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A Systematic Weighted Factor Approach for Curriculum Design

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Abstract

Curriculum revision and course design efforts are typically started partly as a result of constituent input, such as that from industrial advisory boards, potential employers of graduates, recent employers of graduates, and alumni. This process is often performed on an ad-hoc basis with various constituents who express conflicting opinions. This study offers a more formalized approach to the decision making process applied to curriculum revision by using a weighted factor index method to remove much of the subjectivity. Starting with an existing program, a new program is developed and the presented method is used compare the curriculum and course related options and decisions to evaluate the curriculum. An analysis is performed on the decision making process to determine the extent to which changes in weight assignment affect the final conclusion. It is found that by using this methodology, subjectivity may be minimized and rational decisions may be made during the conflict resolution phase of curriculum or course design.

1. Introduction

Many higher education programs perform curricular revision or course redesign on a regular or semi-regular basis with concerns of producing employment-ready graduates. These efforts are typically undertaken at least in part as a result of constituent input. Constituents of an academic program typically include industrial advisory boards, potential employers of graduates, recent employers of graduates, and alumni. However, design of a curricular revision is often performed on an ad-hoc basis.

Most curricular design efforts, particularly in engineering and technical degree programs, begin with the identification at some level of the desirable attributes of a graduate of the program[1]. Having identified these attributes, a number of factors may be formulated which may have an influence on the design of the program's curriculum or course. These may include (but are not limited to)[2-5].

- Employer demand
- Stakeholder engagement and commitment
- Size of the target audience
- Industrial relevance and emulation of the industrial experience
- Other relevant programs in the same institution
- Mission, vision, and expectations of the program
- Institutional/cultural compatibility
- Mathematical rigor in the curriculum
- Academic relevance
- Accreditation requirements
- Delivery mode and limitations
- Facility, space, and equipment needs
- Faculty backgrounds and experiences

- Other resources (Lab technicians, libraries etc.)
- Program robustness

While this list of factors is not extensive, it does provide some insight with regard to the types of issues which may inform curriculum design decisions. However, collecting, classifying, analyzing the data may become an exhaustive activity in the design process. Moreover, these factors often are in conflict with one another.

When there are conflicting factors, it falls to the faculty of the program in question to make the ultimate decision as to which of those conflicting opinions prevails. It is this decision making process which may be performed using a very informal, ad-hoc approach. In that case, none of the decision making processes incorporates a formal, mathematical or semi-mathematical, non-subjective approach. This study addresses that approach. A formal method is presented here to bring structure to the process and add value both from the perspective of the administration and from the perspective of the faculty and constituents[6]. The weighted factor index method, which has long been employed as a decision support tool in in other settings, is used to remove much of the subjectivity associated with decision making. This method removes much of the subjectivity involved in competing opinion resolution and results in much more objective decisions.

2. Weighted Factor Index Method

The factors to be employed in curriculum design and course content decisions are often of differing orders of magnitude and expressed in differing units. For example, industrial relevance may be expressed using a one to five Likert scale while the need for new or additional laboratory resources may be expressed in units of dollars. For purposes of comparison, these values must be normalized so that their magnitudes are of the same order and rendered dimensionless. This can accomplished through the use of one of the formulation below[7]:

$$\beta_{ij} = \frac{\text{value of factor i for candidate j}}{\text{largest candidate factor value under consideration}} \qquad (1)$$

$$\beta_{ij} = \frac{\text{smallest candidate factor value under consideration}}{\text{value of factor i for candidate j}} \qquad (2)$$

where β_{ij} is scaled factor i for candidate option j. Equation (1) is employed when large factor values are desirable and Equation (2) is employed when small values of the factor being considered are desirable. Once factors have been selected and scaled, a weighted factor index can be formulated as:

$$\gamma_j = \sum_{i=1}^{n} W_i \beta_{ij} \qquad (3)$$

where γ_j is the performance index (weighted factor index) for alternative j, W_i is the importance weight for scaled factor i and n is the number of factors upon which the decision is to be based.

For the purposes of weighting factor assignment, it is good practice to use that the sum of weights is 1. Once a weighted factor index γ_j has been calculated for each curricular design option under consideration then decision options with large γ_j values are superior to those with small γ_j values. Using this approach, all factors to be employed in making the decision are scaled to lie in the range $0 \leq \beta_{ij} \leq 1$. In this fashion, differences in relative magnitude from one factor to another are normalized to the same scale.

3. Examples of the Method in Curriculum and Course Design

The ___________ Department at ____________ University initiated a curriculum review and revision process for its Bachelor of Science program in Technology Management beginning in August, 2013. The program, as it existed at that time, was heavily weighted toward "enterprise skills", including personnel management and supervision, production management, financial management, project management, safety management, and accounting. These topics comprised approximately 24% of the credit hours required to complete the existing degree. The mathematical rigor and technical content of the degree program had been reduced over a period of more than a decade.

A series of discussions was held with regional representatives from industry with the objectives of determining the characteristics of successful program graduates, the employment potential for graduates of the existing program, and the employment potential for graduates of a redesigned degree program. A consensus developed regarding the following curriculum criteria:

- There was a need for increased mathematical rigor in the degree program.
- The enterprise skills component of the program should not be completely eliminated.
- The technical content of the program should be significantly increased, particularly with regard to engineering design content and content in the area of automation, sensing, and control.

Based on these discussions, as well as an analysis of existing, similar programs in the state and each of its neighboring states, the existing Technology Management B.S. degree program was transformed into a newly revised program leading to the Bachelor of Science in Mechanical Engineering Technology. Numerous curriculum design decisions were made in light of the recommended curriculum criteria from industry as above stated. One such decision dealt with the amount of enterprise skill content which should remain in the newly redesigned curriculum. In this example, the following factors are employed:

- Industrial Relevance (evaluated using a 1 to 5 Likert scale)
- Academic Relevance (evaluated using a 1 to 5 Likert scale)
- Intellectual Resources (evaluated using an estimated required dollar amount)
- Institutional/Cultural Compatibility (evaluated using a 1 to 5 Likert scale)
- Accreditation Factors (evaluated using a 1 to 5 Likert scale)

At this stage of analysis, it was unclear whether the inclusion/exclusion of enterprise content in the revised program would require additional intellectual resources. The options evaluated were:

- Option 1: Include no enterprise content in the newly redesigned curriculum.
- Option 2: Include enterprise content comprising approximately 5% of the program.
- Option 3: Include enterprise content comprising approximately 10% of the program.
- Option 4: Include enterprise content comprising approximately 15% of the program.

The following variables were employed:

IR_j = the value of industrial relevance for option j
AR_j = the value of academic relevance for option j
ICC_j = the value of institutional/cultural compatibility for option j
ACR_j = the value of desirability (from an accreditation perspective) for option j

β_{IRj} = scaled factor of industrial relevance for option j
β_{ARj} = scaled factor of academic relevance for option j
β_{ICCj} = scaled factor of institutional/cultural compatibility for option j
β_{ACRj} = scaled factor of accreditation desirability for option j

W_{IR} = weight (importance) assigned to industrial relevance
W_{AR} = weight (importance) assigned to academic relevance
W_{ICC} = weight (importance) assigned to institutional/cultural compatibility
W_{ACR} = weight (importance) assigned to accreditation desirability

Before beginning the analysis, departmental faculty were consulted and the following weights were assigned:

$W_{IR} = 0.30$
$W_{AR} = 0.25$
$W_{ICC} = 0.15$
$W_{ACR} = 0.30$

In this case, industrial relevance and the desirability (from an accreditation perspective) of any curricular changes were weighted most heavily, followed by academic relevance and institutional/cultural compatibility of the contemplated changes. At this stage of the analysis, additional intellectual resources were not considered. For those factors enumerated using a Likert scale, a value of 5 was defined as high, a value of 4 was defined as relatively high, a value of 3 was defined as moderate, a value of 2 was defined as relatively low, and a value of 1 was defined as low. Table 1 details the Likert scale values assigned to each factor.

Table 1. Likert Scale Values by Option and Factor

Option	IR	AR	ICC	ACR
1	2	4	2	3
2	3	3	3	3
3	4	3	3	3
4	4	2	4	2

Table 2 details the scaled factor values calculated for each option and factor. Note that since a high value for each factor is desirable, Equation (1) was employed in the calculation of each value presented in Table 2.

Table 2. Scaled Factor Values by Option

Option	β_{IR}	β_{AR}	β_{ICC}	β_{ACR}
1	0.50	1	0.5	1
2	0.75	0.75	0.75	1
3	1.0	0.75	0.75	1
4	1.0	0.5	1	0.67

The β_{IR} value for Option 1 is presented as an example. A larger value of industrial relevance is desirable, and as a result, Equation (1) is employed. The largest industrial relevance value, as presented in Table 1 is 4, and the industrial relevance value for Option 1 is 2. Then,

$$\beta_{IR\,1} = \frac{2}{4} = 0.50$$

The weighted factor index for Option 1 is calculated as:

$$\gamma_1 = 0.30(0.50) + 0.25(1) + 0.15(0.50) + 0.30(1) = 0.78$$

Table 3 presents the weighted factor index values calculated for each option.

Table 3. Weighted Factor Index Values

Option	γ_j
1	0.78
2	0.83
3	0.90
4	0.78

The options, in order of superiority are Option 3 (10% enterprise content), Option 2 (5% enterprise content), Option 4 (15% enterprise content), and Option 1 (no enterprise content). The assignment of different weights may change the result of the calculation. In the next analysis, it was assumed that additional intellectual resources in the form of adjunct faculty would be required to accommodate additional sections of out-of-department enterprise skills related courses. If Option 1 is pursued, then it is possible that an annual additional expenditure of approximately $15,000 will be incurred for adjunct faculty to serve as instructors for in-department courses since additional courses (not enterprise skills courses) would be offered by the department. If Option 2 is pursued, no additional funds would be required for in-department adjunct faculty but funding at a level of approximately $7,500 would be required to provide out-of-department adjunct faculty for additional sections of enterprise skills related courses. If Option 3 is pursued, $15,000 of out-of-department adjunct faculty funding would be required. If Option 4 is pursued, out-of-department adjunct faculty requirements are estimated at $22,500.

Table 4 details additional intellectual resource (adjunct faculty) funding as well as the scaled factor values associated with additional intellectual resources under each option. Note that the subscript AF is used to denote adjunct faculty funding.

Table 4. Intellectual Resource Funding Estimates and Scaled Factor Values

Option	Resource Funding	β_{AF}
1	$15,000	0.50
2	$7,500	1.00
3	$15,000	0.50
4	$22,500	0.33

Since a smaller expenditure of funds is desirable, the scaled factor values delineated in Table 5 were calculated using Equation 2. For example, β_{AF1} for Option 1 is the smallest required funding amount presented in Table 4 ($7,500) divided by the funding required for Option 1 ($15,000), which is 0.50. The weights assigned to the factors in this scenario are:

$W_{IR} = 0.25$
$W_{AR} = 0.15$
$W_{ICC} = 0.10$
$W_{ACR} = 0.25$
$W_{AF} = 0.25$

Table 5 presents the weighted factor index values calculated under the new the new scenario.

Table 5. Weighted Factor Index Values Including Intellectual Resource Funding Estimates

Option	γ_j
1	0.70
2	0.88
3	0.81
4	0.68

With the new criterion, the options, in order of superiority, are Option 2, Option 3, Option 1 and Option 4 equally undesirable. The inclusion of monetary considerations associated with the potential need for additional faculty has resulted in the emergence of Option 2 as the most desirable option.

In addition to curriculum development decisions, the method was used to determine the course content in curriculum. The Technology Management Program had a course, named Introduction to Engineering Design that mainly focused on computer aided design (CAD) and computational analysis tools. More specifically, the course was developed around sketching theory and conventions as well as the use of a CAD software. After a series of discussions, the decision was to keep the course but redesign it for the purposes of new Mechanical Engineering Technology Program. However, the course was taken by a number of students from different disciplines. Current electrical engineering, civil engineering, and mechanical engineering students took the course in their first semester therefore, the new content had to be relevant to those disciplines as well as the Mechanical Engineering Technology. Moreover, the faculty decided that the course had to be relevant to the industry needs and that can be addressed by aligning the course content with the Fundamentals of Engineering exam questions. Accreditation was also another important factor under consideration so the course should satisfy the accreditation requirements of the new program and should address and measure some of the student learning objectives. The last important category of factors was resources and capability including required materials, software, equipment, instructor/teaching assistant time as well as library resources.

After extensive investigations of similar Mechanical Engineering Programs, it was decided that the course should introduce the engineering design process through a group design and fabrication project. With the introduction of new content and group project, the course would address some of the student learning outcomes for accreditation purposes such as understanding the process of translating an engineering design into a product, identifying ethical engineering practices and potential design failures, improving teamwork and communication skills. The options evaluated for the new course included:

- Option 1: Include engineering design process and group project content comprising approximately 10% of the course.
- Option 2: Include engineering design process and group project content comprising approximately 25% of the course.
- Option 3: Include engineering design process and group project content comprising approximately 50% of the course.
- Option 4: Include engineering design process and group project content comprising approximately 75% of the course.

The following factors are employed:

- Program relevance (evaluated using a 1 to 5 Likert scale)
- Industrial relevance (evaluated using a 1 to 5 Likert scale)
- Accreditation factors (evaluated using a 1 to 5 Likert scale)
- Resource and capability (evaluated using a 1 to 5 Likert scale)

The following variables were employed for this analysis:

PR_j = the value of program relevance for option j
IR_j = the value of industrial relevance for option j
AF_j = the value of accreditation factors for option j
RC_j = the value of resource and capability for option j

β_{PRj} = scaled factor of program relevance for option j
β_{IRj} = scaled factor of industrial relevance for option j
β_{AFj} = scaled factor of accreditation factors for option j
β_{RCj} = scaled factor of resource and capability for option j

W_{PR} = weight (importance) assigned to program relevance
W_{IR} = weight (importance) assigned to industrial relevance
W_{AF} = weight (importance) assigned to accreditation factors
W_{RC} = weight (importance) assigned to resource and capability

The following weights were assigned:

$W_{PR} = 0.25$
$W_{IR} = 0.35$
$W_{AF} = 0.25$
$W_{RC} = 0.15$

The same Likert scale was used where a value of 5 was defined as high and a value of 1 was defined as low. Table 6 details the Likert scale values assigned to each factor. This analysis employed Equation (1). Scaled factor values and the weighted factor index values calculated for each option are presented in Tables 7 and Table 8 respectively.

Table 6. Likert Scale Values by Option and Factor

Option	PR	IR	AF	RC
1	2	2	2	3
2	3	3	3	3
3	3	4	3	4
4	2	3	4	2

Table 7. Scaled Factor Values by Option

Option	β_{IR}	β_{AR}	β_{ICC}	β_{ACR}
1	0.67	0.50	0.50	0.75
2	1.00	0.75	0.75	0.75
3	1.00	1.00	0.75	1.00
4	0.67	0.75	1.00	0.50

Table 8. Weighted Factor Index Values

Option	γ_j
1	0.58
2	0.81
3	0.94
4	0.75

Based on the values the options, in order of superiority, are Option 3 (50% engineering design process content), Option 2 (25% engineering design process content), Option 4 (75% engineering design process content), and Option 1 (10% engineering design process content). The inclusion of monetary considerations associated with the potential need for additional adjunct faculty has resulted in the emergence of Option 2

5. Conclusion

In this study, the use of the weighted factor index method as a decision support tool for curriculum and course design choices has been presented. Using this methodology, subjectivity may be reduced and rational decisions may be made during the conflict resolution phase of curriculum or course design. This methodology is easily customized to include factors and considerations on a situation-specific basis.in addition, it is generalizable to be adopted at different institutions for curriculum/course change or other settings. One major practical value of the methodology is that it leads to take more objective approach towards decision-making under complex scenarios in education and other contexts.

In addition, two practical examples taken from the redesign of an academic program at _____ University were presented. The effects of inclusion/exclusion of various factors in the decision making process, as well as changes in the relative importance associated with each factor, were illustrated. It should be noted that subjectivity is present in the method described here during the weight assignment phase of the analysis. It is recommended that at least an informal sensitivity analysis be employed to determine the extent to which changes in weight assignment affect the final conclusion of the analysis. In addition, it should be noted that while the method presented here is useful with regard to setting general directions for curriculum and course design, it is not easily employed to make specific choices with regard to the selection of one course over another or topic level detailed content of a particular course. Educators, faculty, or administrator may use this methodology as an objective decision-making tool for some of the major curricular changes. Even though the methodology provides with a practical approach, it may not be used for straight forward, minor or necessary curricular changes such as inclusion of a specific lecture in a course or minimum credit requirements for accreditation.

This study did not present how the solutions suggested by the systematic weighted factor approach were implemented. The transition phase of new program implementation, during which an old degree program may be phased out as a new program is phased in, may present complex challenges. Further work may be merited in order to formulate rational approaches to this problem as well.

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