education sciences

Essay

Teaching in Higher Education after COVID-19: Optimizing Faculty Time and Effort Using a Proposed Model

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Abstract: We propose a model for use in higher education after COVID-19 that addresses how to organize class methods for effective and efficient teaching outcomes for both students and instructors. Faculty have a finite amount of time that they may spend on their courses and must determine which time combinations produce the best outcomes. First, we discuss the key work-related challenges faced by faculty and contend that competing demands on faculty time result in inefficient allocation of their time and effort. We then model the issue as an optimization problem and illustrate through examples how to help faculty choose optimal method combinations along with time spent. We use time as a measure of effort and define which combination of methods might be most effective for achieving course learning objectives. There are opportunities for wider use of this methodology, as effective application of effort toward meeting the appropriate learning objectives should create better outcomes. Numerical examples are used to demonstrate the applicability of the proposed model, including how administrators can use it to support and encourage faculty.

Keywords: teaching model; faculty workload; teaching methods; higher education; time and effort

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1. Introduction

The COVID-19 pandemic disrupted higher education across the globe. Most schools shifted to online class formats during this time. Both instructors and students made the best use of video conferencing and other digital learning tools [1]. Clearly, some administrative changes will be permanent—including new modes of delivery and learning [2]. Many faculty had to redesign their course methods and learn new ways of effective teaching in the post-COVID-19 world. The fact that online teaching changes may not just be an option, but a continued necessity or a more widespread student desire, has far-reaching implications for academic leadership [3]. The online education space has its dynamics and requirements, and the usual “rules of success” that worked in the past may not be fully applicable in the new environment. More research is needed to better understand the administration of this digital transformation, the online environment, and the behavioral changes that are associated with isolation/remote education. Furthermore, instructors also need to continue to reevaluate the efficacy of the traditional teaching methods and tools they have been using in the past. In addition, balancing competing activities other than teaching, such as research and service, is a challenge for most academics and administrative evaluators, especially for faculty just starting in the profession [4]. Many find themselves struggling to develop and deliver classes while maintaining a steady stream of research [5]. While a doctoral program prepares academics well for research, the programs are not usually designed to train university teachers [6]. Becoming an effective teacher requires a great deal of dedication and time commitment as we come to better understand how students learn and how different teaching strategies deliver different outcomes [7].

However, this can be a daunting task because of other administrative factors, such as class size, student characteristics, departmental support, and reward mechanisms. These involve not just teaching expectations, but often research and service requirements [8]. A professor will attempt to adopt the best-suited teaching strategies and methods but must take into consideration the time and effort required for successful implementation. Thus, a question arises: How should faculty time and effort be distributed effectively? There are limited best practice studies for measuring the educator effort required for appropriately addressing student learning. In this paper, we propose that a mixture of learning methods could achieve these desired learning objectives [9], and that our proposed optimization model for dealing with this resource allocation can be applied to approximate this educator effort. We use research from education, organization science, and management science to present a practical model.

Of course, instructors should design learning methods to enable students to achieve specific learning objectives based on the needs of the discipline, the course, and the students attending. However, there is an absence of developed literature researching the specific combinations of methods needed to produce the best outcomes, which also means that administrative leadership does not know how to best support this combination. Instructors must put forth effort and time to (a) create the objectives; (b) design, develop, and assess methods; and (c) give students feedback and help as needed. The instructor can only optimize student learning within the bounds of given constraints on time and effort.

We present a brief review of previous research addressing student learning styles and effective teaching methods. Then, we briefly discuss the changing context and expectations of higher education, as well as faculty workload and causes of stress in academia. We discuss our proposed model with examples using an appropriate objective function (maximize learning) with a description of the decision variables (the time allocated to different methods), constraints (the total time available), and assumptions. The application of this proposed model may help educators, with the support and encouragement of administrators, to better determine whether they are both efficient and effective in teaching; that is, whether they are doing things right and doing the right thing [10]. Finally, we summarize the contributions of this research and invite others to expand upon it.

2. Issues in Instruction Effort and Expectations of Faculty

Much research is available regarding teaching and learning, but there is little concerning the arrangement of methods in terms of effort to outcome. Early on, Atkinson [11] presented an excellent decision-theoretic analysis of instruction. His proposed framework comprises five elements used for deriving the instructional problem. While we acknowledge that there are significant differences between different educational fields and suitable learning styles, a decision model of instruction, in general, requires (a) a description of the learning process, (b) a choice of instructional actions, and (c) the cost of the inputs versus the benefits. Significant challenges exist in terms of defining the three aforementioned groups. The process of learning is not predictable, there are varying short- and long-term results, and generalizations may not be possible for all fields of study. Selecting an optimal or suitable subset of instructional methods, defined as any learning undertaking in the classroom, is critical to determining the effectiveness of the teaching strategy, defined as all methods used for meeting learning objectives. This requires a clear understanding of the learning process and how each instructional method contributes to the desired learning objectives. Lastly, the cost, in this case, is the time and effort required for implementing the chosen subset of instructional methods.

Academic research on learning styles and teaching methods spans disciplines, cultures, demographics, and modes of delivery [2,12–14]. Researchers present insights and propose techniques for designing and delivering effective courses at all levels of instruction, but these studies do not consider the fact that instructors have a finite amount of time to allocate among competing courses and teaching methods. If the instructor has already designed a course and determined the key objectives that the student should develop during a course, the instructor should broadly know the estimated total amount of time that can be devoted to course teaching methods such as assessments, lectures, and group exercises. The instructor then needs to decide how much of his total time should be allocated to each learning objective and which criteria should be used to measure these learning objectives. Furthermore, how should the instructor divide this allocated time for a particular objective into learning, analysis, practice, and application? Clearly, expecting the instructor to maximize student learning without considering the time and effort needed is unrealistic.

3. Defining Time and Effort

In this paper, "time and effort" refers to the actual time spent on a course method. We acknowledge the research potential and challenges of establishing teaching effort, as it may vary across disciplines and modes of delivery. We are more interested in optimizing time allocation from the instructor's point of view, so we consider time and effort to be the actual time, in minutes or hours, that the instructor spends designing the method; assessing the work; responding to students; and other similar methods, as did other researchers [15–17]. We can assume that putting more effort into developing or delivering a course will mean that more instructor time is spent on methods such as preparation, delivery, and assessment. Because of the enormous variety of higher education courses, assessment is broadly defined as any measure that provides evidence that students are meeting the learning objectives of the course [18].

Most faculty enjoy flexibility and control when it comes to managing their schedules. The main binding time constraints are class schedules, where they are required to be present in a classroom, and scheduled work meetings. Regardless, faculty often assert being constantly overwhelmed and feeling that they do not have enough time [19,20]. Teaching, research, and service activities require meeting workplace deadlines, and research activities also require large chunks of uninterrupted time with external deadlines. Faculty need to manage their time and distribute it wisely to succeed in academia, and administrators need to appropriately lead and help with this process [19–22].

4. Learning and Teaching

Extensive research exists regarding learning and teaching in higher education, exploring student learning styles, and developing methods to improve learning experiences. Student approaches to learning are described in two qualitatively different ways [23–25]. The first is a deep approach, in which students not only understand concepts but also seek meanings by relating ideas to experiences, looking for evidence, engaging in debate, and developing a holistic view. This constructivist learning theory indicates that engaging teaching methods, such as discussions and in-class group efforts, will activate a higher level of learning than those that are less active and more teacher-centered [26]. The second is a surface approach, in which students focus on what is considered essential to meet the course requirements, such as memorizing and reproducing facts for assessment purposes [23–25].

Cameron and Whetten [27] proposed a still-valued model for teaching management skills in higher education, concluding that evaluation and feedback play central roles in developing key competencies. They proposed that the instructor should consider allocating more time to these methods. This means that the instructor must choose specific classroom activities, discussions, and assessments that allow the students to experience, understand, practice, reflect, and apply existing as well as newly acquired knowledge and skills. Whetten and Clark [28] provided one of the best summaries of teaching skills in higher education. The authors proposed an integrated model for teaching that places equal emphasis on thinking, doing, learning, and applying.

Instructors may have different priorities when it comes to learning objectives and choosing a teaching strategy [29]. Some disciplines may have signature pedagogies or preferred ways of teaching [30,31]. While our academic disciplines, teaching styles, and learning objectives do influence what and how we teach, the challenge of determining a set of most appropriate methods is the same across disciplines and types of institutions [31]. Perhaps even more valuable for instructors is the process of reflecting and assessing the effectiveness of these choices. Bain [32] stated that careful and sophisticated thinking, deep professional learning, and often fundamental conceptual shifts are essential characteristics of the best university instructors. However, he did not discuss time or effort management.

In short, faculty members must choose appropriate learning objectives for their courses, select a broad set of learning/engaging methods, pick suitable methods of assessment, deliver the course, evaluate student performance, provide constructive feedback to the students, measure/benchmark performance, and reflect and adjust accordingly. While all these methods contribute to a successful course, are these equally important? Are some more valuable than others, depending on the context? Which ones should the instructor spend more time on? Are there any tradeoffs? At what point does the marginal return from one set of methods start to diminish, indicating that the instructor is better off spending time on an alternate method? What do administrators need to know to support teachers? There are more questions than answers, and each answer depends on the situation. We raise these questions because the answers may guide faculty and help administrators to provide valuable guidance in making relevant tradeoffs and choices when it comes to achieving learning objectives and making the best use of faculty time and effort spent on teaching.

5. Changing Contexts

This includes how to appropriately teach online courses that were already widespread but increased even more dramatically after COVID-19 [33]. While there was little time during COVID-19 for all the necessary online teaching assistance, administrative leadership today must ensure that relevant faculty are thoroughly trained in online learning platforms [34]. Does preparing and delivering online courses take more time than using the face-to-face format? Multiple studies have addressed this question, but the results are inconclusive at best [8,35–37]. However, multiple studies have shown that instructors perceive that they spend more time communicating, coordinating, and providing feedback to online students. Perhaps this is because online students are virtually present 24/7, and instructors feel it necessary to be "on-call" [17,38]. Other factors that may contribute to such a perception (or reality) are inadequate training, inadequate administrative support, technology issues, and lack of policy guidelines for online teaching [39,40]

Online instruction and learning, though still a relatively new frontier in education, is evolving rapidly. Informative frameworks and conclusive empirical evidence answering related research questions are still scarce [41]. Improved design and management of online courses, adoption of new technologies, and student retention are some of the challenges faced by faculty [30]. Moreover, there must be a good fit between the instructor's pedagogy scheme and the course format. Clearly, all these challenges consume time, which is a scarce resource. It is unreasonable to expect faculty to select the best curriculum, design the best course, select the best tools, deliver the best course, have the best assessment plan in place, provide the best feedback to learners, measure the outcomes, and continuously improve their courses without sacrificing their personal time. This is in addition to research and service requirements and expectations. Tradeoffs must be made, just like in any other resource allocation problem.

Initially, the role of institutions of higher education was to provide education to those who wished to receive it. A few decades ago, this role became providing access to education to underserved communities [42]. Now, it is the role of academia to provide education so that completion rates are appropriate and to allow students to be successful in the labor market [43]. The result of these changes is that universities face financial pressures and new challenges as they adapt to a competitive marketplace. The combination of fiscal constraints, social pressure, and new modes of course delivery dictate major adjustments to the faculty workload, affecting the allocation of faculty time between research, teaching, service, and other scholarly activities. Faculty at graduate-level colleges and universities have a much more complex and challenging role to play. It is increasingly difficult to publish in leading academic journals, and classroom performance matters as well [44]. Many schools have fewer resources available to support research. Most faculty are now required to learn and adopt new technologies for delivering their courses that serve students in diverse contexts [45].

6. Faculty Workload

We have seen changing trends in the last two decades: student diversity in higher education, the increasing role of technology in teaching practices, and a shift in emphasis toward student learning and development, as opposed to former ways of teaching. Expectations from faculty have also changed, as have their workload requirements. Multiple studies [44,46–48] have shown that workload and the resulting time constraints are a primary source of faculty stress. Barnes, Agago, and Coomb [49] identified early on that time constraints were a key determining factor in faculty intent to leave academia.

Perry et al. [50] found that faculty in liberal arts and Carnegie Comprehensive I institutions experience higher levels of teaching-related stress relative to faculty in two-year colleges and Carnegie Research I institutions. Greene et al. [51] found that untenured faculty reported stressful and unbalanced lifestyles across several institutions, with work expectations exceeding assigned workloads. Research-related stress is much higher for faculty in Carnegie Research I institutions. Decisions regarding faculty time allocation for different activities are fundamental to the functioning of a university. These decisions cannot be made in isolation and must align with the institution's mission and incentive structure. The challenge is real, particularly for newer faculty. Their academic lives are likely to be very different from those of the professors teaching them. Several studies have raised similar concerns [45,52–54].

7. Models of Effort

Chant and Atkinson [55] studied the problem of allocating instructional effort to two interrelated blocks of learning. They presented a linear model and used control theory to arrive at optimal policies. Their framework is also applicable to randomly determined (stochastic) problems and may be extended to cases in which learning is a nonlinear function. Singell and Lillydahl [56] presented a multinomial logit model to predict how faculty allocate their time between research, teaching, service, and leisure. They concluded that significant differences exist between public and private institutions, that personal characteristics are significant determinants of faculty use of time, and that the institution's mission and reward structures reinforce these decisions.

Faculty time allocation between competing activities affects their probabilities of success in different career paths [57]. Universities would like to see time allocation patterns that better serve institutional missions [58]. Public universities also have legislative, public, and social pressures relating to inputs, processes, and outputs of education [59]. Resource constraints in higher education bring the effectiveness of faculty time and effort into sharp focus. It is not just about how much time the faculty allocates to teaching, but also the effectiveness of the time spent. However, defining, quantifying, and measuring faculty effectiveness is a challenge. Satisfactory performance by faculty now indicates the requirement for a multiplicity of capabilities because of the high demands on faculty time [44,60].

There is extensive coverage of theoretical studies and empirical evidence addressing differing aspects of learning and teaching in academic literature [44,61,62]. However, research on frameworks and tools for faculty to "optimize" learning objectives is missing. Is it rational to expect faculty to efficiently design, prepare, and deliver courses to maximize student learning, given that they spend only a portion of their time on teaching-related methods? If we can measure the effect of time spent on different teaching methods on desired learning objectives, instructors can make better informed trade-offs and choose the most effective methods. A better understanding of such relationships may assist in conducting a marginal benefit analysis; that is, determining at what point the incremental benefit of an instructor's time spent on method "x" becomes less than the benefit of time spent on methods "y" and "z".

8. Overall Research Design

Designing and delivering university-level courses requires due consideration of the expectations of all stakeholders, including students, faculty, administrators, government, industry, and communities [63–65]. While there are differences across disciplines and subjects, the philosophical principles are similar and are applicable across the disciplines [66]. Faculty should select course objectives that reflect stakeholders' expectations and the needs of the discipline; choose teaching strategies; adopt a set of teaching methods and tools; assess student learning; and provide feedback, among other design features [9,22,32].

We propose that by determining an optimal set of activities and the amount of effort required for each activity in a classroom, educators can achieve an optimal level of learning objectives. Research in management science indicates that there is a way to determine what combination of inputs produces appropriate outputs. The first question that should be addressed is this: What is the best set of teaching methods to use in the course? For example, five different methods may contribute to a learning objective, but should the educator use all or a subset of these methods? Then, how much time will be allocated to these methods?

Selection of an optimal subset of methods and times may become a daunting task, especially for large-scale problems. Combinatorial optimization techniques or heuristics may be used to answer this question. We model this problem as a nonlinear resource allocation problem, where the effort (input) from the educator is the limited resource that may be allocated to competing methods to maximize the student learning objectives. Resource allocation problems have been widely addressed in management science literature. For example, Zipkin [67], Luss and Gupta [68], and Einbu [69] studied different classes of allocation problems and proposed solution methodologies. It is worth mentioning that the resulting model is a mixed integer nonlinear program, which is a complex problem to solve. Management science literature proposes decomposition techniques to solve this class of problems.

In this study, we use the outer approximation technique to solve the problem using the experimental method [70]. The process is an iterative one that splits the problem into two parts and iteratively solves two sub-problems until their solutions converge into one [71]. The input for these methods is the faculty's time and knowledge, and the output is student learning and success. Like any other process, productivity and effectiveness depend upon the careful choice of methods and time allocated [72]. In examining the problem of resource allocation, in terms of the amount of effort, we describe our solution approach here and use an example to illustrate the point.

For the ease of the readers, use of the mathematical notation in the main body of the paper was avoided, but the mathematical model is outlined in Appendix A for readers who are interested in the details. The input for these methods is the faculty's time and knowledge, and the output is student learning and success. Like any other process, productivity and effectiveness depend upon the careful choice of methods and time allocated [72].

Modeling the relationship between teaching effort and teaching efficacy requires some estimates of how much time we should spend on a particular teaching method and the impact on student learning [73–77]. Not all the time spent on a particular method will yield the same output [72]. We present three possible ways of modeling the relationship in Figure 1. The simplest form is a linear relationship in which the incremental return on effort does not change at different levels of effort [78,79]. The second option is to model the relationship as a concave curve. The underlying assumption in this option is that, as effort increases, the return increases as well; however, at some point, the effort reaches a saturation level and a further increase in effort results in little or no return [78,79]. The third option is to model the relationship as an S-curve. In this case, the marginal return on effort first decreases, then reaches a point of inflection, after which it starts to increase [80]. In this case, as well, it reaches a maximum amount of effort expended beyond which there is no further benefit obtained by increasing the effort. While the linear relationship is the simplest one, the other two approaches capture the result of spending too much time on methods with diminishing returns.

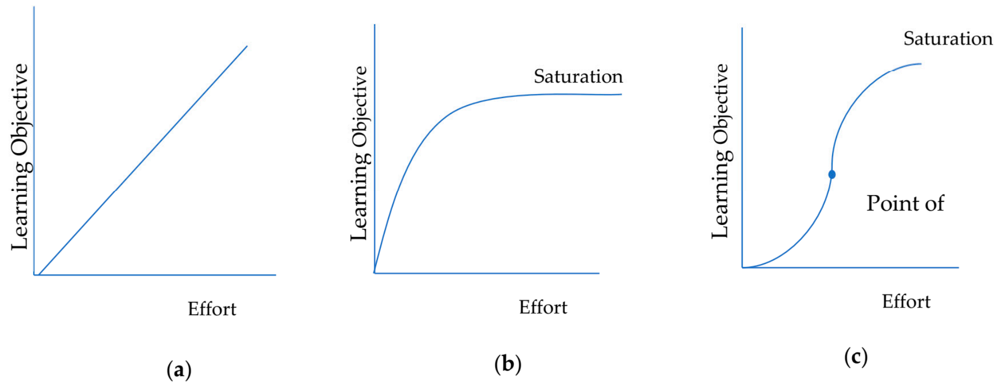

Figure 1. Learning objective and effort. (**a**) Linear; (**b**) concave; (**c**) S-shaped.

8.1. Methodology

We propose, in our model, to try to answer this overall question: What is the optimal mix of teaching methods and instructor teaching effort required for students to successfully meet course learning objectives? The first step is deciding the course objectives, which might already have been determined through the curriculum process. The learning objectives should determine the teaching methods used, not vice versa [81], within the constraints of class size and resource availability, including time. The second step is identifying methods and tools to use to achieve the desired learning objectives. This list cannot be complete because of the large variety of methods that may fit a particular course, but examples might include lectures, videos, quizzes, exams, simulations, exercises, analytical assignments, projects, written papers, class participation, reflections, presentations, group activities, blogs, and role-playing. The third step is to rank the effectiveness of each method chosen through initial assessment as best as possible based on information such as prior knowledge from previous courses, teaching seminars, related research, faculty discussions, or even intuition. This will be a tentative teaching method effectiveness ranking before learning assessments are completed in the course.

Ranking these methods helps with the fourth step that involves the allocation of time to each of the teaching methods. Time allocation could also vary based on other factors, such as the instructor, the course, the teaching materials available, the preparation of the students, the class size, and even whether the course is online, in-person, or hybrid. For example, weekly quizzes may take a large amount of time to prepare and grade, but showing and discussing weekly videos instead may take less instructor time. However, weekly quizzes that are provided by a textbook and graded automatically online might take little time, and self-created videos might take an extensive amount of time compared to videos that have already been professionally prepared. In other words, there are factors even when the same method is used that can impact how much time is needed.

This leads to the fifth step, which is total time. Total time is a constraint on the maximum time an instructor has decided to spend on teaching methods for each assigned course. If the total time is not enough, then the instructor will have to either reduce the time allocations to teaching methods or increase the total time. Increasing the total time might not be realistic or even reasonable. Total time estimates might vary for many reasons, even personal ones, but most likely based on teaching load and other required academic work such as research or service. For example, if an instructor has decided that the maximum time available for the teaching of three courses is thirty hours per week, which would include preparation, grading, class time, or other related methods, then the total time per course per week is approximately ten hours, as one course might take more time than another. We model the instructor's time as a scarce resource that is consumed by the methods the instructor chooses to use in each course. The time spent on each method contributes to at least one learning objective.

Steps three to five repeat with adjustments made based on course assessments until the instructor is satisfied with the results. Course assessments will vary greatly depending on the course, but some examples might include information gathered from exams, quizzes, classroom participation, assignments, or even student feedback. If one method seems not to be getting the positive results expected, the instructor could reduce the time put towards it, increase the time put towards another method, and then reevaluate using the steps in the model. This also includes evaluating the chosen methods for overuse. At some point, the returns for a method may start to diminish—meaning the instructor is better off allocating the rest of the available time to another method. In other words, too much emphasis or too little time allocated to one method may not produce the best results. The purpose is to find an optimal mix of teaching methods and the time devoted to each.

We present the logic of this approach in Figure 2. As specifically and visually shown, the model is used to rank each of the methods versus learning objectives based on assessment, thus identifying the most suitable method for each objective. This is followed by an iterative process in which in each iteration "i" allocates time (t_i) to method (M_j), where "j" is the highest rank in iteration "i". It then calculates the remaining time available and re-ranks the methods for the next iteration. It models the diminishing returns of spending more time on each of the methods and continues allocating incremental time to the highest-ranked method, given the remaining time. The iterations continue until the total time has been allocated.

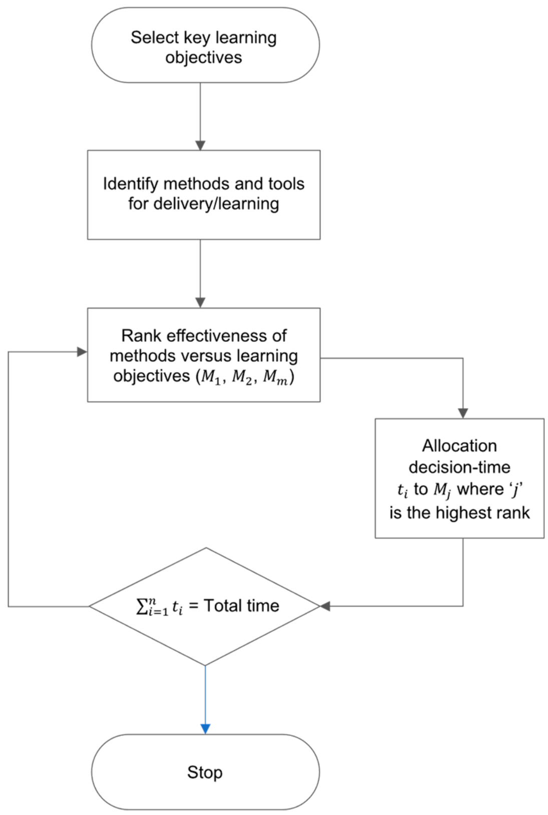

Figure 2. Flow chart showing solution approach.

8.2. Data Source and Collection

The data used are conceptual to fully illustrate the model. Conceptual articles can "bridge existing theories in interesting ways, link work across disciplines, provide multiple insights, and broaden the scope of our thinking" [82]. This approach should also be helpful for instructors that wish to try to use the model. The example given involves a hypothetical instructor going through each step of the model with the desire to determine the optimal mix of teaching methods and teaching effort required for students to successfully meet course learning objectives. In addition, we add related commentary about instructors, teaching, and the data analysis to fully explain concepts and results.

8.3. Data Analysis

In this example, the instructor has identified four major learning objectives for a graduate-level course in management: (a) to be able to apply analytical tools for problem-solving; (b) to develop a strategic thinking approach; (c) to learn the value of cross-functional collaboration; and (d) to use critical thinking to address organizational opportunities and challenges. The instructor plans to use the following six methods/modes (referred to as Set M) in conjunction with the regular class lectures: (1) simulations; (2) interactive group exercises; (3) video recordings; (4) analytical assignments; (5) reflective assignments; and (6) blogs and discussion boards. The instructor may use intuition or previous experiences to try to determine which of the methods lead to the desired results [83]. Some instructors may try to achieve a balance, while others may be inclined toward a preferred method of choice. Then, there is the instructor who tries to do it all and is overburdened with the workload.

Table 1 summarizes the linkages between each of these learning methods and learning objectives. While this is just an example, similar linkages exist for other disciplines and courses, and most instructors use multiple teaching tools in their classes. Figure 3 indicates that there is marginal return associated with each increasing level of learning activity. As instructors, we may want to switch from one method to the other, for example, when the marginal learning from group discussions becomes less effective than the marginal learning from individual assignments. The proposed method finds the optimal mix of selected learning methods and the instructor's time allocated to those methods.

Table 1. Linkages between learning methods (M) and objectives (L).

Set of Learning Methods	Strategic Thinking (L1)	Collaboration (L2)	Analytical Skills (L3)	Critical Thinking (L4)
Simulations (M1)	X		X	
Group Activities (M2)	X			X
Videos (M3)	X	X		
Analytical Assignments (M4)	X		X	X
Reflections (M5)	X			X
Blogs and Discussions (M6)	X	X		X

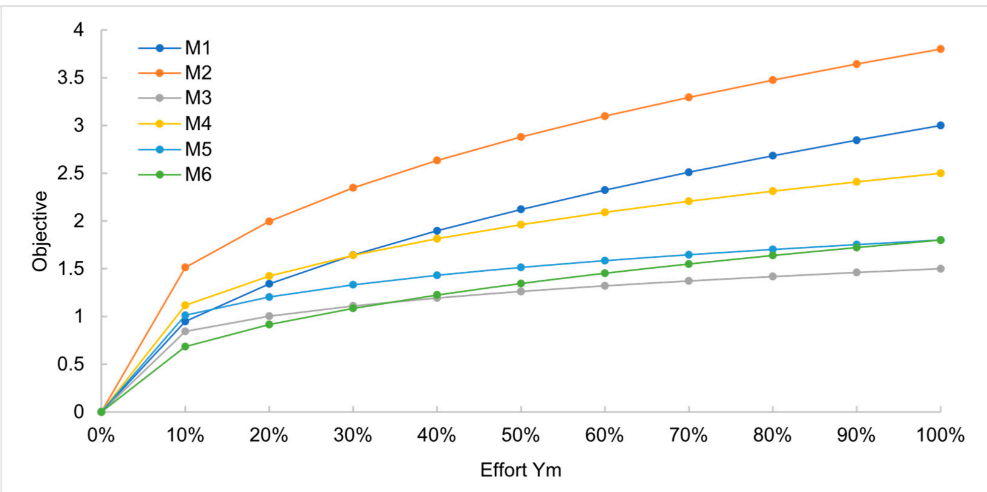

Figure 3. Effort and learning objective (L1) for a set of methods (Example 1).

Given these problem parameters, we modeled and solved the problem to find out which of the methods from set M the instructor should choose and what proportion of her effort should be allocated to these methods such that the total learning objective is maximized. We suggest that the optimal solution for the problem when ranking methods based on course learning assessments is to use methods M1, M3, M4, and M6, with 55%, 15%, 18%, and 12% of the instructor's time allocated to these methods, respectively, as determined by the actual time spent. Notice that in this example, we used monotonically increasing functions to relate the effort (time) spent on methods and the resulting gain in learning objectives. That is, as the time and effort increase, the resulting gain in learning objectives does not. One may argue that spending too much time on a particular method may result in less learning. For example, using videos in class may be a good tool to enhance learning; however, excessive use of videos beyond a critical threshold may lead to decreasing returns.

We present a second example in which the learning increases based on specific assessments as the instructor increases the effort spent on a particular method, reaching a maximum threshold, and then learning starts to decrease as the effort increases beyond that point. We illustrate this example in Figure 4. Our model shows that, for this problem, the preferred methods are M1, M2, and M6, with desired allocation of the instructor's effort (time) of 10%, 30%, and 60%, respectively.

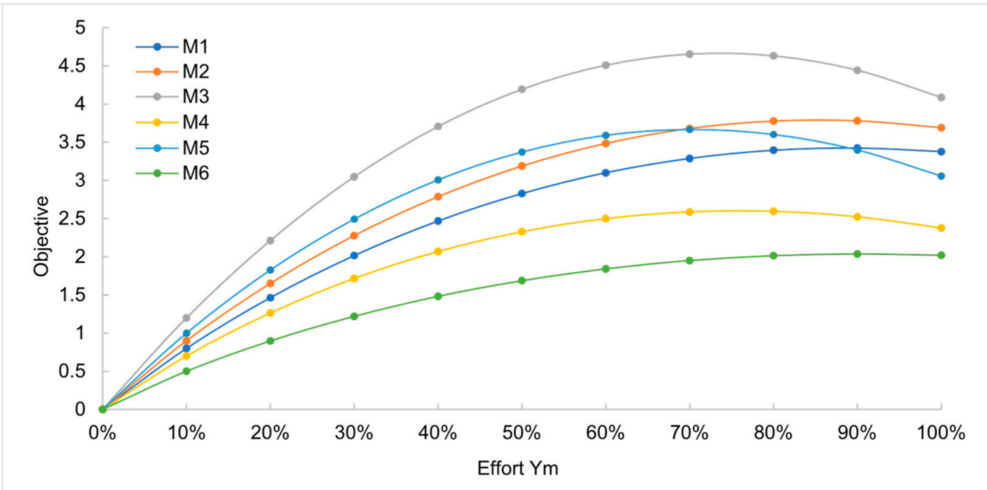

Figure 4. Effort and learning objective (L1) for a set of methods (Example 2).

These examples illustrate that the proposed model is flexible and may be adapted for different types of courses and learning environments. While the burden of determining the problem parameters for different learning environments is on the instructor, the model itself is quite general and practical. It is easy to model different functions for different methods and objectives, to select minimum and maximum thresholds on sets M and L, and to study the effects of changes in parameters on the overall learning of the students.

9. Limitations of the Study and Future Research

Application of our proposed model relies on input data for making any impactful decisions. However, these data are not easy to measure and generalize. What works for one set of students or subject matter might not work for another. While there are many common themes in learning styles, significant differences may exist across disciplines. For example, faculty teaching business courses may find a very different set of effective methods vs. faculty teaching languages or art. Though the model is still applicable, the results may not be generalized. Furthermore, the current work does not consider the impact of differences due to countries and cultures. Future research on discipline-based education combined with our proposed methodology may lead to more specific insights for the instructor.

In addition, different faculty might have different skills or approaches to a teaching method, too, that might influence effectiveness. A professor may enjoy one method more than another, even if it takes more time. The current work does not consider these issues. Assigning different weights to different methods could be one way to address this limitation in future extensions of the paper. The scope of the current work focused on the instructor's time and perspective of teaching and learning based on course objectives. It does not adequately include perceived learning from students' perspectives, although students' perception of learning might be inaccurate [83]. Future research adding these variations to the model may help advance findings.

10. Discussion and Conclusions

Teaching has always been recognized as an important part of academia for most faculty. The amount of teaching in any given institution is dependent on the type of institution and the requirements within the faculty contract. Teaching methods are often designed by faculty based on observation and intuition [84] rather than through a methodological approach for comparing various efforts to the outcomes along with considering time constraints. We argue that the methodological approach can be useful in deciding the teaching methods used in courses and can help better balance other work requirements. We do not doubt that intuition can have value in decision-making [85] and we do not assert that our model will eliminate it, but an objective methodological approach will lead to more effective decisions.

There is limited research on faculty workload and faculty often report being overwhelmed [19–22] and stressed [46,50,51], with time constraints reported as one major reason for faculty to leave academia [49]. This study contributes to this research by providing a useful model to help guide faculty in managing their limited time that can be devoted to teaching. Faculty can explore various teaching methods, but by using the model they can also be more conscious of the limited time available for each method, along with the impact on student learning based on assessment outcomes. The ideal is an optimal balance between faculty effort on teaching methods and learning outcomes.

We developed this model that faculty can try to utilize to better meet learning objectives effectively and efficiently, and that administrative leadership might even support with more resources. We hope that our model creates significant discussions around workload and faculty effort for both faculty and academic leadership. This includes teaching online courses versus regular classroom courses [14–17]. Our research has contributed to the literature on faculty time allocation [55,57,58]. We also hope that our research can add value to future studies in teaching methods [2,12–14,31], learning theory [11,23,60,63], course assessment [18,62], and faculty motivation [8]. With the current changes in higher education, that is, expectations and delivery methods, a more scientific look at faculty curriculum decision-making is necessary. Many of our teaching methods are based on what has worked for us in the past, and not necessarily on what is more effective and efficient while also juggling a research agenda and increased academic service requirements. In developing the model demonstrated herein, we noted that the amount of faculty time and effort spent designing, developing, assessing, and giving feedback is considerable in any course.

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Appendix A. Mathematical Model

Sets and Indexes

L set of learning objectives for a course.
M set of teaching methods/tools available to achieve learning objectives.
$l \in L$ index for learning objectives.
$m \in M$ index for teaching methods/tools.

Decision Variables

U_m 1, if teaching method m is used in the course, 0 otherwise.
Y_m level/intensity of effort devoted to method m, expressed as a proportion of the total effort/input of the instructor for that course.

Problem Parameters

X_{ml} 1, if teaching method m contributes to learning objective based on assessment, 0 otherwise.
a_{ml} maximum possible contribution of method m towards objective.
b_{ml} a parameter to determine contribution of a method m towards an objective at effort Ym.
Objective function:

$$\text{Max } Z = \sum_{m \in M} \sum_{l \in L} a_{ml} Y_m^{bml} U_m X_{ml} \tag{A1}$$

Subject to constraints:

$$\sum_{m \in M} \boldsymbol{Y_m} = 1 \tag{A2}$$

$$\sum_{m \in M} \boldsymbol{a_{ml}}\, \boldsymbol{Y_m^{bml}}\, \boldsymbol{U_m}\, \boldsymbol{X_{ml}} \geq \boldsymbol{O_l}\ \forall\, \boldsymbol{l} \in \boldsymbol{L} \tag{A3}$$

$$\boldsymbol{N_{min}} \leq \sum_{m \in M} \boldsymbol{U_m} \leq \boldsymbol{N_{max}} \tag{A4}$$

$$\boldsymbol{U_m}\ \boldsymbol{binary}\ \forall\, \boldsymbol{m} \in \boldsymbol{M} \tag{A5}$$

The objective function (A1) sums up the contribution of all the educational methods to overall student learning objectives. Constraint (A2) ensures the sum of effort across all methods does not exceed the total time the instructor has decided to spend working on the course. Constraint (A3) ensures each learning objective l meets or exceeds the minimum required effort, $\boldsymbol{O_l}$. Constraint (A4) provides lower and upper bounds on the number of educational methods that may be used for the course. Finally, constraint (A5) ensures that decision variable $\boldsymbol{U_m}$ = 1 when a method is used for achieving the desired learning objectives in the course.

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