AC 2007-219: A CASE STUDY OF COURSE CLUSTERING STRATEGY TO ENHANCE RELATIONAL LEARNING

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A Case Study of Course Clustering Strategy to Enhance Relational Learning

Abstract

A case study of curriculum experimentation based on the course clustering strategy to enhance student learning is reported in this paper. The study involved, in an unconventional manner, clustering the courses in dynamics and design of machinery by changing their sequence from serial to parallel; namely, the two courses were offered in the same semester and taken by the same group of students. A third course on computer applications covering tools of MCAD and CAE was also included in this study, as part of the course cluster to further solidify the just-in-time, learn-and-apply process. Results from student performances and course surveys indicate that the study was a success and the course clustering strategy indeed improves student learning.

Introduction

Traditional mechanical engineering curriculum typically follows a well accepted practice where courses in dynamics and design of machinery are offered in series. This is also typically the case at USD where mechanical engineering students take the two courses in the first and second semesters of their junior year. While the sequential arrangement seems to make good logical sense, it is not without drawbacks in its pedagogical effectiveness. A major drawback observed by the authors is the sense of disconnectedness demonstrated by students between the theories learned in dynamics and their applications in design of machinery as a result of the sequential separation, even if two courses are taken back to back.

Students learn and retain the knowledge best when the underlying theory is presented together with its applications and reinforced with opportunities to apply the concepts themselves[1,2]. This suggests that, in addition to opportune use of application examples at the topical level within the same course, it should also be beneficial to adapt the same learn-and-apply strategy across the boundary of courses between foundational and applied ones. In other words, related foundational and applied courses, such as dynamics, design of machinery and others, may be clustered with care so that, when taken together by the students and with proper executions by the instructors, they can amplify students learning responses in a way similar to that of a resonance phenomenon under forced excitations.

In this paper, we report a case study of curriculum experiment at USD based on the course clustering strategy to enhance student learning. The experiment, which took place in Spring 2006, involved clustering the courses in dynamics and design of machinery (formally MENG 375 Dynamics and MENG 380 Machine Design I in the ME curriculum at USD) by changing their sequence from serial to parallel; namely, the two courses were offered in the same semester and taken by the same group of students. It was postulated that 1) through careful coordination, basic dynamics concepts and knowledge needed for the applied design of machinery course could be covered in a just-in-time manner, and 2) coupling a foundational course (e.g., dynamics) with a directly related applied course (e.g., design of machinery) would accentuate the associations between materials and broaden understanding. In this experiment, a third course on computer applications (formally MENG 430 Computational Applications in ME) covering tools of MCAD and CAE was also included as part of the course cluster to further solidify the just-in-time, learn-and-apply process.

There have been a number of cases reported in the literature regarding horizontal and vertical integration of courses[3,4,5,6,7]. The present case study, in essence, is similar to those examples as it also is concerned with integrating course materials across courses. However, this course clustering experiment differs in the type and nature of courses involved. That is, rather than integrating a group of courses that are related but independent, a major difference in our study is that we clustered together courses which are normally sequential and dependent. Results from student performances and course surveys indicate that the experiment was a success and the course clustering strategy indeed improves student learning.

The Course Clustering Experiment

Pedagogical Design

When clustering two sequential courses in the same semester, one needs to consider three factors: namely, compatibility, feasibility and accessibility. The first factor refers to the requirement that learning objectives for the courses of concern should be generally compatible. The feasibility factor has to do with the question if it is actually feasible to arrange all the topics needed to be taught in both so that the required materials in the pre-requisite course are covered in proper sequence before their related applied topics in the more advanced course. This obviously is the key concern and a necessary condition for the proposed clustering experiment. The third factor, accessibility, is about students' access to the courses, which in turn dictates the student audience involved. While it is not absolutely necessary, it is desirable both for effectiveness of relational/contextual learning and logistical issues that the courses are taken by the same group of students.

Considering the above factors for the two courses involved in our clustering experiment, Dynamics (MENG 375) and Design of Machinery (MENG 380 Machine Design I), their match in the compatibility and the accessibility factors were obvious in that both would be taken by the same group of students (second semester mechanical engineering juniors) and both had fairly compatible learning objectives. Although not as straightforward as the aforementioned ones, the feasibility factor was affirmed as well after performing a detailed review and planning of the topics to be covered for both courses. During the review, in addition to topical concerns, attention was paid especially to the timing aspect of the related topics across the two courses, to ensure that there could be adequate time gap between the key foundational concepts introduced in the Dynamics and when the students would see their corresponding applications in the Design of Machinery. To this end, the generation of a topics breakdown schedule (similar to the work breakdown schedule commonly used in project management practices) was found to be very useful in coordinating the clustered instructions of the two courses.

To heighten the learning effect, it was decided that a common integrated project, similar to that reported by Yoder[5], should be used in place of the three individual projects originally required in the three courses involved. One natural consequence and benefit of using a single cross-course project was that the scope of the combined project could have more depth and breadth (thus more meaningful) than the single-course one.

Implementation

The foregoing curriculum experiment was implemented in the Spring 2006. The Mechanical Engineering program at USD was in its third year of inception at the time and had just completed a second iteration of streamlining its curriculum. The junior class had only nine students; all had been taking courses in tandem up to that point and were all scheduled to take the three courses together. Admittedly, having relatively new program and small class size had its advantages in that it was not difficult for us to afford the risks of carrying out such an experiment.

Two instructors were assigned to this experiment, Kohl for the Dynamics and Huang for the Machine Design I as well as the Computer Applications. In preparing for the execution, both met extensively to review topics and coordinate timing so as to ensure feasibility. An instructional plan, particularly relating the Dynamics and MD I courses, was then generated to ensure coherency and synchronization. Since the topics in the Computer Applications course were generally independent and their timings not as critically related as the other two courses, there was no need for explicit coordination and its instruction plan was left to the discretion of the instructor.

Table 1 shows a weekly schedule of topics arranged for the Dynamics and MD I courses in our clustering implementation. While students were learning the requisite topics of particle dynamics in the Dynamics course during the first half of the semester, they were going through the portion of topics in Machine Design I which did not require the requisite knowledge of dynamics. This worked out mainly because of the extra two weeks 'gained' in the MD I course by placing the mechanism synthesis *before* the position analysis, not after as has been traditionally done.

Table 1: Topics breakdown for clustering implementation of Dynamics and Machine Design I

Week	**MENG 375 Dynamics** (MWF 9-10 am)	**MENG 380 Machine Design I** (MWF 11-12 pm)
1	Particle: Kinematics	Basic Concepts and Definitions
2	Kinematics	Mobility Analysis & Number Synthesis
3	Kinetics	Functional & Type Analysis; Grashof Condition
4	Work and Energy	Mechanism Synthesis (Graphical)
5	Review and Exam	Mechanism Synthesis (Graphical)
6	Particle: Impulse & Momentum	Position Analysis
7	Impulse & Momentum	Review and Exam
8	Rigid Body: Kinematics	Velocity Analysis
9	Kinetics	Velocity Analysis
10	Kinetics	Static Force Analysis and Mechanical Advantage
11	Review and Exams	Acceleration Analysis
12	Work and Energy	Dynamics Force Analysis
13	Impulse & Momentum	Gear Trains and Cams
14	Review and Project Presentation	Review and Project Presentation

Note that, during the second the half of the semester, the topics covered (namely, rigid body kinematics and kinetics) were very much in synchronization between the two courses. However, due to purposeful arrangement of class schedule, the students would literally first see the foundational concepts discussed and presented in the Dynamics class and then would see the same concept reinforced and applied in the more practical context of mechanisms and machines, sometimes on the same day and an hour later.

During the course of execution, the instructors regularly met throughout the semester to review progress and exchange information regarding students' performances and feedbacks. Special attention was paid to any problem or issue associated with difficulties in understanding of topics in MDI with required background materials in Dynamics. And where appropriate, the instructors made it a point to mention the relationships between the basic concepts and their related applied ones. Overall, with the exception of one student who had been historically weak, relatively few problems were encountered and the experiment was deemed to have gone well. A definite positive was observed that the students seemed to have a better knowledge of how various topics fit together, regardless of the levels of accomplished proficiency.

Results of Experimentation

<u>Projects</u>

The three courses that were involved in the combined project were Dynamics, Machine Design I, and Computational Applications in Mechanical Engineering (use of solid modeling software is taught in this class). There were nine students that were taking these classes simultaneously. These nine students were divided into three teams of three. These students were allowed to choose to design any device as long as it contained components that moved. Some possible topics were given to the students in case they had "designers block." Each project had to contain three components that the students had to include in their reports. These components were a kinematic analysis, dynamic analysis, and a solid model using concepts that were learned in each of the three classes. The following three projects were chosen and submitted by the students: "Sidewinder Six-bar Suspension", "Garbage Dump Mechanism," and "The Floating Arm Trebucet."

Sidewinder Six-bar Suspension: This project involved design, analysis, and solid modeling with motion animation of a six-bar suspension mechanism for an off-road, Mini-Baja type vehicle. The three students who proposed the project were all involved in an extra-curricular activity in the construction of the off-road vehicle called "The Sidewinder." They faced the need of having to come up with a suspension linkage to accommodate the use of an existing coil spring they acquired earlier. They took on the project after seeing the relevance of the course materials to the problem, and successfully came up with a satisfactory design of the six-bar suspension which not only met the necessary space constraint but also the requirement of having optimal progressive rate response to loading. Selected slides from the report showing the solid model of suspension design, the results of analysis and a plot of mechanical advantage are included below.

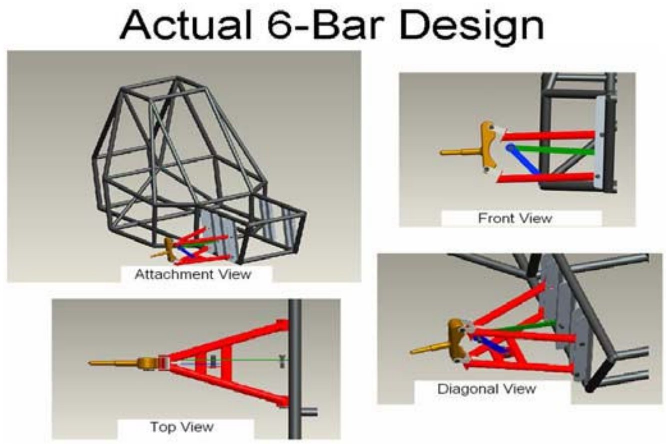
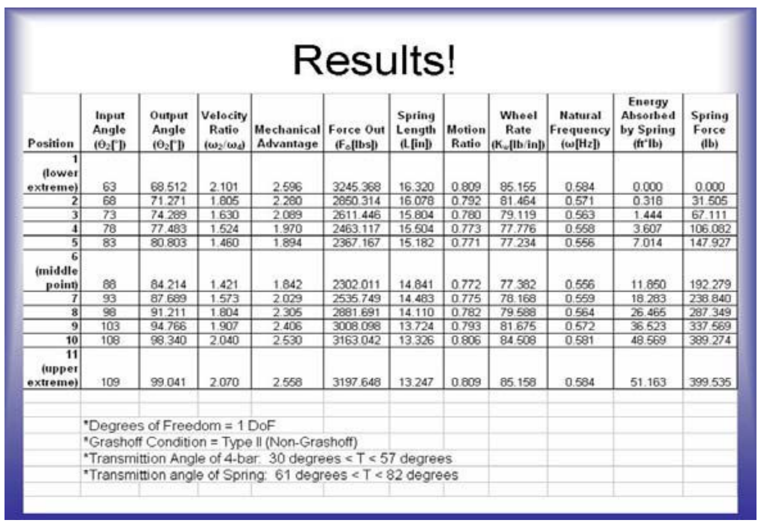


Figure 1a: Solid model of the 6-bar suspension designed with Pro/ENGINEER Wildfire



Results!

Position	Input Angle (Θ_2[°])	Output Angle (Θ_2[°])	Velocity Ratio (ω_2/ω_4)	Mechanical Advantage	Force Out (F_o[lbs])	Spring Length (L[in])	Motion Ratio	Wheel Rate (K_w[lb/in])	Natural Frequency (ω[Hz])	Energy Absorbed by Spring (ft*lb)	Spring Force (lb)
1 (lower extreme)	63	68.512	2.101	2.596	3245.368	16.320	0.809	85.155	0.584	0.000	0.000
2	68	71.271	1.805	2.280	2850.314	16.078	0.792	81.464	0.571	0.318	31.505
3	73	74.289	1.630	2.089	2611.446	15.804	0.780	79.119	0.563	1.444	67.111
4	78	77.483	1.524	1.970	2463.117	15.504	0.773	77.776	0.558	3.607	106.082
5	83	80.803	1.460	1.894	2367.167	15.182	0.771	77.234	0.556	7.014	147.927
6 (middle point)	88	84.214	1.421	1.842	2302.011	14.841	0.772	77.382	0.556	11.850	192.279
7	93	87.689	1.573	2.029	2535.749	14.483	0.775	78.168	0.559	18.283	238.840
8	98	91.211	1.804	2.305	2881.691	14.110	0.782	79.588	0.564	26.465	287.349
9	103	94.766	1.907	2.406	3008.098	13.724	0.793	81.675	0.572	36.523	337.569
10	108	98.340	2.040	2.530	3163.042	13.326	0.806	84.508	0.581	48.569	389.274
11 (upper extreme)	109	99.041	2.070	2.558	3197.648	13.247	0.809	85.158	0.584	51.163	399.535

*Degrees of Freedom = 1 DoF
*Grashoff Condition = Type II (Non-Grashoff)
*Transmittion Angle of 4-bar: 30 degrees < T < 57 degrees
*Transmittion angle of Spring: 61 degrees < T < 82 degrees

Figure 1b: Results of the kinematics and mechanical advantage analyses for the 6-bar suspension

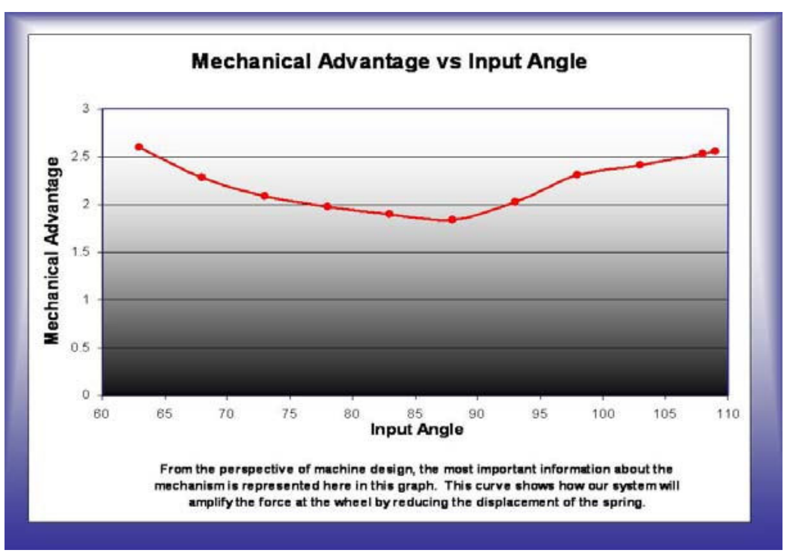


Figure 1c: Representative plot of analysis result in the Sidewinder six-bar suspension project

Garbage Dump Mechanism: This project involved the assigned task of designing a lifting mechanism which was able to be operated from the bed of a pickup truck to lift a garbage dumpster and dump its content into the truck bed. The design must be such that it could lift a minimum weight of 500 lb and be easily stowed when not in use. In completing the project, the students applied the synthesis and analysis techniques learned in Machine Design and Dynamics, and used the solid modeling tool to realize and verify their design. Figure 2 shows the resulting design of their work.

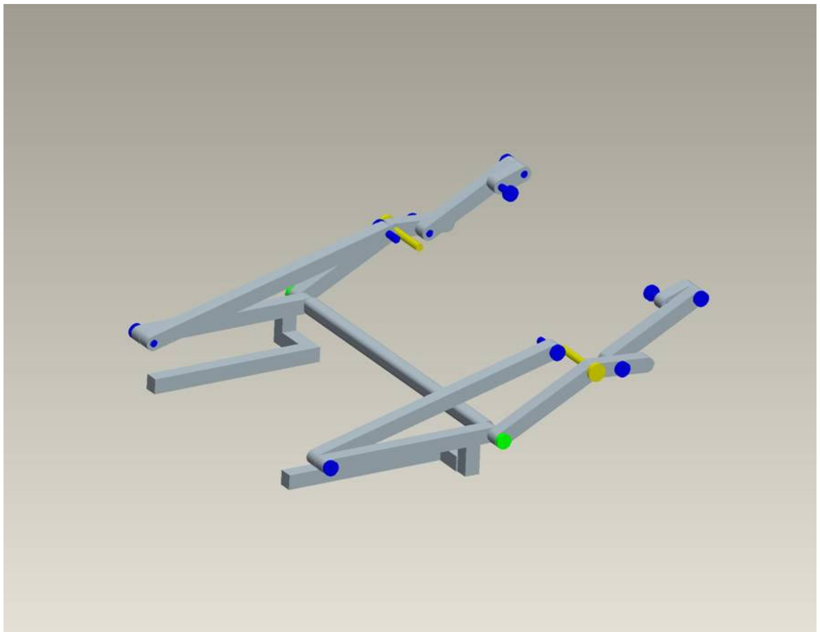


Figure 2a: Garbage Dump Mechanism Project - Six-bar lift mechanism

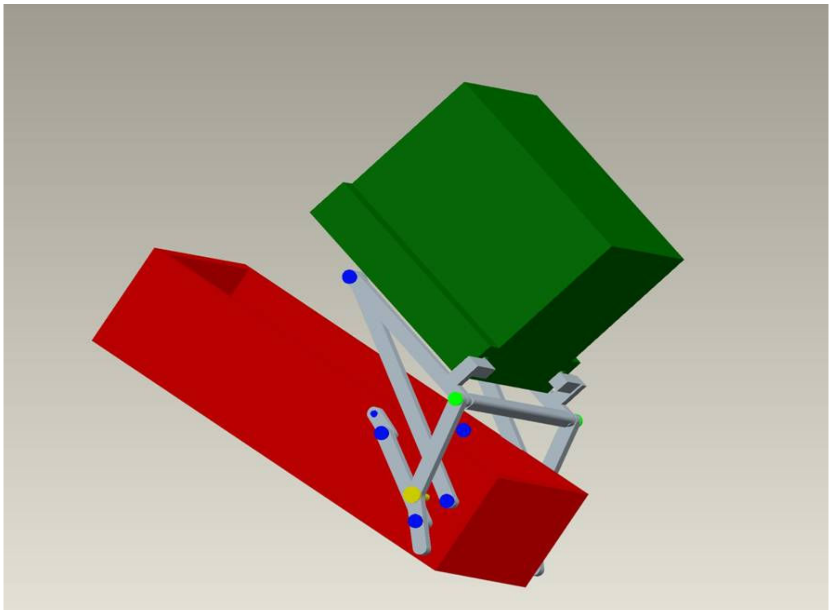


Figure 2b: The mechanism mounted to truck body in dumping configuration

Floating Arm Trebuchet: This project involved the design and analysis of an unconventional floating arm trebuchet. In contrast to the standard trebuchet, which is basically a lever arm rotating about a pivot fixed to the frame, a floating arm trebuchet is one that constrains its counterweight to drop along a vertical track and its pivot (about which the arm rotates) to slide along a horizontal track. The project was proposed by students out of their interests to improve the performance of an existing trebuchet previously constructed. In carrying out this project, the students first analyzed the dynamic interplays between the lengths of the sling and the arm as well as the cocking angle, and found an optimal sling length under the given overall size and weight constraints. Solid modeling was then employed to render the new design.

From the project reports it was evident that they were more in depth than if each component would have been assigned independently in their respective classes. The students clearly demonstrated an understanding of and the ability to apply the concepts learned in the three classes. Indeed, in one of the reports the students wrote -*"It has been interesting to apply the principles we have learned in Machine Design (MENG 380) and Dynamics (MENG 375) to a complex suspension system. This project has both solidified our understanding of the coursework while providing an excellent opportunity for intellectual growth."*

<u>Surveys</u>

In order to get information on how the students perceived the benefits or detriments of the concurrent offering of Dynamics and Machine Design I. The following survey was given to the students with the following scale to indicate their level of agreement: 5 for strongly agree; 4 for agree; 3 for neutral; 2 for disagree; and 1 for strongly disagree.

1. Did the concurrent offering of MENG 375 Dynamics and MENG 380 Machine Design I (MDI) benefit your learning, allowing you to gain a better understanding of the topics covered?
2. Do you think you would have performed worse in MDI if you had taken Dynamics a semester or two earlier?
3. Do you believe that overall you have retained more materials as of today from Dynamics and MDI than you would have by taking the courses at different semesters?
4. Do you agree that the following factors contribute positively to your learning experience last semester:

a) Proximity of learning the fundamentals in Dynamics and seeing the applications in MDI.

b) Use of the joint class project integrating the topics from Dynamics, MDI, and Comp. Applications.

The results of the survey are shown in Table 2. It should be noted that one student's response to the survey was removed because of a clear inconsistency given for question number 2 and the other questions and therefore the response is deemed unreliable.

Table 2: Student Survey Results

Question	Level of Achievement					Number of Responses	Mean	Standard Deviation
	5	4	3	2	1			
1	3	4	1			8	4.25	0.71
2		5	3			8	3.63	0.52
3	1	1	5	1		8	3.25	0.89
4a	2	5	1			8	4.13	0.64
4b	6	1	1			8	4.63	0.74

Overall, it is evident from the student responses that they felt that taking the two classes concurrently enhanced their understanding of the material. They also appreciated the benefits of the joint design project the most. The score for question number 3 was the lowest. It was perhaps because they do not have experience in taking the two classes at separate times and therefore do not have a basis of comparison.

Relating Results to Memory Research

Coupling Dynamics and Machine Design I courses in the same semester, as opposed to sequential semesters, takes advantage of several factors that should improve comprehension and memory. In turn, this enhanced retention should facilitate the application of the learned material at a later date.

There are two primary factors that likely contributed to the enhanced retention of learned material – these being how the exposure to the new information was spaced in time, and the application of learned information. Spacing or distributing learning sessions over time greatly enhances memory and results in the retention of a greater amount of information, without an increase in the total amount of time spent on the material[11]. These effects are thought to be rooted in a basic property of synapses in brain regions involved in memory encoding. Bursts of synaptic activity that are spaced appropriately elicit more robust and lasting synaptic efficacy[14]. In regards to educational material, spacing increases the quantity, as demonstrated by Ebbinghaus[12], but perhaps more importantly, also increase the comprehension of the material learned[10].

However, if the time between learning sessions is too long, then forgetting occurs before the next learning session takes place[12]. We suggest that when students take Dynamics and Machine Design I sequentially, it is likely the time between learning and application is too long and significant forgetting of material occurs before it can be applied. By learning and applying dynamics principles in the same semester, the students were able to benefit from a more optimal distribution of learning sessions without the cost of too much time between sessions.

The second major factor, application of learned concepts, is thought to promote retention in several ways. By applying the concepts they had learned, students were potentially able to focus on the relationship between different concepts, and also the relationship between each concept and its application. This focus on the association between concepts encourages more elaborative processing, which has been shown to increase retention[1,2]. In addition, application of learned concepts is also thought to facilitate organization of the material, thereby enhancing retention[8]. Furthermore, another approach used in this study also likely enhanced retention. In this case of the students' application of concepts, they were asked to generate their own strategies to reach project goals. Such generation of responses has also been shown to enhance retention[13]. This effect occurs even when comparison groups are given the same amount of exposure to the information, and is thought to be related to retrieval practice[8].

Thus coupling the Dynamics and Machine Design I courses likely yielded better student projects for a multitude of reasons, including spacing, elaborative processing, greater organization of material, the generation effect, and retrieval practice.

Conclusions

Teaching Dynamics and Machine Design I concurrently appears to have strengthened the students understanding of both classes better. This was evident by the high quality of the joint design projects that he students presented. The reinforcement of the basic concepts learned in Dynamics by applying them almost sequentially in Machine Design I should increase their retention of the concepts learned in both courses.

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