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Multidisciplinary Learning: Impact of Internal and External Factors*

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This study examined the moderating effect of scientific literacy between self-regulated learning and quality online material, as well as that between teaching effectiveness and multidisciplinary learning outcomes. The study also tested how quality online material mediated the effects of scientific literacy, self-regulated learning, and teaching effectiveness on multidisciplinary learning outcomes. Survey data was collected from 242 participants to determine the appropriate scale structure by performing an exploratory factor analysis. Another set of data, comprising 922 participants, was also analysed to confirm the factor structure and build a predictive model. The results indicate that the mediating effects of quality online material on the relationship between scientific literacy, self-regulated learning, teaching effectiveness, and learning outcomes were supported. Quality online material and teaching effectiveness were identified as the most influential variables on multidisciplinary learning outcomes. In addition, scientific literacy was not only an effective moderator between self-regulated learning and quality online material, but also moderated the relationship between teaching effectiveness and multidisciplinary learning outcomes.

Keywords: e-learning; engineering education; learning competency; multidisciplinary learning outcomes; teaching effectiveness

1. Introduction

Multidisciplinary learning, defined as the combination of academic disciplines that independently approach and study problems and achieve goals through a specific lens [1], has become increasingly popular in engineering education. The majority of engineering practice is carried out by the collaborative efforts of an engineering team with mixed disciplines, or by individual engineers who are competent across multiple fields [2]. As Christy and Lima stated, multidisciplinary learning approaches spark the creativity required to develop practical solutions for complicated problems [3]. Iskander and others also indicated that instructors with multidisciplinary learning experiences can provide students with rich learning opportunities and encourage them to seek higher achievement in science [4]. Moreover, Dederichs and others suggested that universities should offer a variety of multidisciplinary courses, which would provide engineering students with new collaborative method experiences [5].

Numerous studies have indicated that instructors in higher education should develop innovative teaching strategies that cultivate multidisciplinary engineering talents to fit industrial needs. For example, Urrestarazu and others adopted a mixed traditional—PBL (problem-based learning) model and online learning resources to inspire student involvement in learning activities [6]. According to Steiner and others, the multidisciplinary instructional teams, accompanied with mentors from sponsoring companies, have formulated a new team-teaching format for engineering education [7]. For example, the Multidisciplinary Design Stream programme, initiated in Canada by Queen's University and industry partners, was formed to enhance student design, professional knowledge, and problem-solving skills by assigning multidisciplinary learning teams to industry-sponsored projects [2]. Hotaling and others added that students who enrolled in the multidisciplinary learning approach have more opportunities to be hired than their peers [8].

Moreover, previous studies have demonstrated that the application of information and communication technologies (ICTs) is an effective instructional strategy to improve learning outcomes among engineering students [9]. For example, Yueh and Sheen found that students reacted posi-

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tively towards the integration of real and virtual nanobio technology laboratory corridor [10]. Goulding and others introduced a virtual-reality interactive environment, which he noted provides a risk-free environment for multidisciplinary learning without the severe consequences often faced on real construction projects [11]. Moreover, Soetanto and others demonstrated that the development of effective virtual collaboration is effected by discipline-specific training, as evidenced by a virtual team working with multidisciplinary undergraduates from the United Kingdom and Canada [12]. In short, ICTs are convenient and easy-to-access, and their application enables the multidisciplinary learning to occur and fosters great partnerships across various disciplines.

In addition to the influence exerted by online materials on multidisciplinary learning outcomes [13], other research has revealed that engineering and science students' learning outcomes are influenced by various factors, including scientific literacy [14], self-regulated learning [15], and teaching effectiveness [16]. However, Walker and Zeidler indicated that little research exists to explain how these influences jointly affect students' learning outcomes [17]. Thus, the present study examined the effect of the interaction between scientific literacy and self-regulated learning on quality online material, and the effect of the interaction between scientific literacy and teaching effectiveness on multidisciplinary learning outcome, in multidisciplinary engineering-related courses. This study also tested how quality online material mediates the effects of scientific literacy, self-regulated learning, and teaching effectiveness on multidisciplinary learning outcomes.

2. Literature review

2.1 Internal and external influences on learning outcomes

The factors influencing multidisciplinary learning outcome can be broadly divided into internal and external factors. Personal learning competency is considered a particularly crucial internal factor, indicating individual capability to acquire, select, and integrate knowledge, skills, and attitude for lifelong learning [18], and comprised primarily of scientific literacy and self-regulated learning. Scientific literacy refers to an individual's capability of making social judgments and taking action on science issues by linking basic scientific knowledge and methodologies [19]. Researchers have suggested that students in higher education should be equipped as early as possible with scientific literacy [20], which is an indicator of improved multidisciplinary learning performance and favourable attitudes towards science-related issues [14]. Notably, Balgopal and Wallace found that scientific literacy improves after students engage in socioscientific issues [21].

By contrast, self-regulated learning refers to the active and constructive process in which students self-set goals for their learning, and then monitor, regulate, and control their cognition, motivation, and behaviour that is guided or constrained by their goals and a range of contextual features [22]. Several studies have examined the effect of self-regulated learning on academic performance, demonstrating that high-achieving students use more self-regulated learning strategies to enhance their preparation and performance than do low-achieving students [23, 24]. In addition, Wang and others concluded that self-regulated learning is a significant predictor of course satisfaction and learning performance [25].

Crucial external factors include teaching effectiveness and quality online material. Student evaluations of teaching (SET) is the most popular method used in higher education to gain insight into the quality of teaching [26], and is one of the apparent criterion for assessing teaching effectiveness and learning outcomes [27]. Notably, student learning outcomes consist of both objective (measurement of the actual academic performance) and subjective (self-assessment of knowledge improvement) perceptions of learning [28, 29]. Clayson indicated that the relationship between SET and learning outcome is situational and not applicable to all instructors, academic disciplines, or levels of instruction [28]; Clayson also argued that the more objectively learning outcome is measured, the less likely it is to be related to SET. However, Stehle and others claimed that the strength of the association between SET and learning outcome varies with the criteria used to indicate students' learning [30].

Considerable efforts have been made to develop quality online material to promote positive learning outcomes [31]. For example, several studies have examined the appropriateness and effectiveness of quality dimensions of online material [32, 33]. The usefulness, accuracy, and quality of information presented in online materials, as well as the multimedia attributes and overall course design are critical factors affecting students' perceived satisfaction toward e-learning activities [34, 35]. In addition, Stricker determined that performance in a virtual learning environment is the best predictor for the overall student learning outcomes [36]. Furthermore, Marée and others indicated that students who received a multimedia-enriched skeleton concept would generate meaningful understanding and retention of the conceptual structure of the domain, the concepts, and their relationships [37].

2.2 *Teaching effectiveness on quality online material*

A central component of scientific literacy is the appropriate use of technology to support learning goals [38]. Similarly, Luu and Freeman found that the frequency of browsing the internet is positively associated with scientific literacy [39], and Rias and Zaman suggested that designers of multimedia-based instruction should incorporate students' prior knowledge (i.e., scientific literacy) in their development of online learning environments [40]. Overall, students with high levels of scientific literacy are more motivated to access and use the online resources than their counterparts.

Self-regulated learning is a goal-oriented learning strategy that can be practiced in the e-learning environment, in which leaners initiate and manage their learning process to attain desired learning outcomes [32, 41]. Sha and others indicated that self-regulated learning explains whether and how students selectively work with the features of an e-learning environment by exercising control over their cognition and actions [42]. Numerous other studies have provided support for integrating self-regulated learning mechanisms into e-learning system designs and development [43–46]. In other words, students' self-regulated learning influences how they participate in e-learning activities and use online materials.

In addition, instructors' teaching effectiveness can be judged by their preparedness in presentation and use of appropriate method to present materials [47]. A study by Koeber revealed that students not only reacted positively to the instructors' usage of technology, but also increased their involvement in the course and perceived favourable teaching effectiveness through their own use of technology [48]. Similarly, Chou determined that technology (e.g., environment, online materials, teacher scaffolding) correlates to teaching effectiveness (e.g., instructional interaction, instructional evaluation, classroom management) [49]. Thus, highly effective instructors teaching devote themselves to designing and developing quality online material that improves learning outcomes in e-learning environments.

2.3 *The interaction of internal influences and teaching effectiveness*

Numerous studies have indicated that the use of self-regulated learning enhances scientific literacy [50–52]. Yen and others suggested that both information literacy and levels of technology-integration potentially predict students' self-regulated learning [53]. Notably, the interaction between scientific literacy and self-regulated learning is complex: the control strategy of self-regulated learning is most positively associated with scientific literacy, but motivation and memorisation strategies have negative associations with scientific literacy [54].

The influence of teaching effectiveness on scientific literacy is well-documented [55–57]. In particular, Hughes and Ellefson determined that graduate assistants who received inquiry-based education not only improved their own scientific inquiry skills, but also applied those inquiry skills to acquire positive teaching effectiveness [58]; furthermore, scientific inquiry is a crucial component of scientific literacy [59].

According to our review of the relevant literature, we proposed the following seven hypotheses:

- H1: Scientific literacy moderates the effects of self-regulated learning on quality online material.
- H2: Scientific literacy moderates the effects of teaching effectiveness on multidisciplinary learning outcomes.
- H3: Quality online material mediates the effects of scientific literacy on multidisciplinary learning outcomes.
- H4: Quality online material mediates the effects of self-regulated learning on multidisciplinary learning outcomes.
- H5: Quality online material mediates the effects of teaching effectiveness on multidisciplinary learning outcomes.
- H6: Quality online material mediates the interaction of scientific literacy and self-regulated learning on multidisciplinary learning outcomes.
- H7: Quality online material mediates the interaction of scientific literacy and teaching effectiveness on multidisciplinary learning outcomes.

3. Method

3.1 *Instrument*

A course evaluation questionnaire was developed by the research team. The questionnaire consisted of four scales: (1) a learning competency scale, which comprised 13 items and investigated students' scientific literacy and self-regulated learning; (2) a teaching effectiveness scale, which comprised 9 items and examined students' perceptions of instructors' preparation, conscientious, and tutoring attitude; (3) an online material scale, which comprised 7 items and elicited the quality of online materials; and (4) a multidisciplinary learning outcome scale, which comprised 11 items and evaluated the degree of agreement to learned capabilities after completing the multidisciplinary engineering course. The scales were all designed as 6-point Likert scales (1 = not proficient at all, 6 = very proficient), and internal consistency was assured through the Cronbach α values for learning competency (0.923), teaching effectiveness (0.941), quality online material (0.934), and multidisciplinary learning outcomes (0.940).

3.2 Participant

The seven proposed hypotheses were tested using data from 22 universities in Taiwan. A total of 1,164 students enrolled in ten multidisciplinary engineering courses participated in this study, and all were informed that participation in this study was voluntary and anonymity was guaranteed. The survey was conducted at the end of each semester and identical procedures were conducted at each university.

Because the total data pool was relatively large, it was divided into two smaller samples to cross-validate the results. First, 242 students were randomly sampled through SPSS to form an exploratory group. This group comprised 199 males (82.2%) and 43 females (17.8%), of whom 194 (80.2%) were undergraduate students and 48 (19.8%) were graduate students. Most of the exploratory group participants were engineering majors (74.8%). The remaining 922 students formed a confirmatory group, comprising 740 males (80.3%) and 182 females (19.7%). Similar to the exploratory group, these students were a mix of undergraduate (77%) and graduate (23%) level, and most were engineering majors.

4. Results

4.1 Exploratory factor analysis

Exploratory factor analysis (EFA), using principal axis factor analysis with promax rotation, was conducted to extract salient factors for the four scales. Factor loadings were determined on the basis of the 0.40 loading criterion that was suggested for first-generation surveys [60].

A two-factor solution (scientific literacy and self-regulated learning) that significantly met the Barlett test of sphericity (χ^2 = 1951.228, p = 0.000) and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (0.917) was determined for the learning competency scale. This factor structure had eigenvalues greater than 1.0, and explained 63.98% of the variance. The loadings of scientific literacy ranged from 0.509 to 0.883, and the loadings of self-regulated learning ranged from 0.666 to 0.951; therefore, construct validity was assured. However, a high correlation between scientific literacy and self-regulated learning (r = 0.68) was also found, suggesting the need to confirm the discriminant validity of these constructs.

A one-factor solution that significantly met the Bartlett test of sphericity (χ^2 = 1566.151, p = 0.000) and the KMO measure of sampling adequacy (0.944) was determined for the teaching effectiveness scale. This factor structure explained 66.87% of the variance; additionally, the loadings ranged from 0.729 to 0.857, which assured construct validity.

Another one-factor solution that significantly met the Bartlett test of sphericity (χ^2 = 1448.049, p = 0.000) and the KMO measure of sampling adequacy (0.921) was determined for the quality online material scale. This factor structure explained 74.77% of the variance; additionally, the loadings ranged from 0.814 to 0.878, which provided construct validity.

Finally, a third one-factor solution that significantly met the Bartlett test of sphericity (χ^2 = 1914.174, p = 0.000) and the KMO measure of sampling adequacy (0.940) was determined for the multidisciplinary learning outcome scale. This factor structure explained 63.02% of the variance; additionally, loadings ranging from 0.715 to 0.820 were identified, which provided construct validity.

4.2 Confirmatory factor analysis

To examine the discriminant validity of the factors, thus ensuring that the factor structures derived from EFA were accurate, a confirmatory factor analysis (CFA) using LISREL 8.70 was performed. The model-fit indices for the learning competency and the teaching effectiveness scales revealed a strong fit of the model to the data (χ^2 = 1161.12, df = 206, $p < 0.05$, RMSEA = 0.071, SRMR = 0.034, CFI = 0.98, NFI = 0.98, NNFI = 0.98). Furthermore, confidence intervals between the latent variables ranging from 0.7996 to 0.4712 represented the structures, and indicated that discriminant validity was achieved [61]. The CFA for the quality online material and the multidisciplinary learning outcomes scales also revealed an overall strong fit (χ^2 = 975.23, df = 134, $p < 0.05$, RMSEA = 0.088, SRMR = 0.033, CFI = 0.98, NFI = 0.98, NNFI = 0.98). Similarly, confidence intervals between the latent variables ranges from 0.7996 to 0.7604 represented the structures, and indicated that discriminant validity was achieved. Table 1 presents a summary of the factor loadings and composite reliability of CFA.

4.3 Moderating effects

Following the EFA and CFA, structural equation modeling (SEM) with maximum likelihood estimation using LISREL 8.70 was conducted to test the moderation hypotheses. According to the results, both H1 and H2 are supported. Subsequently, simple slopes and regression lines were calculated for each level of moderation: students with high

Table 1. Factor loadings and of CFA composite reliability (n = 922)

Item	Scientific literacy	Self-regulated learning	Teaching effectiveness	Quality online material	Multidisciplinary learning outcome
1	0.78***	0.90***	0.89***	0.85***	0.79***
2	0.76***	0.92***	0.86***	0.83***	0.78***
3	0.80***	0.84***	0.84***	0.84***	0.74***
4	0.74***	0.86***	0.87***	0.82***	0.81***
5	0.63***		0.88***	0.83***	0.81***
6	0.81***		0.84***	0.73***	0.69***
7	0.79***		0.84***	0.76***	0.78***
8	0.78***		0.83***		0.75***
9	0.69***		0.84***		0.81***
10					0.79***
11					0.73***
Composite reliability	0.92	0.93	0.96	0.93	0.94

***p < 0.001.

scientific literacy (one SD above the mean), students with average scientific literacy, and students with low scientific literacy (one SD below the mean). As Fig. 1 illustrates, the more self-regulated learning ability students possess, the more positive their attitude is towards quality online material. Notably, among students with lower levels of self-regulated learning ability, those with limited scientific literacy also expressed a more positive attitude towards quality online material; however, students with high scientific literacy only expressed a more positive attitude toward quality online material when they possessed an equally higher level of self-regulated learning ability.

According to the graph depicted in Fig. 2, the high scientific literacy slope was steeper than the low scientific literacy slope. This suggests that the multidisciplinary learning outcomes among students with higher positive attitudes towards teaching effectiveness increased to a greater extent than did the multidisciplinary learning outcomes of students with lower positive attitudes towards teaching effectiveness, in response to their growing scientific literacy.

4.4 Structural model

The SEM showed a model fit (χ^2 = 42243.35, df = 11,367, p < 0.05, RMSEA = 0.061, SRMR = 0.18, CFI = 0.97, NFI = 0.97, NNFI = 0.97) and accounted for the substantial variance in quality online materials (53%) and multidisciplinary learning outcomes (69%). As Fig. 3 reveals, scientific literacy did not predict a multidisciplinary learning outcome through quality online material; thus, H3 is rejected. Self-regulated learning and teaching effectiveness directly and indirectly predicted multidisciplinary learning outcome, respectively, through quality online material; H4 and H5 are thus supported. Furthermore, the data indicated that the interaction of scientific literacy and self-regulated learning indirectly predicted multidisciplinary learning outcomes through quality online material; thus, H6 is supported. Finally, the interaction of scientific literacy and teaching effectiveness directly predicted multidisciplinary learning outcomes; thus, H7 is rejected.

Table 2 summarises the results of hypothesis testing.

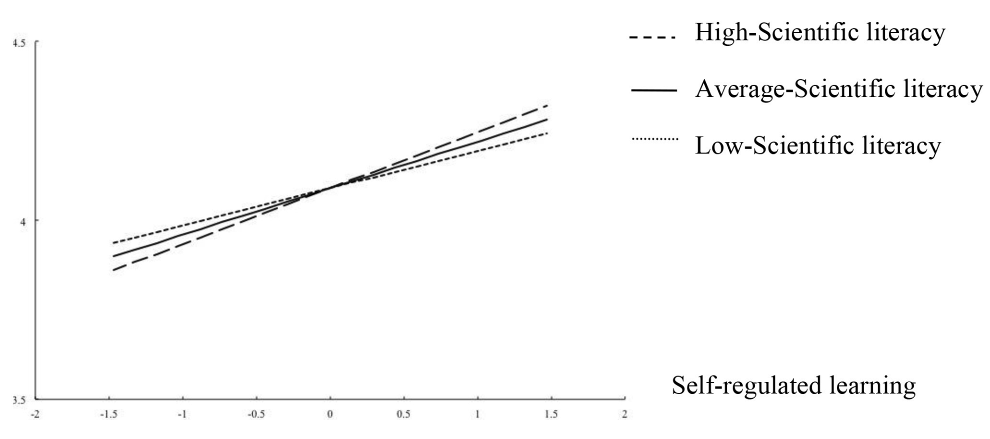

Fig. 1. Effect of scientific literacy and self-regulated learning on attitudes to quality online material.

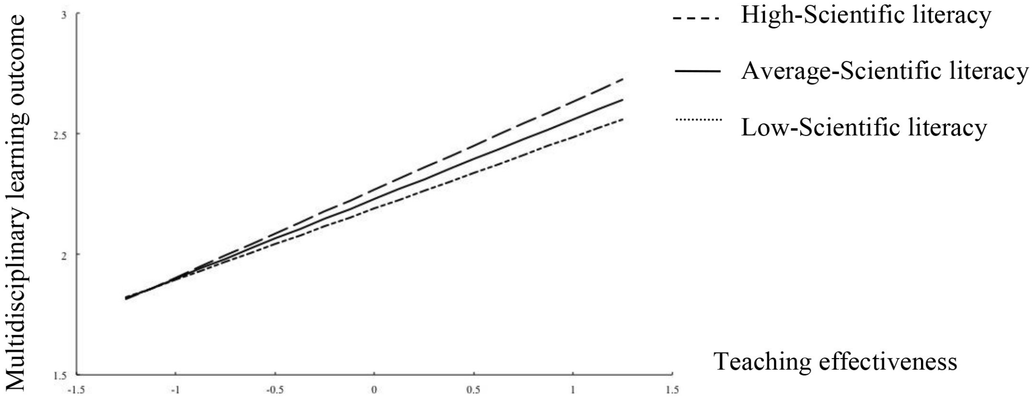

Fig. 2. Effect of scientific literacy and teaching effectiveness on multidisciplinary learning outcomes.

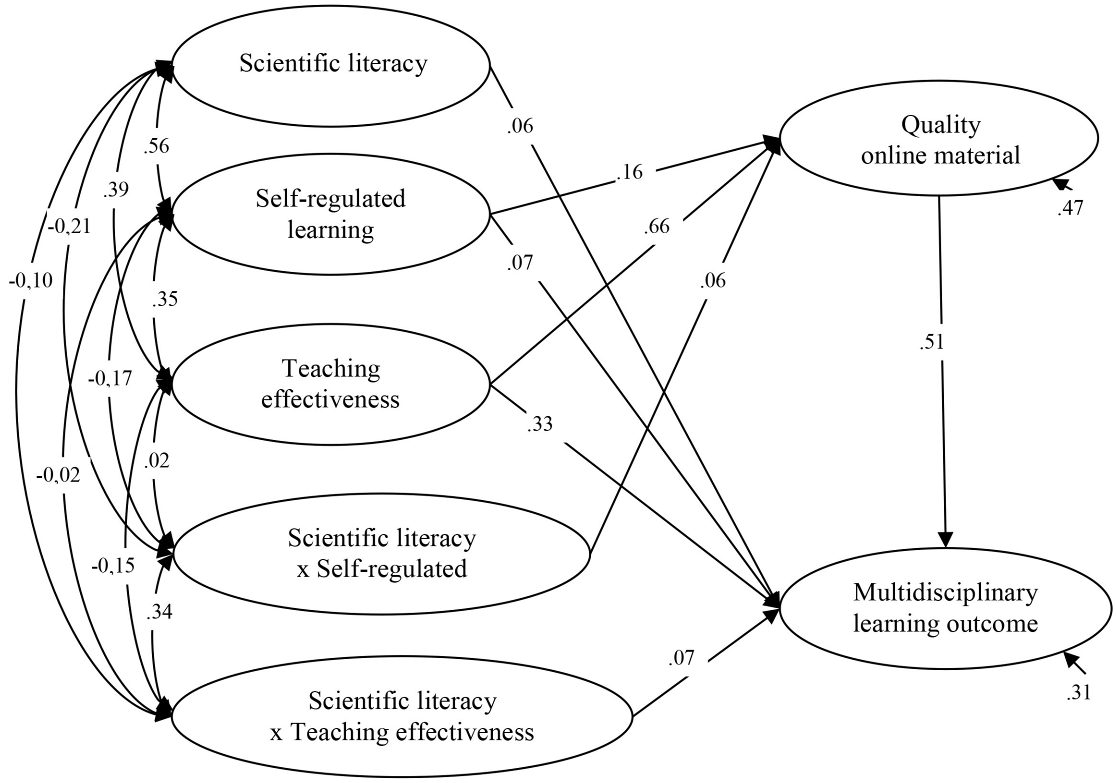

Fig. 3. Mediated moderation model of multidisciplinary learning outcomes (n = 922).

Table 2. Results of hypothesis testing

Hypothesis	Results
H1: Scientific literacy moderates the effects of self-regulated learning on quality online material	supported
H2: Scientific literacy moderates the effects of teaching effectiveness on multidisciplinary learning outcomes	supported
H3: Quality online material mediates the effects of scientific literacy on multidisciplinary learning outcomes	rejected
H4: Quality online material mediates the effects of self-regulated learning on multidisciplinary learning outcomes	supported
H5: Quality online material mediates the effects of teaching effectiveness on multidisciplinary learning outcomes	supported
H6: Quality online material mediates the interaction of scientific literacy and self-regulated learning on multidisciplinary learning outcomes	supported
H7: Quality online material mediates the interaction of scientific literacy and teaching effectiveness on multidisciplinary learning outcomes	rejected

5. Discussion

Few studies have examined the effects of learning competency and teaching effectiveness on students' learning outcomes through quality online material. Because of this research gap, we proposed applying the mediated moderation model to observe the moderating effects of scientific literacy, and the mediating effects of quality online material, on multidisciplinary learning outcomes.

5.1 Moderating effects of scientific literacy

Despite the lack of research on the interaction between scientific literacy and self-regulated learning [51, 62], this study determined that the interaction not only existed, but significantly influenced students' perceptions toward quality online material (r = 0.06). In short, scientific literacy can serve as a moderator between self-regulated learning and quality online material.

In particular, when students were less self-regulated and had low scientific literacy, they expressed a more positive attitude towards quality online material than did students with high scientific literacy. Similarly, students who were more self-regulated and had high scientific literacy also expressed a more positive attitude towards quality online material than did students with low scientific literacy. This is possibly because the less self-regulated students considered the learning management system to be an effective support mechanism in developing their self-regulated learning ability and attaining learning objectives [45, 46], and considered e-learning activities beneficial in learning content knowledge [63]. As Santhanam and others pointed out, e-learning activities are more suitable for high self-regulated students than their counterparts, and it is reasonable to assume that highly scientifically literate students would possess the necessary professional capabilities to assess learning resource quality; this results in their favourable assessments towards quality online material [41].

In addition, our results indicated that scientific literacy moderated the relationship between teaching effectiveness and multidisciplinary learning outcomes. No matter what level of scientific literacy students possessed, those with less positive attitudes towards teaching effectiveness also reported lower scores in multidisciplinary learning outcomes, compared with those that had more positive attitudes towards teaching effectiveness. The results also suggested that scientific literacy functions as an 'engine' over the positive effects of teaching effectiveness on multidisciplinary learning outcomes. Because individuals with high levels of scientific literacy exercised the prerequisite knowledge and process skills to respond to a range science and technology challenges [19, 64], highly scientifically literate students may benefit from the multidisciplinary instruction approach more than their counterparts.

5.2 Mediating effects of quality online material

This study also demonstrated the significant effect of scientific literacy on multidisciplinary learning outcomes (r = 0.06), which is consistent with previous studies that have indicated students with higher levels of scientific literacy are expected to be superior at linking humanistic and scientific knowledge [65]. Quality online material, however, did not play a mediating role between scientific literacy on multidisciplinary learning outcomes; this contradicts research by Mbajiorgu and Ali, which suggested that instruction interventions can serve as an effective mediator between scientific literacy and academic achievement [66]. Because the development of multidisciplinary talents with sufficient scientific literacy is a crucial concern in engineering education, further study into the relationship between scientific literacy and quality online material is required.

In addition, our results determined that both self-regulated learning and teaching effectiveness directly and indirectly influence multidisciplinary learning outcomes, respectively, through quality online material. This concurs with prior research [25, 67] that has demonstrated that self-regulated learning is a significant predictor of learning outcomes. Furthermore, our results suggested that engineering educators should offer diverse and authentic practises for students to actively experience critical self-regulated learning processes [68], and build metacognitive tools into e-learning systems to support and model students' self-regulatory processes [69].

Quality online material was viewed in this study as an instructional intervention that mediates the relationship between self-regulated learning and multidisciplinary learning outcomes. The results validated previous studies that found that instructional intervention has significant and positive associations with self-regulated learning and learning outcomes [70]. Without the supervision of instructors, students in an e-learning environment must set learning goals, use study strategies, and self-monitor to complete tasks, which are critical self-regulating behaviours [71]. Our results also mirror the work of Tsai and others [72], who noted that the integration of e-learning and self-regulated learning is beneficial to students' learning performances.

The influence of teaching effectiveness on multidisciplinary learning outcomes also echoes Clayson [28], who argued that teaching effectiveness has a positive relationship with subjective learning outcomes. However, our research partially contradicts the findings of Galbraith and others [73], which indicated that teaching effectiveness is only associated with lower levels of student achievement. This may be because the student self-assessments that were adopted in this study had only one indicator of learning outcomes. Other criteria used to assess learning outcomes could include academic knowledge and skills, learning attitude, and motivation dimensions, especially in a multidisciplinary learning context where interactions among peers from varied fields are crucial. In addition, the present study revealed that quality online material mediated the influence of teaching effectiveness on multidisciplinary learning outcomes; this implies that students who have more positive attitudes towards teaching effectiveness also express more favourable perceptions towards quality online material.

Furthermore, the results indicate that quality online material mediated the interactive effects of scientific literacy and self-regulated learning on the multidisciplinary learning outcomes; the interaction between scientific literacy and teaching effectiveness also directly influenced multidisciplinary learning outcomes. The current study offers insight into the complexities of the mediated moderation model of multidisciplinary learning. Particularly, the identification of quality online material as a crucial mediator between selected factors and academic performance provides developmental possibilities for a variety of intervention packages, under the premise that multidisciplinary learning and online education are valuable to engineering education.

Overall, the total influence of teaching effectiveness on multidisciplinary learning outcomes ($r = 0.67$) is greater than the individual influences of self-regulated learning ($r = 0.15$) and scientific literacy ($r = 0.06$). This is similar to the research by Yueh and others [74] that demonstrated that external variables exert more significant effects on learner achievement compared with internal characteristics variables. Furthermore, our results highlighted the importance and necessity of instructors in the multidisciplinary learning outcomes of engineering courses, indicating that instructors can serve as facilitators who develop quality online material to improve student performance. Finally, self-regulated learning, the internal mechanism that regulates an individual's cognition and actions in response to online learning resources, was proven to be a critical factor in the distance education context.

5.3 Limitations

Although the final model this study presented fit the data well, the predictive validity could have been stronger. We suggest that, in addition to scientific literacy, self-regulated learning, teaching effectiveness, and quality online material, variables including self-efficacy, multimedia formats, and instruction channels, should be taken into account in future studies. Furthermore, social desirability bias and context variability across universities may have influenced our results. However, self-reporting measures allow us to generalise our findings to the broader population and the consistency between the EFA and CFA results supports the factor structure of the measures [75]. Finally, this study only adopted the items related to metacognitive constructs as the assessment tool of self-regulated learning; however, the lack of a comprehensive assessment of students' self-regulated learning abilities may have affected the interaction effects between the involved variables.

6. Conclusions

Although the limitations of this study must be considered, the results of this study nonetheless provide a comprehensive understanding of how students' multidisciplinary learning outcomes are improved by the combined influence of internal and external variables. The structural model demonstrated that quality online material has a mediating effect of on the relationship between scientific literacy, self-regulated learning, teaching effectiveness, and learning outcome. In addition, quality online material and teaching effectiveness are the most directly influential variables on multidisciplinary learning outcomes. Moreover, scientific literacy is not only an effective moderator between self-regulated learning and quality online material, but also moderates the relationship between teaching effectiveness and multidisciplinary learning outcomes.

Although numerous studies have examined the influences of self-regulated learning and teaching effectiveness on learning outcomes through various higher education instruction interventions, little research has analysed the predictive effect of scientific literacy in the e-learning environment or its moderating effects on online material and multidisciplinary learning outcomes. Thus, this study offers a unique contribution to the structural view regarding the mediating effects exerted by quality online material, as well as how the moderating effects exerted by scientific literacy influence multidisciplinary learning outcomes. Engineering educators are encouraged to provide diverse opportunities for students to exercise their self-regulated abilities which could improve their scientific literacy and further enhances learning outcomes. In particular, the online material of multidisciplinary courses should be prepared to cover broad knowledge that goes beyond the scope of classroom instruction.

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