math, science and engineering and work on multi-disciplinary teams to solve complex engineering problems (CSU 2016; Graham 2018). In China, strengthening interdisciplinary elements is also a strategy to motivate student interest, enhance learning efficiency and address student

complaints on instruction methods and course contents(MOE 2017).

Furthermore, as STEM subjects are hard disciplines with high degree of paradigm development based on cumulative knowledge (Umbach 2007), disciplinary connectedness of courses especially counts in the design and development of STEM programs. Sequence of contents and knowledge extremely matters in STEM education, where absorption of knowledge in one course must be built on the mastery of pre-requisite courses. The reverse of course order could lead to academically epistemological chaos. For instance, whether computer science students should start their core courses from computation theory or a programming language is heatedly debated (Crawley et al., 2014).

In countries like Sweden, the concept of development route has been introduced specifically to guide STEM students' academic progression (Crawley et al., 2014), and in others like Greece, disciplinary connectedness of courses is now a yardstick to guide the development of inclusive diploma study plans(Davim 2012). In China, the emphasis on disciplinary connectedness among courses is aimed at enabling students to better understand the overall knowledge structure of their program courses, thus for students to gain a solid academic and applicable foundation in STEM fields. It also attempts to address the complaints on courses that are provided in a piecemeal rather than systematic fashion, particularly in second and third-tier institutions (MOE 2017). Our second and third hypotheses are therefore:

H1b. Interdisciplinary feature (IDF) of STEM program courses significantly predicts STEM undergraduates' PS.

H1c. Disciplinary Connectedness of Program Core Courses (DCPCC) significantly predicts STEM undergraduates' PS.

2.3 Examination rigor and student learning

Existing literature on the association between assessments (examinations included) and educational quality at postsecondary institutions has identified inadequate rigor and low bars as barriers for realizing expected learning outcomes (Schnee 2008; Walt, Potgieter, and Wolhuter 2016). Among all assessment forms, examination remains the most prevalent for higher education institutions (HEI) to measure 'hard-discipline' students (i.e. STEM students)(Umbach 2007) in their knowledge gain. Examination difficulty reportedly makes a difference in motivating students' learning (Evans 2013), as students do not take learning seriously if ascertained to pass exams with low bars, hence grade inflation(Chan, Hao, and Suen 2007). Easy examinations could also be devastating by eroding students' long-term academic capability, as loose standards ill-prepare for the complexity of real-world STEM challenges(Ortiz and Sriraman 2015), thus affecting students' ultimate satisfaction (O'Donovan 2017).

In China, tightening standards in end-of-course examinations is highlighted in the latest higher education reform, including STEM fields. A special notification was issued in 2018 by MOE to combat clearance examinations, which refer to easy exams specially organised at departmental or institutional level for undergraduates who had failed certain subjects more than twice. Clearance exams are regarded as a corrosive problem of the education system because these exam papers are made up for the pure purpose of promoting their takers to pass without challenging students at all. The mandatory elimination of these easy examinations and the prevalent emphasis in the increased examination difficulty were aimed at ensuring that students make the cut in academic attributes(Yan 2018). Therefore, our fourth hypothesis goes as:

H1d. Examination difficulty(ED) significantly predicts STEM undergraduates' PS.

2.4 Course and Program satisfaction

Course and program, though being two distinctive concepts, have inextricably close links with one another. Concerning both concepts' connotations, course normally constitutes the basic element of a program, and numerous courses underpin a program together with other elements including hardware facilities, campus service, program goals, etc. (Zhuang and Xu 2018). Comparatively, program involves broader goals and longer phases in cultivating students and is degree-oriented, while a course in most education systems lasts for one academic term focused on knowledge impartment.

As such, course quality often works as a yardstick for measuring program quality (Devinder and Datta 2003; Husband 2013), being the most important tangible product a program offers (Grace, et al., 2012). How satisfied with courses affects students' perceptions of the overall effectiveness of their program and even interest in the field they study(Douglas, Douglas, and Barnes 2006). However, looking at the flip-side of the coin, literature has suggested that course satisfaction is also affected by factors such as faculty support and assessment(O'Donovan 2017) which are assumed to impact program satisfaction. Meanwhile, the interdisciplinarity and connectedness of courses represent STEM attributes at the level of not only program but also course(MOE 2017). Therefore, it seems that course plays a mediating role between relevant antecedents and program satisfaction, hence the following hypotheses:

H2. Course satisfaction (CS) significantly predicts STEM undergraduates' PS.

H3. CS mediates the impact of SFFM(**H3a**), IDF(**H3b**), DCPCC(**H3c**) and ED(**H3d**) on PS.

3. Methodology

3.1 Circulating the e-survey

Before collecting data, the study and the e-questionnaire used were granted the ethical

approval by the Survey and Behavioral Research Ethics Committee of the first author's affiliation. Then we administered the e-questionnaire on Wenjuanxing (Questionnaire Star), a widely used online survey platform that could bind itself with the most popular app WeChat in China. We requested four familiar faculty members at four universities in China to forward our e-survey to their STEM-program students' WeChat groups. STEM programs in our study refer to any of the 205 specialties subsumed within the Big Category of 'Science' and 'Engineering' in the *Catalogue of Specialty* issued by China's MOE[3]. The four faculty members asked students to finish the survey carefully but on a totally voluntary basis. They also asked these students to help forward the e-survey to their fellow students and friends who had to be officially enrolled in a STEM program of an MOE-recognised university, excluding independent colleges and postsecondary vocational schools. A mandatory demographic question on participants' major in the e-survey helped us sift non-STEM students' answers later. On the questionnaire's heading, students were explicitly informed of the purely academic purposes of the study and ensured confidentiality. Whether to participate in our study was entirely up to each student who received our e-survey.

3.2 Participants

After eliminating 59 ineffective responses from 670 submissions including non-sense responses to demographic questions, responses from non-STEM students, and unengaged responses with standard deviation of answers being zero, responses of 619 participants from 75 HEIs in China were deemed effective. Among all, 143 participants came from first-tier and 476 from non-first-tier HEIs. There were 155 freshmen, 175 sophomores, 209 juniors and

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[3] The *Catalogue of Specialty* has twelve Big Categories to differentiate academic disciplines such as philosophy, economics, science, engineering and arts. Under each Big Category, there are various sub-categories and specific programs. Under 'Science' are 12 sub-categories (i.e. mathematics, physics) and 36 programs (i.e. applied physics, applied mathematics, bioscience). Under 'Engineering' are 31 sub-categories (i.e. energy, electronic information) and 169 programs (i.e. vehicle engineering, energy and power engineering, software engineering) (http://old.moe.gov.cn/publicfiles/business/htmlfiles/moe/s3882/201210/143152.html)

80 seniors in the total sample. 302 students were male and 317 were female.

3.3 Instruments

Support from Faculty Members (Cronbach's alpha: .912)

A 5-item scale was used to assess the support faculty members provided in promoting STEM students' learning, adapted from the part *Teacher Support* from Yin and Lu's (2014) validated University Mathematics Classroom Environment Questionnaire (UMCEQ). One exemplar item is 'Instructors are generally willing to keep communications with students in and outside class'.

Interdisciplinary Features of STEM Program Core Courses (Cronbach's alpha: .858)

Four items were developed to assess STEM undergraduates' perceptions of the degree of interdisciplinarity of their programs, exemplified by items such as 'There are interdisciplinary courses especially offered in my program' and 'Course assignments or capstone projects in your program cannot be finished without interdisciplinary knowledge and skills'.

Disciplinary Connectedness of STEM Program Core Courses (Cronbach's alpha: .778)

This aspect of STEM programs' uniqueness including course sequence and course connectedness was assessed by three items. Example items include 'Courses can only be selected after students finish relevant pre-requisite courses' and 'Contents of courses generally build upon contents of pre-requisite courses'.

Examination Difficulty (Cronbach's alpha: .775)

Three items were employed to measure students' perceptions of the general difficulty of examinations they usually sat, informed by relevant literature pertaining to the influence of assessment on students' learning outcomes (Wilson et al. 1997). One example item is 'Exams are generally difficult and demand much effort to prepare for.'

Course Satisfaction (Cronbach's alpha: .897)

Apart from the one original item on course satisfaction in CEQ (Wilson, Lizzio, and Ramsden 1997), two other items were developed to capture other aspects of satisfaction in the present study, such as whether STEM program courses were satisfactory in terms of helping students build a solid theoretical foundation and enhance students' competence in applying knowledge.

Program Satisfaction (Cronbach's alpha: .891)

Two items of Grace et al (2012)'s course satisfaction scale were adapted to measure STEM students' intention to recommend their program to prospective students and their overall satisfaction with the program. As retention in the STEM field is a key indicator to measure education quality (Ortiz and Sriraman 2015), we developed another item 'The program makes me willing to pursue further study in my major or field', hence a three-item scale.

All the items were scored on a 6-point Likert scale from '1' (strongly disagree) to '6'(strongly agree) to avoid the central tendency. Each item was translated and back translated and proofread by two native Chinese speakers. The CFA and other psychometric results of all the six measures show their validity.

3.4 Data analysis

The study used SPSS 23.0 to calculate descriptive statistics, and AMOS 20.0 to perform analysis for established structural equation models and conduct multiple group analysis. No missing values were identified.

According to Hair et al.(2014), 300 cases can be the minimum sample size for conducting structural equation modeling (SEM) for models with seven or fewer constructs.

Kline (2011) identifies applicability in running SEM when the sample size (N) to the model parameter number (q) ratio is greater than 10. In this study, the N-q ratio (619:57) is 10.86, hence feasibility of conducting SEM.

The measurement model was tested to see whether every construct we employed had acceptable to good psychometric properties prior to dealing with hypotheses. In testing hypotheses, especially concerning mediation, we followed the principles of Baron and Kenny (1986) in three steps. Firstly, whether independent variables(SFFM, IDF, DCPCC and ED) significantly predicted the dependent variable(PS) was tested; secondly, if yes, the mediator was added to form a new SEM model for investigation of whether independent variables(SFFM, IDF, DCPCC and ED) significantly predicted the mediator(CS); thirdly, we investigated whether the mediator(CS) significantly predicted the dependent variable(PS) controlling for independent variables.

4. Results

4.1 Measurement Model Test

Based on the conceptualised approaches above, a confirmatory factor analysis(CFA) was performed on all the factors(SFFM, IDF, DCPCC, ED, CS and PS). A model can be considered good provided that its parameters satisfy $\chi^2/df<3$ (Schreiber et al. 2006), RMSEA<.08 (Browne and Cudeck 1989), and TLI and CFI>.9 (Bentler 1990). CFA generated results that met such standards ($\chi2=556.961$, df=174, $\chi2/df=3.201$, GFI=.920, TLI=.944, CFI=.954, RMSEA=.060[.054, .065]), supporting the good fit for the CFA model. As displayed in Table 1, the standard factor loadings for each item ranged from .662 to .899, indicating that all items were well loaded on their respective latent variables. Composite reliability values for each variable ranged from .775 to .912, all greater than the recommended .7 (Nunnally and Bernstein 1994), showing that all the factors had good

reliability. Average Variance Extracted (AVE) values for all factors ranged from .534 to .743, all greater than the recommended .5 (Hair 2014), thus validating adequate convergence of all the constructs.

Table 1:Results of the Measurement Model

Construct	Item	Std FL	Composite Reliability	AVE
Support	SFFM1	0.812	0.912	0.675
(SFFM)	SFFM2	0.769		
	SFFM3	0.884		
	SFFM4	0.827		
	SFFM5	0.813		
Interdisciplinary	IDF1	0.815	0.858	0.603
Features (IDF)	IDF2	0.773		
	IDF3	0.749		
	IDF4	0.767		
Disciplinary	DCPCC1	0.787		
Connectedness			0.778	0.541
(DCPCC)	DCPCC2	0.751		
	DCPCC3	0.662		
Exam-difficulty	ED1	0.726	0.775	0.534
(ED)	ED2	0.75		

	ED3	0.716		
Program Satis	PS1	0.899	0.891	0.732
(PS)	PS2	0.884		
	PS3	0.778		
Course Satis	CS1	0.858	0.897	0.743
(CS)	CS2	0.847		
	CS3	0.881		

Furthermore, as the correlation matrix revealed that the square roots of AVE value for each construct, which is the average factor loading of this factor, was greater than all the correlation values between this construct and the remaining ones(Table 2), the discriminant validity of constructs was thus evidenced (Fornell and Larcker 1981).

Table 2:Discriminant Validity Results

	AVE	1	2	3	4	5	6
1. SFFM	0.675	(0.822)					
2. IDF	0.603	0.630	(0.777)				
3. DCPCC	0.541	0.519	0.700	(0.736)			

4. ED	0.534	0.442	0.510	0.387	(0.731)	
5.PS	0.732	0.743	0.644	0.560	0.458	(0.856)
6.CS	0.743	0.728	0.680	0.571	0.435	0.756	(0.862)
Mean	/	4.800	3.690	4.460	4.410	4.610	4.350
Std.	/	0.860	0.690	1.030	1.050	1.000	1.040

*Values in parentheses on the diagonal are the square roots of AVE. The lower triangular is the correlation matrix for all the factors.

4.2 Structural Model Results

Suggested by Baron and Kenny (1986), an SEM was firstly performed (Model 1) to examine independent variables' effects on PS without the mediator (Fig 1), yielding acceptable model fitness with χ^2/df=3.489, GFI=.925, TLI=.942, CFI=.953, and RMSEA=.063. Variables of SFFM (β=.524, p<.001), IDF (β=.183, p<.001), DCPCC (β=.127, p<.01), and ED (β=.083, p<.05) all positively and significantly predicted PS (Table 3). Thus, **H1a, H1b, H1c** and **H1d** were **supported**. It's worth noting that ED's impact on PS was weaker than the other variables' impact.
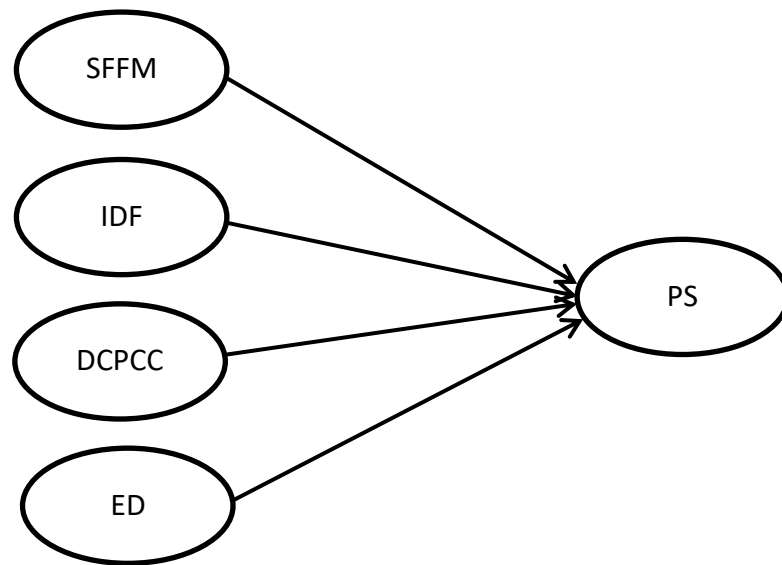
Fig 1. Hypothesized SEM Model (Model 1)

Table 3:Results for Structural Model 1

			Unstd. Coeffi (B)	Std. Coeffi(B)	S.E.	z value
Support from Faculty Members(SFFM)	→	Program Satisfaction (PS)	0.669	0.524	0.059	11.327***
Examination Difficulty (ED)	→	Program Satisfaction (PS)	0.107	0.083	0.054	1.998*
Interdisciplinary Features of Program Core Courses (IDF)	→	Program Satisfaction (PS)	0.206	0.183	0.068	3.022***
Disciplinary Connectedness of STEM Core Courses (DCPCC)	→	Program Satisfaction (PS)	0.149	0.127	0.063	2.363**

To test other hypotheses, we put CS in as a mediator between SFFM, IDF, DCPCC, ED and PS to form a new structural model (Fig 2). Model 2 also showed a good model fit

($\chi2$=556.961, df=174, $\chi2$/df=3.20, GFI=.920, TLI=.944, CFI=.954, RMSEA=.060), with path coefficients shown in Table 4.
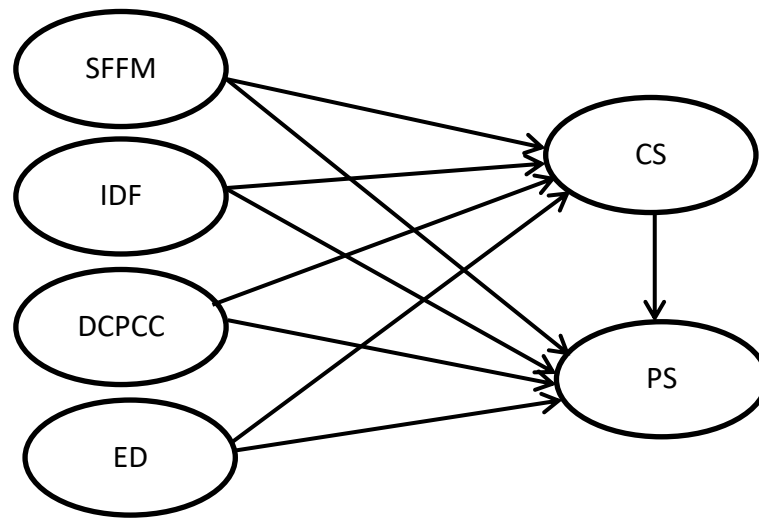

Fig 2   Hypothesized SEM Model (Model 2)

			Unstd Coefficient	Std Coefficient	S.E.	z value
SFFM	→	CS	0.620	0.475	0.061	10.240***
ED	→	CS	0.049	0.037	0.055	0.893
IDF	→	CS	0.327	0.285	0.071	4.628***
DCPCC	→	CS	0.133	0.111	0.065	2.053*
CS	→	PS	0.365	0.371	0.053	6.877***
SFFM	→	PS	0.450	0.350	0.064	7.060***
ED	→	PS	0.091	0.070	0.051	1.786
IDF	→	PS	0.084	0.074	0.067	1.253

DCPCC	→	PS	0.104	0.088	0.060	1.723

Table 4:Results for Structural Model 2

*SFFM: Support from Faculty Members, ED: Examination Difficulty, CS: Course Satisfaction

IDF: Interdisciplinary Features, DCPCC: Disciplinary Connectedness of Program Core Courses, PS: Program Satisfaction

Table 4 reveals that in Model 2, CS significantly predicted PS (β=.371, p <.001), thus **supporting H2**. Specifically, as CS was significantly explained by SFFM (β=.475, p<.001) and PS was significantly predicted by SFFM as well (β=.350, p<.001), it evinces that SFFM has a significant but indirect effect on PS. In other words, CS partially mediates the relationship between SFFM and PS, hence **supporting H3a**. IDF (β=.074, p>.05) and DCPCC (β=.088, p>.05) were found not significantly predicting PS, but significantly predicted the mediator CS (β=.285, p<.001; β=.111, p<.05). Considering that in Model 1 without CS, IDF and DCPCC were both significant predictors of PS, it evinces that the impact of IDF and DCPCC on PS were totally through CS (full mediation), thus **supporting H3b** and **H3c**. As for ED, its impacts on both CS (β=.037, p>.05) and PS (β=.070, p>.05) became not significant when CS was added in the model. This indicates that ED was not a significant predictor of PS, thus **rejecting H3d**. R^2 values pertaining to CS (.618) and PS (.669) were strong, above the recommended level of .10 (Falk and Miller 1992) (Fig. 3).
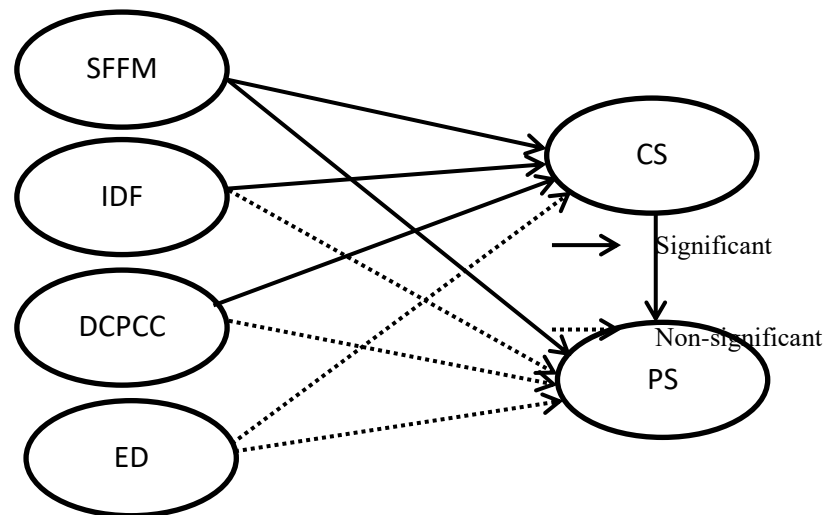
Figure 3:Overall SEM model results (Model 2, n=619)

4.3 Comparing program satisfaction across different student groups

As research evidences the differences in learning between male and female students (Malik and Coldwell-Neilson 2018) and between students of different academic years (Cramer 1998), this study also conducted multiple-group analysis across gender (302 male, 317 female) and students' grade levels. Specifically, we classified juniors and seniors as higher grade-level students (n=289) and freshmen and sophomores as lower grade-level students (n=330) in this study.

The comparison of fully constrained models against the unconstrained models in AMOS showed no significant difference at the model level between male and female students (p=.511). However, significant difference was found between lower-grade level students and higher-grade level students (p=.031) at the model level (Table 5).

Table 5:Group Comparison across Gender, Program Type and Grade Level

	Δdf	$\Delta \chi^2$	p
Gender	9	8.236	0.511

Program Type	9	12.035	0.211
Grade Level	9	18.349	0.031*

*These are fully constrained values (assuming model unconstrained to be correct).

A path-by-path analysis was made between higher-grade level and lower-grade level students by firstly constraining each path one by one while letting all other paths unconstrained to identify the possible paths bearing significant differences across the two groups. Then all the paths were constrained except those found with possible differences to confirm whether these paths in fact contributed to the model differences across the two groups. Finally, the differences were found on the path of IDF to CS, and SFFM to CS (Table 6). Specifically, IDF had a stronger impact on CS for lower grade-level students (β=.406) than for higher grade-level students (β=.187), while the impact of SFFM on CS was stronger for higher grade-level students (β=.589) than for lower grade-level students (β=.350) (Table 7).

Table 6:Path by Path Analysis for Higher Grade-Level and Lower Grade-Level Students

Model	Δdf	$\Delta\chi^2$	p
Fully constrained	9	18.349	0.031*
IDF-CS constrained	1	4.107	0.043*
SFFM-CS constrained	1	8.488	0.004**
DCPCC-CS constrained	1	0.208	0.649
ED-CS constrained	1	2.219	0.136
CS-PS constrained	1	0.187	0.665

IDF-PS constrained	1	0.004	0.949
SFFM-PS constrained	1	0.139	0.709
DCPCC-PS constrained	1	0.803	0.370
ED-PS constrained	1	2.108	0.147
All-paths constrained（except IDF-CS & SFFM - CS)	7	8.116	0.322
All paths constrained (except SFFM-CS)	8	16.815	0.032*
All paths constrained (except IDF-CS)	8	15.721	0.047*

Table 7:Standardised Path Coefficients for Students across Grade Level

Path	Lower-grade Students	Higher-grade Students
IDF-CS*	.406	.187
SFFM-CS*	.350	.589
DCPCC-CS	.073	.126
ED-CS	.107	-.029
CS-PS	.427	.318
IDF-PS	.088	.077
SFFM-PS	.377	.333
DCPCC-PS	.051	.135
ED-PS	.011	.116

* denotes significant difference in path coefficients between the two groups

5.Discussion

This study reveals that with strongest path coefficients, support from faculty members constitutes the most significant predictor of program satisfaction in both models with and without course satisfaction as a mediator. The strongest impact it exerts on students' program satisfaction indicate that faculty's role in shaping undergraduates is much more prominent than non-human factors such as subjects and examinations. The items of this construct used reveal that students expect their faculty members to care their academic performance, keep communications, empower and challenge them even in after-class settings. The finding identifies with some global literature such as the US National Research Council (2003) that learning is enhanced through socially supportive interactions, and Bain (2004) that 'best teachers expect more of their students and often try to create conditions in the learning environment that are challenging yet supportive' (pp. 18). In STEM fields, these ideas are substantiated by this study.

Another finding is interesting that the direct impacts of interdisciplinary features and disciplinary connectedness of STEM program core courses on program satisfaction become totally indirect while remaining significant when course satisfaction is added in. This finding on the one hand substantiates the growing value placed upon strengthening interdisciplinarity and disciplinary connectedness in university-level STEM education reform, as reflected in both China's NEE project and the practices of establishing interdisciplinary programs across the world (National Academies of Sciences, Engineering and Medicine 2018). On the other hand, it unravels an easily overlooked fact that it is courses rather than other elements that underpin the so-called interdisciplinarity of a program. In other words, though interdisciplinarity is a buzzword widely applied to program development and higher education reform in recent years, endeavours on it are castle in the air and doomed to fail if course improvement is not attended to enough. It also evinces the importance of focusing on

forming meaningful connections between preceding and ensuing courses while universities launch program reform, so that students can construct a solid and scientific knowledge structure while aligning knowledge with their epistemological progression (Trowler 2001). Course's prominence in program development is also reflected by the R^2 value of course satisfaction and program satisfaction in Model 2. When STEM students report program satisfaction(R^2=.669), more than half of such satisfaction results from their satisfaction with the courses offered(R^2=.371) in addition to other factors.

The finding that examination difficulty does not significantly predict either course satisfaction or program satisfaction in Model 2 speaks to the marginally significant impact it has on program satisfaction in Model 1. As such, it cautions against policy intentions to maximise student learning by bumping up difficulty in examinations. That could fair against students' epistemological development reflected by learning science theories such as zone of proximal development. Though Ramsden (2003) argues that university students favor being assessed by various assessment methods, such assessment methods were still not as micro as the level of examination difficulty. In fact, assessments, including examinations, are goal-oriented and work best when they have explicitly stated purposes and when it is ongoing but not episodic (National Research Council 2003). Therefore, tightening standards in student learning, such as reflected in China's reform initiatives, should consider reforming the overall assessment mechanisms and implementing alternative assessment methods rather than merely increasing difficulty level of one-shot exams.

Regarding group comparison results, while previous studies demonstrate gender difference's impact on educational outcomes (Malik and Coldwell-Neilson 2018), this study indicates no significant differences between male and female students in program satisfaction. The finding on interdisciplinary features' impact on program satisfaction, significantly stronger for freshmen and sophomores than for juniors and seniors, reveals that new students

need more interdisciplinary exposure to multiple disciplines to have a holistic view of their field. For a significant period, the failure for STEM disciplines in retaining students emanates from the mechanicalness of courses, especially in first two years, across countries including China (Chen, 2014) and even the technology superpower USA (Olson and Riordan 2012). Though theoretical courses such as mathematics and physics lay a foundation for lower grade-level students' specialised learning that ensues, students at this stage need more than just the basis. Rather, they need elements across disciplines to understand how the theoretical knowledge they learn can be applied in various scenarios to spur further interest in the field. The stronger impact of faculty support on program satisfaction for junior and senior students than for freshmen and sophomores indicates that students of higher academic years need more resources and support outside classrooms to improve academic and applicable capabilities. Unlike first and second-year students who largely learn knowledge in classrooms, juniors and seniors face the pressure to finish their capstone projects, find internships or employment, or be prepared to proceed into postgraduate studies. At this stage, they need faculty and institutions to provide a wider range of scaffoldings to prepare themselves for future academic endeavours or job markets.

6. Conclusion and Implications

In light of China's strategies on its STEM education reform, this study has illuminated antecedents of STEM undergraduates' program satisfaction, unraveled the mediating mechanism involved and also disproved the effect of certain factor on program satisfaction, thus contributing to an enhanced understanding of the topic of student satisfaction of global interest. The variables involved in this study shed lights on how student-centered education reform can be carried out, considering students, subject features and faculty members. Limitations of this study include relying on cross-sectional data and participants from only China as the sample, which point to future research that uses more varied methods and

samples from multiple countries to further investigate the topic. However, the findings and discussions thus far do provide several important implications for HEIs around the world.

First, HEIs need to configure policies around motivating faculty members to provide increasing and diverse after-class support for students. In the context of the widespread managerialism-based faculty evaluation system that values research in preference to teaching across countries(Huang, Pang, and Yu 2018; Leshner and Scherer 2018), incentives to reward faculty's support to students must be incorporated in HEIs' formal evaluation system on faculty's overall academic performance. Such a change would exert potentially long-term impact on student learning, especially for third and fourth-year STEM undergraduates whose need of such extra support is accentuated. Second, compared with putting forward enchanting mottos and ambitious reform goals, strengthening course quality constitutes the core of program update as it directly impacts learning and other measures' impact on students' gain, as reflected in this study, and thus must be topped high in all program reform agendas. Specifically, HEIs should strengthen research to reinforce the disciplinary connectedness of different courses within disciplines, and meanwhile mobilise intellectual and physical resources to dismantle cross-departmental barriers, develop interdisciplinary courses and offer students more interdisciplinary educational experiences. STEM students, especially freshmen and sophomores, need to be exposed to interdisciplinary elements as early as possible to ignite interest in learning STEM and understand how different knowledge dots should be connected. Though sounding a tall order, developing voluminous high-quality interdisciplinary courses is the most urgent challenge STEM programs need to meet in the age of 'Industry 4.0'. Finally, purely raising examination difficulty may not lend itself to students' perceptions of the program improvement, and therefore should be carried out with caution.

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