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Identifying Factors Affecting the Quality of Teaching in Basic Science Education: Physics, Biological Sciences, Mathematics, and Chemistry

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Abstract: Basic science education provides the most fundamental knowledge for preparing students to pursue departmental major courses. Considering that basic science courses are laboratory classes conducted alongside theory classes, the factors affecting instructor–student communication and feedback can vary between theory and laboratory classes. We applied the ordinary least squares model to the refined data of basic science courses. We drew on variables reflecting instructor–student interaction such as class size, type of subject, and instructor characteristics to analyze the factors affecting student satisfaction with theory and laboratory classes. The analysis results indicated that the educational environment of a large-sized class could be improved by subdividing it into smaller groups to facilitate feedback. The use of online platforms to supplement offline courses provides an additional mechanism for the exchange of feedback and positively affects student satisfaction. We also confirmed empirically that the instructor–student communication which takes place during laboratory work, in contrast to the one-sided conveyance of course materials by the instructor in lectures, was a crucial factor in the quality of education. These results are linked to the demand for knowledge in engineering education, the student's educational performance, and the labor market performance needed to establish a sustainable system in engineering education.

Keywords: science education; feedback; instructor experience; hybrid course; student evaluations

1. Introduction

Student evaluations of teaching are very important to students, faculty, and administrators in both higher education and science education. Most universities employ student evaluations in some form as a measure of the efficacy of instructors and lectures [1], making them a key factor in determining not only the quality of an instructor's performance but also the quality of the education provided [2–6]. In the absence of firsthand, real-time data on classroom environments, outcomes, and instruction characteristics, student evaluations have become a useful alternative, contributing to the literature on higher education relating to factors affecting teaching quality. Universities have developed relatively complex procedures and instruments for collecting, analyzing, and interpreting these data, as they are often the sole indicator of teaching quality [7].

Teaching evaluations are widely used in many studies related to higher education because this approach allows researchers to identify the various factors operating in the classroom that affect the overall learning process, from those that rest with individual students (e.g., learning performance and expectations for learning outcomes), to those having to do with classroom teaching (e.g., clarity of instruction, adequacy of course materials, and instruction methods), individual instructors (e.g., faculty competence and enthusiasm), to overall satisfaction, and so forth. Student evaluations provide insights and information useful in improving teaching quality while also serving as evidence of institutional accountability (e.g., demonstrating the presence of adequate procedures for ensuring teaching quality [8]). Also, teachers are convinced of the value of student evaluations for providing feedback on their teaching [9–11]. The results obtained from student evaluations help instructors improve the quality of their teaching, as such evaluations provide insight into the strengths and weaknesses of their teaching practices that are based on their students' opinions. For this reason, many instructors welcome the results of student evaluations to improve their subsequent teaching. Many studies in the field of education have employed student evaluations to examine instructor and lecture efficacy, generally finding that student, course, and instructor characteristics significantly affected evaluation score [10,12–14]. In fact, these studies have observed a significant effect between student attitudes toward teaching evaluations of teaching and the success of a teaching evaluation system. For example, many studies have tried to examine the effects of faculty characteristics, such as age, gender, and position [15–17], while others have focused on the effects of course characteristics, such as course type or class size [12,15,18]. As for student characteristics, some studies have indicated that the relationship between a student's grade and his or her evaluation is a reflection of either teaching effectiveness or student learning [7,19].

Nonetheless, while many previous studies have analyzed the correlations between student evaluations and such variables as individual courses, students, and instructors [4,15,18,20–22], most do not focus on a particular field. As the factors affecting student evaluations vary across academic fields, it is important to conduct analyses in ways that suit the characteristics of each academic major. In particular, there is almost a complete lack of research drawing on data derived from the educational environment in the sciences.

Our research, therefore, looks at how such factors such as teacher experience, class size, and type of course delivery influence students' satisfaction levels in theory and laboratory classes in basic science and mathematics. We highlight how the interaction between instructor characteristics and educational environment, such as class size, course type, and mode of course delivery, influence student evaluations in the instructor–student–educational environment. Considering the characteristics of laboratory courses especially, instructor–student interaction is most effective when part of an active learning environment that requires students to stand, move, or manipulate items rather than simply to sit through a traditional lecture, discussion, reading, or chalk-board presentation [23]. In this respect, although some studies examining student evaluations expected the quality of the education environment to increase with an increase in teaching experience since more time in the classroom should increase the quality of one's teaching [24,25], we have found that the interaction between instructor characteristics and educational environment are more important in laboratory courses than in other offline courses, even including theory classes.

In addition, while previous studies examined the determinants of student evaluations in a general field, this study targets basic science and mathematics courses. Basic science and mathematics courses are cornerstone courses offered by physics, chemistry, biological sciences, and mathematics departments that provide the fundamental background for pursuing a major in the sciences in addition to higher-level courses in mathematics; because these courses make up a unique foundation essential to future study, it is important that we understand the factors that contribute to a successful learning environment in these specific fields. In Korea, universities have difficulty implementing mathematics courses for liberal arts subjects given the serious disparities in educational attainment among new students; this is associated with university admission procedures, as each university applies different criteria for early acceptance; cross-applications are allowed and special favor is given to socially-favored students or to those from rural areas and vocational high schools [26,27]. Furthermore, despite the importance of hierarchy in mathematics, most students majoring in engineering subjects find the subject difficult because their prerequisite knowledge in mathematics is insufficient [28]. Therefore, basic science and mathematics courses provide the most fundamental and essential knowledge for preparing students to pursue departmental major courses in the natural sciences and engineering, and the need for student evaluations in science education has been a topic of much research [29–31].

Still, most of these studies were concerned with employing student evaluations as a proxy variable for faculty instructional techniques in order to analyze their effects on student achievement [31], while others used questionnaires designed to conduct comparative analyses across certain courses [32]. For example, Liu, Tan, and Chu [33] looked at the relationship between student learning and environments that are supported by mobile, embedded computer, and wireless networks with the educational resources that were available to promote learning in the natural sciences. This research was based on data obtained by a questionnaire administered to 72 fifth-grade students and four natural-science teachers. Tan, Lin, and Chu [34] also analyzed 218 responses provided by students in an open-question survey and interviews as well as through transcripts from researcher observations and student discussions to determine the effect on students' performance in natural science courses from factors such as the pedagogical strategies used and the educational environment. The previous studies reported that field trips and positive feedback led to improved student learning. Although these studies were limited in their analyses because they used only a small-scale observational design using questionnaires, they are valuable in a context where natural science education data is lacking.

The reason we have focused on science education is that the field includes laboratory classes conducted alongside theory classes. A substantial number of recent studies have emphasized the advantages of active learning [35,36]. Active learning stems from any class activity that "involves students in doing things and thinking about the things they are doing" [37]. In short, the core elements of active learning involve student activity and engagement in the learning process. Active learning is often contrasted with the traditional lecture, where students passively receive information from an instructor; in general, laboratory activities are considered "active" [38]. For example, Freeman et al. [36] asserted that active learning in laboratories maximized student learning and course performance when comparing students' theory and practical performance in undergraduate science, technology, engineering, and mathematics (STEM) courses. Despite this, previous studies have not sufficiently identified the factors affecting laboratory or experiment classes (as opposed to lectures in general), which has motivated some educators and researchers to ask how to improve student satisfaction with laboratory or experiment classes. In many cases, there are studies describing laboratory work for the natural sciences that involve providing cookbook-style recipe experiments for instructors or students [39–43]. According to these studies, even in laboratory classes, students only rarely experience freedom in their thinking or in the latitude given to them for their approaches to solving a given problem. This kind of restriction of hands-on work has been evident in the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) studies conducted since 1997 [39].

As a result, despite the potential for science education laboratory classes to serve as an effective means of improving student achievement, existing studies have focused primarily on experimental methods, including the instructor's role in stimulating students with questions to resolve a specific problem and providing feedback to students. While the effects of experimental methods on student achievement in science courses continue to be debated, albeit only at the theoretical level, this study used empirical analysis to examine which effects are significant. Most studies have failed to review classroom learning environments as well as the variables identifying teacher–student interaction. We, however, have focused in particular on how factors such as instructors' capacity for communication and class types that are more conducive to feedback among other factors, affect satisfaction with each type of class. Although our analysis focuses on basic science and mathematics courses, our findings may present possible directions not only in science education but also in general education.

This paper is divided into six main parts. The next section presents the theoretical framework regarding teacher–student interaction in student evaluations of teaching. The third section outlines the models and associated hypotheses for the analyses of student characteristics and student evaluations, while the results are examined in the fourth section. A discussion follows in the fifth section, and the paper ends with some brief concluding remarks in section six.

2. Theoretical Framework

Previous research on student evaluations has tended to focus on the cultural and statistical validity of student surveys, the process of evaluation, and the subsequent changes implemented by faculty [44]. There is a scarcity of studies examining the effects of the immediate reaction by faculty. Over the last two decades, there has been a shift in the way teachers and researchers have written about student learning in higher education. Instead of characterizing it as a simple acquisition process based on teacher transmission, learning is now more commonly conceptualized as a process whereby students interact with subject content, transforming and discussing it with instructors and others [45–47]. Educational researchers have emphasized the importance of teaching methods and techniques by exploring the impact of learning differences on students' responses to learning [48,49]. The literature on human resource studies has recognized not only the general need to design and implement feedback systems, but also the specific need to understand and empirically analyze the importance of feedback reactions [50,51]. In science education, specifically laboratory/experiment classes, students' reactions to feedback, and other factors in the educational environment may play a key role in helping students attain higher achievement and in informing instructors' efforts to improve their teaching. Ambrose et al. [52] recommended the use of adequate and effective feedback to improve students' positive expectations of their classes. Therefore, we reviewed previous studies related to the learning environment and supported by feedback in order to develop our three-factor theoretical model, which includes class size, mode of course delivery, and teacher experience as sub-sections of student evaluations. Figure 1 illustrates three instructional forms designed to promote students' active participation and instructors' feedback. In effect, the feedback and communication responses have to be interpreted, constructed, and internalized by the student when he or she responds and details his or her satisfaction [53].

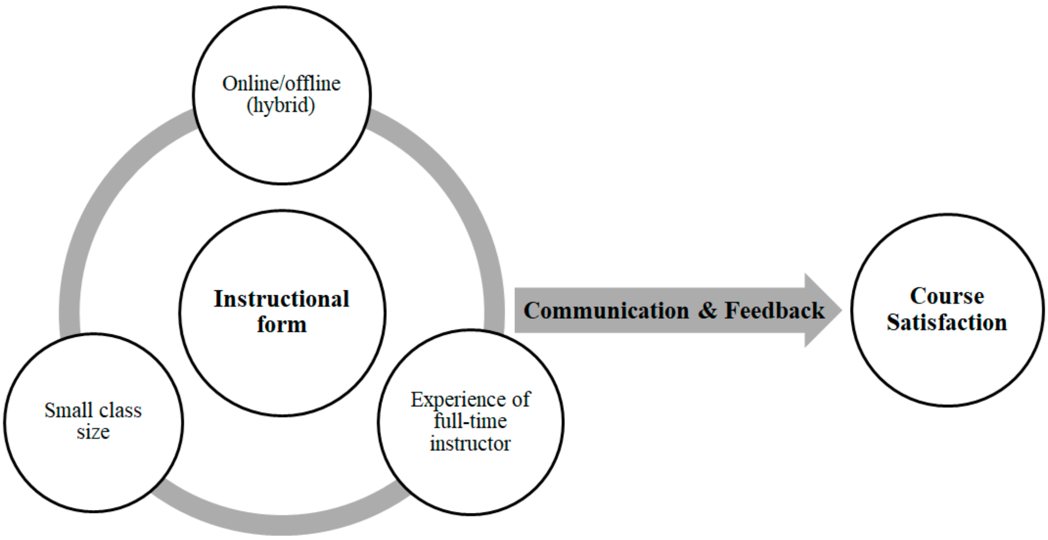

Figure 1. Theoretical framework for the impact of instructional form on course satisfaction.

2.1. Class Size Effect

A student may gain access to high-quality learning opportunities through attending classes of varying sizes, depending on the topic of the course. The class size effect is specific to certain dimensions of effective teaching, namely group interaction and communication among instructors and students [12,54]. This indicates that class size has a significant impact on the effectiveness of teachers' classroom teaching and students' performance. Depending on class size, theory or laboratory classes aim to generate useful insight into how, in large and small classes, learning for a range of different purposes can best be promoted. For instance, in large classes, efficient use of teaching assistants and visual aids will maximize teaching [55,56]. However, Carbone and Greenberg [57] found that large class size reduces the frequency and quality of instructor interaction with and feedback to students. As class size increases, teachers tend to lose the ability to consider the diverse characteristics of students, and instructor–student interaction is reduced markedly. Conversely, smaller class sizes allow for more immediate feedback compared to larger class sizes. As demonstrated by Light [58], a relationship between students' active involvement in higher education in general and their enrollment in small-sized classes is suggested, because active involvement in college education is strongly correlated with instructor–student interactions [59,60]. In addition, the effect of small classes on progress in mathematics is that students are stronger at all ability levels [55]. This suggests that smaller class sizes may be better suited for mathematics-based, natural science, and engineering courses, and, in particular, for courses with laboratory/experiment classes, where instructor–student discussions or group interactions play an important role.

2.2. Mode of Course Delivery Effect

Another factor in the educational environment that may facilitate interactions and feedback is class type. Students tend to prefer face-to-face classes to online courses—the reason for this may be the latter's lack of personal contact between students and teachers [61,62]. However, the online courses examined in these studies featured no materials uploaded to the online platform and no activities such as instructor–student communications. Estelami [63] proposed that hybrid-online courses (a combination of online and traditional classroom teaching) have the potential to positively affect course satisfaction because such hybrids could allow for the efficacious use of course content, student–teacher communication, and effective learning tools. In modern STEM courses, the use of science education videos, an online resource, significantly improved student learning and reinforced conceptual understanding for important foundational concepts, and these results hold even for students who did not feel positively toward the videos [64]. Therefore, the online platforms in the hybrid online/offline basic science and mathematics courses considered in this study play a supplemental role in the support of offline classes; they serve as a repository for course materials covered in class—thus allowing for preparation and review—while also facilitating feedback on instruction and homework. The use of hybrid online/offline basic science and mathematics courses may influence the communication and feedback aspects of course satisfaction.

2.3. Instructor Experience Effect

Instructors play an important role in determining course satisfaction as they participate in interactions with students and convey feedback. In natural sciences courses, especially laboratory-based learning, the expertise and practical knowledge of experienced instructors play an important role [65–67]. For example, the role of experienced science instructors is focused on promoting students' understanding and interest in laboratory work on the basis of their accumulated knowledge and expertise, which is different from the role of science instructors with little or no experience [67]. Pintrich [66] also suggested the need for instructors' professional and experience-based feedback to improve student participation in classes and to help students create effective learning experiences, both of which are necessary for students to learn to tackle complex problems. According to Litzinger et al. [65], instructors are required to have enough experience to help students identify and effectively use the knowledge and skills required for practical work. Centra [68] has examined student instructional ratings across multiple fields of study, including a group of natural sciences courses from 2- and 4-year colleges, and found that courses in the natural sciences tend to receive lower course and instructor ratings than courses in other disciplines. Many science instructors believe that when students perceive a course to have a high workload, they will rate the course and the performance of the course instructor poorly [16,69–71]. Moreover, any concern over low student satisfaction with teaching in science courses is associated with the belief that students are required to demonstrate their creativity in these subject areas [71]. Whether instructors agree with this practice or not, the instructors in the sciences faculty focus their teaching methods on maintaining teacher–student interaction in accordance with the characteristics of related courses and with the aim of improving student satisfaction [70].

Therefore, in consideration of the education characteristics in science departments, the empirical analysis of science courses must be conducted separately from that of other majors. Courses in science departments must strike a balance between the theoretical backgrounds imparted in the classroom and the practical work and investigative methods of learning that are imparted through hands-on laboratory classes. Thus, instructors teach both practical work and investigative methods of learning [72]. As laboratory-based classes allow for the immediate evaluation of students' degree of learning, facilitate instructor–student interaction, and rely more heavily on feedback, instructors with more experience may be more effective in such settings [73]. Accruing such experience requires a significant investment of time, and the resulting expertise and experience are characteristic of tenure-track faculty, particularly senior faculty. Compared to part-time instructors, full-time instructors who are more directly affected by lecture evaluation scores (particularly for promotion and tenure decisions) have a relatively stronger sense of responsibility regarding their lectures and are more enthusiastic about communicating with students [7,17,24,25].

3. Student Evaluation Data and Empirical Models

As noted, the data for student evaluations used for this study included all basic science and mathematics courses offered at a university in South Korea, from spring 2012 to fall 2015. The College of Science comprises the departments of physics, mathematics, biological sciences, and chemistry, with each department offering theory classes for exploring the theoretical aspects of each academic major and laboratory/experiment classes wherein students test and familiarize themselves with the materials covered. From 2012 to 2015, there were 51,399 students enrolled in theory classes in the basic sciences and mathematics courses offered by the College of Science, whereas the number of students who took laboratory classes was 12,132.

We applied the ordinary least squares (OLS) model to the refined data of basic science courses. OLS estimates are effective unless parameters such as instructor experience, class size, and online delivery are fully correlated. Satisfaction in the questionnaire usually shows a rational choice; however, the gap between the standard size and choice is hardly significant economically. A study by Blanchflower and Oswald [74] reports that estimates based on the ordinary methods and OLS, do not produce significant differences in the results. When testing for variance inflation factors, OLS is the appropriate estimation technique. In the existing literature dealing with the determinants of student evaluations, OLS is used to examine the relationship between instructor, student, and class characteristics as well as student satisfaction [4,8,75–78]. The objective was to estimate the impact of instructor–student instruction variables on student satisfaction with the course. Let

$$Satis_i = \alpha_i + \beta_i \log(C_i) + \gamma_i D_i + \delta_{is} \sum_{s=1}^{n} X_{is} + \tau_{ik} \sum_{k=1}^{m} p_{ik} + \varepsilon_i, \quad (1)$$

where $Satis_i$, the dependent variable, represents the satisfaction scores of student evaluation; $\log(C_i)$ is the natural log of class size; D_i is dummy variable indicating whether the course was a hybrid course; X_{is} is the vector of instructor characteristics such as tenure and rank; and P_{ik} is the vector of student characteristics such as age, gender, and grade-affecting satisfaction, the year and semester that each course was offered, and major; and ε_i is the residual error term. The key variables identifying instructor–student interaction are class size, whether or not the course is hybrid, and instructor characteristics.

Summary statistics for all the variables are reported in Table 1. The summary statistics demonstrated that theory and laboratory classes have differences in course and faculty characteristics.

Table 1. Summary Statistics of Student Evaluations of Teaching.

	Theory Class		Laboratory Class (Experiment Practice)	
Satisfaction scores	3.94	(0.94)	3.92	(0.97)
Instructor's tenure	7.11	(7.34)	12.50	(8.23)
Professor	0.26	(0.44)	0.59	(0.49)
Associate	0.13	(0.34)	0.26	(0.44)
Assistant	0.15	(0.36)	0.13	(0.34)
Lecturer	0.46	(0.50)	0.02	(0.13)
Class size	79.04	(26.93)	27.96	(5.81)
Hybrid course	0.65	(0.48)	0.50	(0.42)
Students' age	20.28	(2.04)	19.99	(1.87)
Female student	0.20	(0.40)	0.20	(0.40)
Grade in the current course	3.02	(1.22)	3.58	(0.91)
Expected grade	3.29	(0.83)	3.45	(0.74)
Sample size	51,399		12,132	

Standard deviations are in parentheses.

3.1. Dependent Variable

The student evaluations were anonymously conducted online at the end of classes before students had been informed of their test results, and only the evaluation results were available to instructors. Approximately 91.3% of the students participated in the evaluations, possibly due to the caveat that they could apply an objection during a specific period of time, if desired, after checking their grades. In this study, student evaluations were measured based on the answers to the item "I have obtained lots of knowledge and practical experience." The measures of the satisfaction evaluation were coded into five different levels: (1) poor, (2) fair, (3) good, (4) very good, and (5) excellent. The average satisfaction score for theory classes (3.94) was higher than for laboratory classes (3.92). Likewise, differences were observed in class size, class type, and faculty characteristics between theory and laboratory classes.

3.2. Independent Variables

Following the literature, the determinants of student evaluations are likely to fall into several categories [4,8,25,75–78]. The first are instructor characteristics, such as tenure and rank. Looking at these characteristics, the average years of tenure for instructors of theory classes was 7.1. Full-time instructors comprised full professors (26%), associate professors (13%), and assistant professors (15%), whereas part-time instructors (lecturers) accounted for a large percentage (46%) of instructors. The average number of years of tenure for laboratory class instructors was 12.5, with full professors accounting for the majority (59%) of instructors.

Course characteristics make up the second group of determinants of student evaluations. We included the natural log of class size and dummy variables indicating whether the course was a hybrid course and/or a course in the student's major. The average class size was 79 in theory classes and 28 in laboratory classes. "Hybrid course" refers to a course with a mix of online and offline classes, with core lectures and discussions taking place in offline classes and the online platform functioning as a repository of materials covered in class to aid with preparation and review, and as a channel for real-time Q&A interactions. Hybrid courses accounted for 65% of the theory classes and 50% of the laboratory classes.

Student characteristics, such as age, gender, and grade, make up the third group of determinants of students. Here, we included dummy variables representing the year and semester that each course was offered in order to control for changes in student composition and preferences over time. Looking at student characteristics, 20% of students in the total enrolment for both types of classes were female. The average age of the students was 20, indicating that the majority of students taking basic science and mathematics courses were younger students, mostly in their freshman year. The final and expected grades were measured using a 4.5-grade-point scale, with expected grades being obtained via the student evaluation questionnaires.

Figure 2 depicts the distribution of student satisfaction for theory and laboratory classes as recorded in the student evaluations dataset used in this study. The score for student satisfaction indicates a mean value of the evaluation results with respect to an individual's class organization (whether classes are provided as planned), course content, evaluation of assignments and tests, instructor's passion and sincerity, amount and quality of feedback, level of acquired knowledge, and so forth. Compared to scores for theory classes, those for laboratory classes appears to be evenly distributed at three, four, and five levels. This implies that, even for the same laboratory course, there is a very wide range of factors that may affect course evaluation scores, such as instructional method, faculty characteristics, and student characteristics. Therefore, in this study, it was important to identify the faculty, student, and course characteristics that affect course satisfaction through an empirical analysis of university lectures in science education and through a comparative analysis of theory and laboratory classes. In particular, we examined how the effect of teaching styles that facilitate instructors' communication and feedback differs between the two teaching modes of theory and laboratory. Teaching-evaluation systems are intended to provide an opportunity to improve teaching quality by promoting communication between students and instructors. As feedback items were added after 2012, it became possible to evaluate whether any means of communicating with students were always open for instructors.

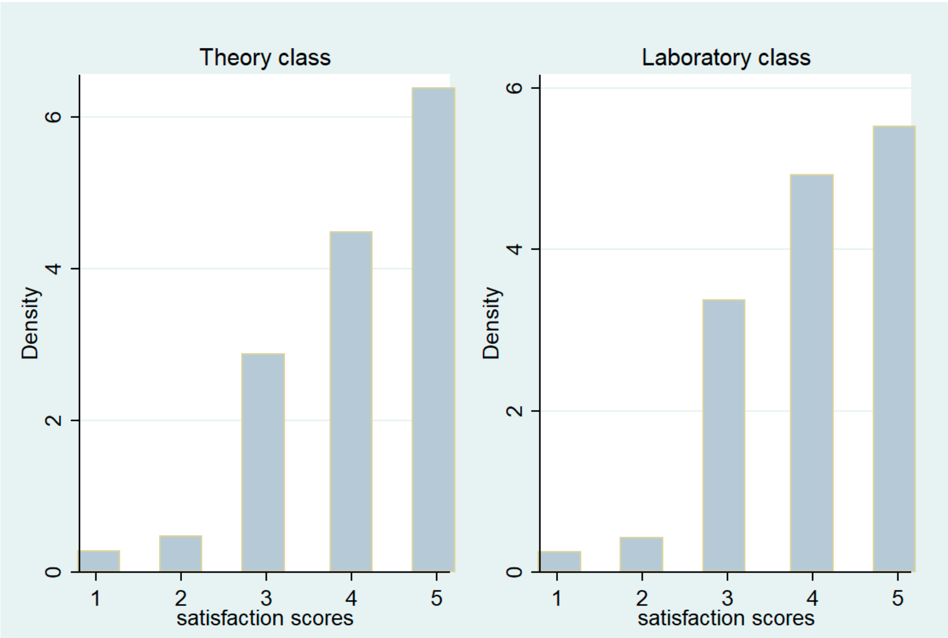

Figure 2. The Distribution of Student Evaluations of for Theory and Laboratory Classes.

4. Main Results

Table 2 reports the estimated effects of feedback-related factors on course satisfaction in basic science and mathematics courses offered by the College of Science. Model 1 displays the results for all basic science and mathematics courses. This model was designed to identify the effects exerted by characteristic variables in fundamental courses that combine both science education theory and practice on student satisfaction with teaching and to examine the influence of feedback-related factors in a concentrated manner. The analysis results indicated that, in comparison to satisfaction in theory classes, satisfaction in laboratory classes was estimated to decrease by approximately 0.16. Furthermore, the effect of the interaction term differed from the effect of a simple dummy variable such as tenure, class size, and mode of course delivery. For example, the classes that had more experienced laboratory instructors resulted in more highly-satisfied students. The smaller the size of the laboratory classes, the more effective the satisfaction. Also, when laboratory classes were supplemented by an online platform, student satisfaction was higher.

Model 3 and Model 4 of Table 3 describe the results of analyzing theory classes and laboratory classes separately for the effects of feedback factors including faculty, student, and course characteristics on course satisfaction.

Table 2. The Impact of Feedback on Student Evaluations of Teaching.

	All	**All**
	(1)	**(2)**
Laboratory class	−0.078 ***	−0.159 ***
	(0.017)	(0.018)
Tenure (in years)	−0.004 ***	−0.005 ***
	(0.001)	(0.001)
Instructors' rank		
Professor	0.098 ***	0.106 ***
	(0.016)	(0.016)
Associate	0.132 ***	0.141 ***
	(0.012)	(0.012)
Assistant	0.180 ***	0.185 ***
	(0.011)	(0.011)
Log of class size	−0.045 ***	−0.047 ***
	(0.013)	(0.015)
Hybrid course	0.068 ***	0.063 ***
	(0.011)	(0.011)
Lab X Tenure		0.004 ***
		(0.001)
Lab X Log(size)		−0.008 ***
		(0.003)
Lab X Hybrid		0.259 ***
		(0.015)
Students' age	0.037 ***	0.037 ***
	(0.002)	(0.002)
Female student	−0.096 ***	−0.096 ***
	(0.009)	(0.009)
Grade in the current course	−0.005	−0.005
	(0.004)	(0.004)
Expected grade	0.421 ***	0.421 ***
	(0.005)	(0.005)
Department		
Biological Sciences	0.062 ***	0.060 ***
	(0.014)	(0.014)
Mathematics	0.052 ***	0.052 ***
	(0.011)	(0.011)
Chemistry	0.071 ***	0.074 ***
	(0.013)	(0.013)
Year	Yes	Yes
Constant	1.820 ***	1.842 ***
	(0.073)	(0.081)
Observations	63,531	63,531
R-squared	0.145	0.145

Standard errors in parentheses; The reference group for the instructors' rank consists of lecturers; The reference group for the department of science is physics. *** $p < 0.01$.

Table 3. The Impact of Feedback on Student Evaluations of Teaching by Class Type.

	Theory	**Laboratory**
	(3)	**(4)**
Tenure (in years)	−0.003 **	0.004 ***
	(0.002)	(0.001)

Table 3. *Cont.*

	Theory	Laboratory
	(3)	(4)
Instructors' rank		
Professor	0.066	0.083 ***
	(0.070)	(0.019)
Associate	0.030	0.148 ***
	(0.068)	(0.013)
Assistant	0.040	0.200 ***
	(0.071)	(0.012)
Log of class size	−0.003	−0.083 ***
	(0.018)	(0.031)
Hybrid course	0.269	0.062 ***
	(0.511)	(0.012)
Student's age	0.038 ***	0.035 ***
	(0.002)	(0.005)
Female student	−0.089 ***	−0.121 ***
	(0.010)	(0.021)
Grade in the current course	−0.002	−0.020 *
	(0.004)	(0.011)
Expected grade	0.421 ***	0.422 ***
	(0.006)	(0.013)
Department		
Biological Sciences	0.002	0.215 ***
	(0.017)	(0.028)
Mathematics	0.010	0.181 ***
	(0.013)	(0.064)
Chemistry	0.002	0.147 ***
	(0.019)	(0.019)
Year	Yes	Yes
Constant	1.643 ***	2.021 ***
	(0.094)	(0.153)
Observations	51,399	12,132
R-squared	0.151	0.128

Standard errors in parentheses; The reference group for the instructors' rank consists of lecturers; The reference group for the department of science is physics. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.1. Class Size

Higher levels of log class size negatively affected course satisfaction in Model 1. According to the results of separate analyses of theory and laboratory classes, while class size had no statistically significant effect on satisfaction in the case of theory classes, smaller classes were found to be more effective in the case of laboratory classes. Specifically, it was estimated that average satisfaction decreased by 0.083/100 when the number of students in the laboratory class increased by 1%. It is hardly surprising that smaller class sizes are more conducive to livelier exchanges of feedback. In smaller classes, students can expect to be satisfied with the feedback they receive.

4.2. Mode of Course Delivery

E-learning—a form of education supplemented by online/offline platforms—was found to be efficacious in Model 1. In Table 3, while the availability of hybrid online/offline courses had no effect in the case of theory classes, laboratory classes via hybrid platforms were associated with satisfaction scores approximately 0.06 higher than those of offline-only courses. These results suggest that, unlike theory classes, where instructors generally convey the course material to students in a one-sided manner, laboratory-based classes consist primarily of student participation, thus underlining the importance of an educational environment that encourages instructor–student communication. Students may be able to gain higher course satisfaction by using online platforms for preparation/review purposes in addition to Q&A activities.

4.3. Instructor Experience

Looking at the faculty characteristics associated with feedback factors in Model 1, years of tenure had a negative effect on student evaluations while courses taught by full-time instructors rank were found to be associated with higher student satisfaction compared to those taught by part-time lecturers.

In Model 3 and Model 4, the results indicated that instructors with longer tenure tended to negatively affect course satisfaction in the case of theory classes, while the distinction between full-time instructors and part-time lecturers had no statistically significant effect on satisfaction. Instructors with longer tenure were associated with higher course satisfaction scores in the case of laboratory classes, while full professors, associate professors, and assistant professors scored 0.08, 0.15, and 0.20 higher, respectively, compared to part-time lecturers. These results suggested that theory classes in science education exhibit similarities to the evaluation of general lectures, in that professors with longer years of tenure may prioritize research over teaching, in addition to the tendency for the faculty with longer teaching experience to overlook updating the course material (faculty who had familiarized themselves with the course tended to use existing handouts, assignments, or presentations). For example, Spencer and Flyr [79] found that only 23% of faculty reported making changes to their teaching based on student evaluation results. In contrast, in the case of laboratory-based classes, we found that faculty experience and rank played important roles in students' course satisfaction. As stated earlier, effective laboratory classes require instructors to strike a balance between practical work and investigative methods of learning through their teaching. Furthermore, faculty experience and sense of responsibility play important roles in ensuring that feedback is exchanged promptly.

4.4. Interaction Effects of Class Type and Feedback-Related Factors

The analysis results of Model 1 revealed significant effects of feedback-related factors on basic science and mathematics courses. However, those effects varied depending on the class type, as suggested in the theoretical framework and by previous studies. Therefore, by including the interaction terms among laboratory classes and tenure, the log of class size, and the hybrid course dummy, Model 2 examined the interaction effects between laboratory activities and feedback-related factors on course satisfaction. By integrating these interaction terms into the model, we could identify the feedback effects corresponding to each type of theoretical and practical basic science and mathematics class. The analysis results suggested that, while longer tenure negatively affected course satisfaction in theory classes, the opposite effect held true in the case of lab classes compared to theory classes. Contrary to the findings of earlier studies, where more senior members of the faculty tended to become negligent in their teaching duties due to their research commitments [24,25], our results suggested that instructors' experience plays a crucial role in teaching laboratory-based classes, as more time in the classroom increases teaching quality. Furthermore, smaller class sizes and hybrid course availability were found to be more efficacious for improving satisfaction in the case of laboratory classes compared to theory classes. As factors such as faculty experience, class size, and hybrid course type informed the feedback-related educational environment, the significant interaction effects indicated that these feedback factors were functioning effectively in laboratory-based classes.

4.5. Other Determinants

Although there is a lack of agreement among previous studies regarding the effects of student characteristics such as age and sex [19,80,81] on student satisfaction with a course, in the case of basic science and mathematics courses offered by the College of Science, older-age students were associated with higher satisfaction, and female students tended to have lower course satisfaction compared to males. The received grade was found to have no effect on satisfaction, whereas higher expected grades were associated with higher satisfaction.

4.6. Feedback Effects by Subjects

Table 4 reports the estimation results for each department. Among the four departments, the feedback effect is relatively more pronounced in the case of physics. While the year of tenure of physics instructors had no effect on course satisfaction, full-time instructors were found to be more effective than part-time lecturers. Furthermore, smaller class sizes and hybrid course availability were associated with higher satisfaction when compared to offline-only courses. In the case of the biological sciences, mathematics, and chemistry departments, instructor experience was found to play an important role in determining satisfaction. Associate professors only received higher scores among full-time instructors compared to part-time lecturers in the departments of biological sciences and chemistry. The estimated coefficients for class size were found to be negative, albeit not statistically significant, in the biological sciences and mathematics departments. Hybrid course availability was found to have a significantly positive effect in all four departments. These findings may be summarized as follows: While laboratory courses may affect course satisfaction negatively or positively in the case of the basic science and mathematics courses offered by the four departments considered here, feedback-related factors such as faculty experience, smaller class sizes, and hybrid online/offline courses were positively associated with higher student satisfaction. Meanwhile, the estimation results for each department suggested that, even among basic science and mathematics courses, different factors affected course satisfaction depending on the specific department or major. These findings imply that each department should improve the contents of the basic science and mathematics courses offered. In particular, considering the substantial role that feedback plays in determining satisfaction in physics courses, it may represent a means of alleviating students' aversion to studying physics and of encouraging students to pursue science and engineering after graduation.

Table 4. The Impact of Feedback on Student Evaluations of Teaching by Department.

	Physics	Biological Sciences	Mathematics	Chemistry
	(5)	**(6)**	**(7)**	**(8)**
Laboratory class	−0.228 ***	0.101 **	0.121 *	−0.095 *
	(0.031)	(0.050)	(0.069)	(0.054)
Tenure (in years)	−0.002	0.011 ***	0.012 ***	0.006 ***
	(0.002)	(0.002)	(0.001)	(0.002)
Instructors' rank				
Professor	0.171 ***	−0.011	0.255 ***	0.016
	(0.050)	(0.042)	(0.026)	(0.037)
Associate	0.175 ***	0.136 ***	0.133 ***	0.069 ***
	(0.042)	(0.036)	(0.020)	(0.022)
Assistant	0.251 ***	0.101	0.240 ***	−0.014
	(0.041)	(0.074)	(0.015)	(0.027)
Log of class size	−0.117 ***	−0.111	−0.036	−0.072 **
	(0.031)	(0.076)	(0.023)	(0.034)
Hybrid course	0.137 ***	0.037 ***	0.061 ***	0.073 ***
	(0.039)	(0.032)	(0.015)	(0.012)
Student's age	0.043 ***	0.037 ***	0.036 ***	0.036 ***
	(0.005)	(0.005)	(0.003)	(0.004)
Female student	−0.099 ***	−0.086 ***	−0.093 ***	−0.096 ***
	(0.021)	(0.022)	(0.015)	(0.017)
Grade in the current course	−0.013	−0.049 ***	0.010 *	−0.016 *
	(0.009)	(0.014)	(0.006)	(0.009)
Expected grade	0.449 ***	0.428 ***	0.406 ***	0.414 ***
	(0.011)	(0.017)	(0.008)	(0.011)
Year	Yes	Yes	Yes	Yes
Constant	1.883 ***	1.344 ***	1.516 ***	2.246 ***
	(0.172)	(0.340)	(0.124)	(0.204)
Observations	14,729	7,445	25,875	15,482
R-squared	0.157	0.126	0.157	0.126

Standard errors in parentheses; The reference group for the instructors' rank consists of lecturers. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. Discussion

The coexistence of theory classes and laboratory practice is a central feature of science education and rarely occurs in other major fields of study. Abundant benefits stemming from learning activities in science fields come from laboratory/experiments. Accordingly, research has been conducted thus far on the use of resources, tools, teaching methods, and so on, to improve the satisfaction and academic achievement of students in science education [52]. A number of studies have reported that, for instructor–student interaction in science courses, classroom atmosphere and teaching delivery methods can impact the learning environment's effectiveness at promoting academic achievement or inducing positive satisfaction in courses [45,82]. Laboratory practices provide students and instructors with the opportunity to participate in and carry out collaborative work together. This experience allows students to solve problems and enhance their understanding [42]. This is one of the most significant learning outcomes in introductory or basic science courses.

Although there are pros and cons associated with the various experimental methods as an effective means of improving student achievement in science courses, existing studies suggest that experiment methods include the instructor's role in stimulating students with questions to resolve specific problems and in providing feedback to students [39–43,83,84]. However, it is very difficult to grasp the interactions occurring in classrooms through the natural experimental environment, and most previous studies have focused on the development and verification of teaching methodologies [35,36,83,84]. Therefore, the present study conducted an empirical analysis of the relationship between class environment and students' reactions to examine how the learning environment (as it relates to interaction in both theory and laboratory basic science courses in college) influences students' satisfaction with those classes. There are many factors related to interaction in the classroom, and, in the present study, we focused on class size, teaching delivery, and instructor characteristics, all of which were presented as feedback factors in previous research [12,54,61,62,65–67]. According to the results of our analysis, we found that, among the basic science subjects and particularly in laboratory-based classes, three things had a positive influence on student satisfaction: small class size, the hybrid course form, and teaching by full-time instructors who were highly experienced or had a strong sense of responsibility. Therefore, the following should be considered for formative feedback to improve student learning and to create an effective learning environment.

First, laboratory practice subjects can provide high-quality learning opportunities in a small class environment. Although it is well known that teaching becomes more effective and student satisfaction increases as the size of the class reduces [12,54], lecture size has no influence on students' satisfaction in sciences theory classes, unlike in laboratory practices; students' interaction with instructors is of great importance in the laboratory environment, where students participate directly in the practice subjects and where immediate feedback should be provided regarding any incorrect procedures or areas that need improvement. Even when large-sized lectures are implemented, having a tutor or making effective use of tools such as video may help allow students to receive appropriate feedback [85].

Second, online and offline parallel classes are one teaching method that can compensate for limited instructor feedback. One reason is that the online portion of the class enables students to become familiar with the class content and laboratory experiment processes before the class and thus to prepare for active participation by understanding the main steps that will be required in an experiment. Moreover, it is important to ensure that appropriate feedback is provided for various constraints and difficult tasks in laboratory practice subjects, and the online platform may be productive as an auxiliary means, as opinions can be quickly provided through online bulletin boards, e-mails, intranet websites, and so on.

Third, assigning full-time professors with a lot of teaching and research experience is necessary for laboratory-based classes. The experience and research studies gained during the teachers' period of service better positions full-time professors to grasp the extent of students' learning immediately and improve teacher–student communication. Furthermore, continuous research activities are very important to enable teachers to apply new information, changing trends, and creativity in their laboratory practices. The tendency to keep up-to-date and professionally curious is common in full-time professors, and, as the lecture satisfaction scores are related to the personnel-related issues of full-time professors, this professional vigor can encourage active communication and thus boost student satisfaction [7,17,24,25].

6. Conclusions

The objective of science education is to impart theoretical knowledge to students and to instill in them a scientific mode of exploration and spirit of inquiry through various experiments and hands-on learning. Since laboratory classes seldom play a part in the more theory-centered courses of the humanities, laboratory work may be seen to be a nearly unique feature of science education. Despite this, almost no previous studies have empirically analyzed the factors that determine course satisfaction in science education—in particular, the effects of student feedback in theory and laboratory classes. In this study, we used student evaluations data from the basic science and mathematics courses offered at a competitive university in South Korea from 2012 to 2015 to comparatively analyze how faculty, student, and course characteristics influenced students' satisfaction with theory and laboratory classes. In particular, we focused on factors that facilitated instructor–student communication and feedback such as class size, instructional form, instructor experience, and instructors' sense of responsibility to examine how they affected students' course satisfaction.

The analysis of the results demonstrated that although laboratory classes for basic science and mathematics courses in the College of Science had lower satisfaction scores compared to those for theory classes, feedback factors (instructors' rank, class size, and instructional form) that had no significant effect in theory classes played important roles in laboratory classes. There are several notable points.

First, smaller classes were found to be more effective in the case of laboratory classes, suggesting that, unlike theory classes where the material is conveyed in a one-sided manner by the instructor, laboratory classes rely more heavily on student participation, thus underlining the importance of an educational environment that facilitates bilateral teacher–student communication. Therefore, the educational environment of a large-sized class may be improved by subdividing it into smaller groups or designating teaching assistants for laboratory sessions to facilitate feedback.

Second, instructors with more experience were associated with higher student satisfaction, as were full-time instructors compared to part-time lecturers. Given the characteristics of science education, which involves the use of laboratory experiments based on a theoretical foundation, these results suggest that the highest-rated instructors are those who spend more time doing research, thus underlining the importance of expertise and experience. Empirical analysis results show the importance of having knowledgeable and experienced instructors, particularly in laboratory classes, as there is an inherent mechanism in the science laboratory educational environment by which the instructors' expertise and experience are delivered to students.

Third, we found that the availability of online platforms to supplement offline classes and provide an additional mechanism for the exchange of feedback regarding course materials and homework assignments played a substantial and positive role in the students' course evaluations. In the case of laboratory classes, instructor–student feedback is important for online platforms to be valid and effective. Instructors were able to assess students' proficiency immediately and were required to take part in instructor–student interactions and feedback sessions; therefore, it is important to make greater use of supplementary platforms for active learning, and not as a substitute for offline courses. A key benefit of online platforms is that they can be easily accessed, updated, and verified in real-time.

In this study, we analyzed the factors determining student satisfaction with courses offered by the College of Science. Our findings can inform future efforts to improve the quality of education by providing students with educational services that better suit their needs. The improvement of basic science and mathematics courses may be a means of highlighting the importance of education in physics and the other sciences in engineering, particularly because of their foundational role in cutting-edge technologies. Basic science and mathematics courses include an element essential to learning in other fields, including higher-level learning in engineering. In this study, we demonstrated the effect of instructor–student interaction on student course satisfaction as an output of macro-engineering laboratory and theory courses. Considering that feedback presents one of the simplest and most potent means of reinforcing academic achievement [86], this study is significant in that it included such feedback-related factors in its analysis. These results are linked to the demand for knowledge in STEM education, the student's educational performance, and the labor market performance needed to establish a sustainable system in engineering education. This study also generated implications regarding the facilitative role of instructors and the educational environment, depending on the characteristics of theory and laboratory-based classes.

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References

1. Kwan, K.P. How fair are student ratings in assessing the teaching performance of university teachers? *Assess. Eval. High. Educ.* **1999**, *24*, 181–195. [CrossRef]
2. Artz, B.; Welsch, D.M. The effect of student evaluations on academic success. *Education* **2013**, *8*, 100–119. [CrossRef]
3. Baek, W.; Cho, J. Challenging the sustainability of an education system of evaluation and labor market outcomes. *Sustainability* **2015**, *7*, 16060–16075. [CrossRef]
4. Cho, D.; Baek, W.; Cho, J. Why do good performing students highly rate their instructors? Evidence from a natural experiment. *Econ. Educ. Rev.* **2015**, *49*, 172–179. [CrossRef]
5. Cho, D.; Cho, J. Does more accurate knowledge of course grade impact teaching evaluation? *Educ. Financ. Policy* **2017**, *12*, 224–240. [CrossRef]
6. Lee, J.; Cho, J. Who teaches economics courses better? Using student–professor matched data for the principle of economics course. *Appl. Econ. Lett.* **2014**, *21*, 934–937. [CrossRef]
7. Spooren, P.; Brockx, B.; Mortelmans, D. On the validity of student evaluation of teaching: The state of the art. *Rev. Educ. Res.* **2013**, *83*, 598–642. [CrossRef]
8. Kember, D.; Leung, D.Y.; Kwan, K. Does the use of student feedback questionnaires improve the overall quality of teaching? *Assess. Eval. High. Educ.* **2002**, *27*, 411–425. [CrossRef]
9. Balam, E.M.; Shannon, D.M. Student ratings of college teaching: A comparison of faculty and their students. *Assess. Eval. High. Educ.* **2010**, *35*, 209–221. [CrossRef]
10. Griffin, B.W. Instructor reputation and student ratings of instruction. *Contemp. Educ. Psychol.* **2001**, *26*, 534–552. [CrossRef]
11. Kulik, J.A. Student ratings: Validity, utility, and controversy. *New Dir. Inst. Res.* **2001**, 9–25. [CrossRef]
12. Marsh, H.W. Students' evaluations of university teaching: Research findings, methodological issues, and directions for future research. *Int. J. Educ. Res.* **1987**, *11*, 253–388. [CrossRef]
13. Hofman, J.E.; Kremer, L. Attitudes toward higher education and course evaluation. *J. Educ. Psychol.* **1980**, *72*, 610–617. [CrossRef]
14. Douglas, P.D.; Carroll, S.R. Faculty evaluations: Are college students influenced by differential purposes. *Coll. Stud. J.* **1980**, *21*, 360–365.
15. Feldman, K.A. Identifying exemplary teachers and teaching: Evidence from student Ratings. In *The Scholarship of Teaching and Learning in Higher Education: An Evidence-Based Perspective*; Perry, R.P., Smart, J.C., Eds.; Springer: Dordrecht, The Netherlands, 2007; pp. 93–143.
16. Marsh, H.W. Distinguishing between good (useful) and bad workloads on students' evaluations of teaching. *Am. Educ. Res. J.* **2001**, *38*, 183–212. [CrossRef]
17. Ting, K. A multilevel perspective on student ratings of instruction: Lessons from the Chinese experience. *Res. High. Educ.* **2000**, *41*, 637–661. [CrossRef]

18. Bedard, K.; Kuhn, P. Where class size really matters: Class size and student ratings of instructor effectiveness. *Econ. Educ. Rev.* **2008**, *27*, 253–265. [CrossRef]
19. Arnold, I.J.M. Do examinations influence student evaluations? *Int. J. Educ. Res.* **2009**, *48*, 215–224. [CrossRef]
20. Brockx, B.; Spooren, P.; Mortelmans, D. Taking the grading leniency story to the edge. The influence of student, teacher, and course characteristics on student evaluations of teaching in higher education. *Educ. Assess. Eval. Account.* **2011**, *23*, 289–306. [CrossRef]
21. Marsh, H.W.; Roche, L.A. Effects of grading leniency and low workload on students' evaluations of teaching: Popular myth, bias, validity, or innocent bystanders? *J. Educ. Psychol.* **2000**, *92*, 202–228. [CrossRef]
22. Tom, G.; Swanson, S.; Abbott, C.; Cajocum, E. The effect of student perception of instructor evaluations on faculty evaluation scores. *Coll. Stud. J.* **1990**, *24*, 268–273.
23. McManus, D.O.C.; Dunn, R.; Denig, S.J. Effects of traditional lecture versus teacher-constructed & student-constructed self-teaching instructional resources on short-term science achievement & attitudes. *Am. Biol. Teach.* **2003**, *65*, 93–103.
24. McPherson, M.A.; Jewell, R.T. Leveling the playing field: Should student evaluation scores be adjusted? *Soc. Sci. Q.* **2007**, *88*, 868–881. [CrossRef]
25. McPherson, M.A.; Jewell, R.T.; Kim, M. What determines student evaluation scores? A random effects analysis of undergraduate economics classes. *East. Econ. J.* **2009**, *35*, 37–51. [CrossRef]
26. Jeong, S.; Kang, Y. Development and application of mathematics teaching-learning model considering learning styles of the students of engineering college. *Korean J. Commun. Math. Educ.* **2013**, *27*, 407–428. [CrossRef]
27. Park, J.S.; Pyo, Y.S. Improvement strategies of teaching methods for university basic mathematics education courses by ability grouping. *Korean J. Commun. Math. Educ.* **2013**, *27*, 19–37. [CrossRef]
28. Pyo, Y.S.; Park, J.S. Effective management strategies of basic mathematics for low achievement students in University General Mathematics. *Korean J. Commun. Math. Educ.* **2010**, *24*, 525–541.
29. Bickel, W.E. Effective schools: Knowledge, dissemination, inquiry. *Educ. Res.* **1983**, *12*, 3–5. [CrossRef]
30. Lasch, C. 'Excellence' in education: Old refrain or new departure? *Issues Educ.* **1985**, *3*, 1–12.
31. Tobin, K.; Fraser, B.J. What does it mean to be an exemplary science teacher? *J. Res. Sci. Teach.* **1990**, *27*, 3–25. [CrossRef]
32. Zoller, U. Faculty teaching performance evaluation in higher science education: Issues and implications (A "Cross-Cultural" case study). *Sci. Educ.* **1992**, *76*, 673–684. [CrossRef]
33. Liu, T.Y.; Tan, T.H.; Chu, Y.L. Outdoor natural science learning with an RFID-supported immersive ubiquitous learning environment. *Educ. Technol. Soc.* **2009**, *12*, 161–175.
34. Tan, T.H.; Lin, M.S.; Chu, Y.L.; Liu, T.Y. Educational affordances of a ubiquitous learning environment in a natural science course. *Educ. Technol. Soc.* **2012**, *15*, 206–219.
35. Braxton, J.M.; Milem, J.F.; Sullivan, A.S. The influence of active learning on the college student departure process: Toward a revision of Tinto's theory. *J. High. Educ.* **2000**, *71*, 569–590. [CrossRef]
36. Freeman, S.; Eddy, S.L.; McDonough, M.; Smith, M.K.; Okoroafor, N.; Jordt, H.; Wenderoth, M.P. Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 8410–8415. [CrossRef]
37. Bonwell, C.C.; Eison, J.A. *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports*; Associations for the Study of Higher Education: Washington, DC, USA, 1991.
38. Prince, M. Does active learning work? A review of the research. *J. Eng. Educ.* **2004**, *93*, 223–231. [CrossRef]
39. Di Fuccia, D.; Witteck, T.; Markic, S.; Eilks, I. Trends in practical work in German science education. *Eurasia J. Math. Sci. Technol. Educ.* **2012**, *8*, 59–72.
40. Eilks, I.; Byers, B. The need for innovative methods of teaching and learning chemistry in higher education—Reflections from a project of the European Chemistry Thematic Network. *Chem. Educ. Res. Pract.* **2010**, *11*, 233–240. [CrossRef]
41. Hofstein, A. The laboratory in chemistry education: Thirty years of experience with developments, implementation, and research. *Chem. Educ. Res. Pract.* **2004**, *5*, 247–264. [CrossRef]
42. Hofstein, A.; Lunetta, V.N. The laboratory in science education: Foundations for the twenty-first century. *Sci. Educ.* **2004**, *88*, 28–54. [CrossRef]

43. Lunetta, V.N.; Hofstein, A.; Clough, M.P. Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In *Handbook of Research on Science Education*; Abell, S.K., Lederman, N.G., Eds.; Routledge: Mahwah, NJ, USA, 2007; pp. 393–441.
44. Moore, S.; Kuol, N. Students evaluating teachers: Exploring the importance of faculty reaction to feedback on teaching. *Teach. High. Educ.* **2005**, *10*, 57–73. [CrossRef]
45. De Corte, E. New perspectives on learning and teaching in higher education. In *Goals and Purposes of Higher Education*; Burgen, A., Ed.; Jessica Kingsley: London, UK, 1996; pp. 112–132.
46. Nicol, D.J. *Research on Learning and Higher Education Teaching. Briefing Paper 45*; Universities and Colleges Staff Development Agency (UCosDA): Sheffield, UK, 1997.
47. Nicol, D.J.; Macfarlane-Dick, D. Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Stud. High. Educ.* **2006**, *31*, 199–218. [CrossRef]
48. Brockbank, A.; McGill, I. *Facilitating Reflective Learning in Higher Education*, 2nd ed.; Society for Research into Higher Education and Open University Press: Buckingham, UK, 2007.
49. Honey, P.; Mumford, A. *The Manual of Learning Styles*; Peter Honey: Maidenhead, UK, 1992.
50. DeNisi, A.S.; Kluger, A.N. Feedback effectiveness: Can 360-degree appraisals be improved? *Acad. Manag. Exec.* **2000**, *14*, 129–139. [CrossRef]
51. Ory, J.C. Changes in evaluating teaching in higher education. *Theory Pract.* **1991**, *30*, 30–36. [CrossRef]
52. Ambrose, S.A.; Bridges, M.W.; DiPietro, M.; Lovett, M.C.; Norman, M.K. *How Learning Works: Seven Research-Based Principles for Smart Teaching*; Jossey-Bass: San Francisco, CA, USA, 2010.
53. Ivanic, R.; Clark, R.; Rimmershaw, R. What am I supposed to make of this? The messages conveyed to students by tutors' written comments. In *Student Writing in Higher Education: New Contexts*; Lea, M.R., Stierer, B., Eds.; Open University Press: Buckingham, UK, 2000.
54. Marsh, H.W.; Dunkin, M.J. Students' evaluations of university teaching: A multidimensional perspective. In *Higher Education: Handbook of Theory and Research*; Perry, R.P., Smart, J.C., Eds.; Agathon Press: New York, NY, USA, 1992; Volume 8, pp. 143–233.
55. Blatchford, P. *The Class Size Debate: Is Small Better?* Open University Press: Philadelphia, PA, USA, 2003.
56. Pedder, D. Are small classes better? Understanding relationships between class size, classroom processes and pupils' learning. *Oxf. Rev. Educ.* **2006**, *32*, 213–234. [CrossRef]
57. Carbone, E.; Greenberg, J. Teaching large classes: Unpacking the problem and responding creatively. *Improv. Acad.* **1998**, *17*, 311–326. [CrossRef]
58. Light, R.J. *Making the Most of College*; Harvard University Press: Cambridge, MA, USA, 2001.
59. Astin, A.W. *What Matters in College?* Jossey-Bass: San Francisco, CA, USA, 1993.
60. Tinto, V. *Leaving College: Rethinking the Causes and Cures of Student Attrition*, 2nd ed.; University of Chicago Press: Chicago, IL, USA, 1993.
61. Kelly, H.F.; Ponton, M.K.; Rovai, A.P. A comparison of student evaluations of teaching between online and face-to-face courses. *Internet High. Educ.* **2007**, *10*, 89–101. [CrossRef]
62. Stojić, S.M.S.; Dobrijević, G.; Stanišić, N.; Stanić, N. Characteristics and activities of teachers on distance learning programs that affect their ratings. *Int. Rev. Res. Open Distrib. Learn.* **2014**, *15*, 248–262. [CrossRef]
63. Estelami, H. An exploratory study of the drivers of student satisfaction and learning experience in hybrid-online and purely online marketing courses. *Mark. Educ. Rev.* **2012**, *22*, 143–156. [CrossRef]
64. Ramachandran, R.; Sparck, E.M.; Levis-Fitzgerald, M. Investigating the effectiveness of using application-based science education videos in a general chemistry lecture course. *J. Chem. Educ.* **2019**, *96*, 479–485. [CrossRef]
65. Litzinger, T.; Lattuca, L.R.; Hadgraft, R.; Newstetter, W. Engineering education and the development of expertise. *J. Eng. Educ.* **2011**, *100*, 123–150. [CrossRef]
66. Pintrich, P.R. A motivational science perspective on the role of student motivation in learning and teaching contexts. *J. Educ. Psychol.* **2003**, *95*, 667–686. [CrossRef]
67. Van Driel, J.H.; Beijaard, D.; Verloop, N. Professional development and reform in science education: The role of teachers' practical knowledge. *J. Res. Sci. Teach.* **2001**, *38*, 137–158. [CrossRef]
68. Centra, J.A. Will teachers receive higher student evaluations by giving higher grades and less course work? *Res. High. Educ.* **2003**, *44*, 495–518. [CrossRef]
69. Dee, K.C. Reducing the workload in your class won't "Buy" you better teaching evaluation scores: Re-refutation of a persistent myth. In Proceedings of the 2004 American Society for Engineering Education

Annual Conference and Exposition, American Society for Engineering Education, Salt Lake City, UT, USA, 20 September–1 October 2004. Session 1331.
70. Dee, K.C. Student perceptions of high course workloads are not associated with poor student evaluations of instructor performance. *J. Eng. Educ.* **2007**, *96*, 69–78. [CrossRef]
71. Paulsen, M.B. Evaluating teaching performance. *New Dir. Inst. Res.* **2002**, *2002*, 5–18. [CrossRef]
72. Eggleston, J.F.E.; Galton, M.J.; Jones, M.E. *Processes and Products of Science Teaching*; Macmillan Education: London, UK, 1976.
73. Handelsman, J.; Ebert-May, D.; Beichner, R.; Bruns, P.; Chang, A.; DeHaan, R.; Gentile, J.; Lauffer, S.; Stewart, J.; Tilghman, S.M.; et al. Scientific teaching. *Science* **2004**, *304*, 521–522. [CrossRef]
74. Blanchflower, D.G.; Oswald, A.J. International happiness: A new view on the measure of performance. *Acad. Manag. Perspect.* **2011**, *25*, 6–22.
75. Davies, M.; Hirschberg, J.; Lye, J.; Johnston, C.; McDonald, I. Systematic influences on teaching evaluations: The case for caution. *Aust. Econ. Pap.* **2007**, *46*, 18–38. [CrossRef]
76. Isely, P.; Singh, H. Do higher grades lead to favorable student evaluations? *J. Econ. Educ.* **2005**, *36*, 29–42. [CrossRef]
77. Krautmann, A.C.; Sander, W. Grades and student evaluations of teachers. *Econ. Educ. Rev.* **1999**, *18*, 59–63. [CrossRef]
78. Langbein, L. Management by results: Student evaluation of faculty teaching and the mis-measurement of performance. *Econ. Educ. Rev.* **2008**, *27*, 417–428. [CrossRef]
79. Spencer, P.A.; Flyr, M.L. *The Formal Evaluation as an Impetus to Classroom Change: Myth or Reality?* University of California Press: Riverside, CA, USA, 1992.
80. Centra, J.A.; Gaubatz, N.B. Is there gender bias in student evaluations of teaching? *J. High. Educ.* **2000**, *71*, 17–33. [CrossRef]
81. Fernandez, J.; Mateo, M. Student and faculty gender in ratings of university teaching quality. *Sex Roles* **1997**, *37*, 997–1003. [CrossRef]
82. Tobin, K. Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *Sch. Sci. Math.* **1990**, *90*, 403–418. [CrossRef]
83. Gess-Newsome, J.; Southerland, S.A.; Johnston, A.; Woodbury, S. Educational reform, personal practical theories, and dissatisfaction: The anatomy of change in college science teaching. *Am. Educ. Res. J.* **2003**, *40*, 731–767. [CrossRef]
84. Wilson, R. Why Teaching is Not Priority No. 1. The Chronicle of Higher Education. Available online: https://www.chronicle.com/article/Why-Teaching-Is-Not-Priority/124301 (accessed on 10 June 2019).
85. Higgins, R.; Hartley, P.; Skelton, A. Getting the message across: The problem of communicating assessment feedback. *Teach. High. Educ.* **2001**, *6*, 269–274. [CrossRef]
86. Brinko, K.T. The practice of giving feedback to improve teaching: What is effective? *J. High. Educ.* **1993**, *64*, 574–593. [CrossRef]