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Article

The impact of conceptual versus memorization-based teaching methods on student performance

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SUMMARY

Recently, the primary focus of high schools has shifted towards success on standardized testing in reading and math, resulting in less time for optional subjects like economics. This leads to 'curriculum narrowing,' where students are only taught test-relevant knowledge. With greater focus on memorizing assessed knowledge, students' understanding may be limited by the lack of conceptual learning. This is exemplified in the case of business-economics, where concepts like marginals stem from calculus — explaining these relationships can help students apply their knowledge more broadly. Without these links, students may miss deeper relationships between subjects, limiting their ability to utilize their knowledge outside of test-based contexts. We aimed to investigate whether students would perform better if key conceptual mathematical elements were connected to give a deeper understanding of the subject. We hypothesized that students would perform better on testing if they were taught business-economic models conceptually, compared to students taught the models through memorization. During the study, we taught two groups of students over a two-week period. One group focused on memorization-based learning, while the other focused on a more conceptual understanding of the subject, which included deeper mathematical explanations. While neither group showed significantly better performance, the concept-based group's scores tended to be closer to the average, suggesting an advantage in consistency of student performance. The increased consistency may suggest students of all levels attained a deeper understanding of the content, benefiting long-term retention. Further research should assess long-term effects of these methods and account for students' prior mathematical abilities.

INTRODUCTION

With the increasing popularity of standardized testing in high schools worldwide, schools aim to let all students compete on equal ground (1–4). However, standardized testing brings the significant drawback of curriculum narrowing, where schools heavily emphasize studying mandatory subjects, like reading and math, at the expense of time for other non-mandatory subjects (5). If these optional subjects are also assessed by standardized tests, such as AP exams (6), schools may restrict teaching to only tested content, reducing opportunities for broader learning. Additionally, since subject-specific tests only cover the tested subject, schools may assume that teaching interdisciplinary links to students provides no benefit to test scores. This issue is exacerbated if school funding is tied to performance on standardized test scores, adding financial incentive to focus on teaching exclusively test-relevant knowledge. As a result, students are often not taught to form connections between subjects. An example of this is high school business-economics, which in many cases includes minimal mathematics despite several key concepts stemming from calculus.

Compared to memorization-based methods, it has been shown that multidisciplinary learning may improve student performance (7). Specifically, providing links between subjects increases student motivation and more easily teaches real-world applications, even in more abstract subjects like mathematics. However, this manner of teaching depends heavily on the commitment and coordination of teachers and administrators to integrate the multidisciplinary aspects into curricula. On the other hand, memorization-based learning holds its own advantages, like strengthening the brain's information-retaining ability and freeing up cognitive space for creative thinking, but may depend more on students' individual memorization abilities (8).

In addition to being a required subject for students in schools worldwide, mathematics is also interconnected with other subjects, like physics and economics, which may be optional to study (9–11). While an understanding of higher-level mathematics is required in some of these subjects, such as physics, others can be taught to high school students using only basic knowledge like percentage change and elementary operations, despite economic concepts like marginals being rooted in more advanced topics like calculus (12–14).

However, given the quantitative nature of subjects like economics, utilizing a multidisciplinary educational approach by including deeper mathematical knowledge into curricula may improve student comprehension (15). In particular, students may benefit from learning basic calculus to understand relationships between variables in terms of rates of change (*e.g.* marginals), and statistics for improved interpretation of economic data and probabilities of predictions. In this case, the more memorization-based learning methods, which have historically dominated education and are still reinforced by standardized testing, may not be as effective as giving students a more conceptual understanding of subjects with a curriculum that integrates mathematics (16). On the other hand, some experts in education favor memorization-based learning, even in the sciences — showing that opinions are divided. Would teaching business-economic models

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conceptually improve student performance compared to a memorization-based approach?

Our hypothesis was that students would perform better on testing after a two-week teaching period if they were taught business-economic models conceptually, compared to students taught the models through memorization. The group taught using concept-based teaching methods would be given mathematical explanations not included in the curriculum syllabus, such as the derivation of formulae through basic calculus, to emphasize relationships between economic variables. There would also be greater emphasis on real-world applications to illustrate economic principles. Meanwhile, the memorization-based group would only be taught content directly mentioned in the course textbook and train students' rote learning abilities through completing more worksheets and exercises (17). We found no significant difference in overall performance between the methods, but we did see suggestions of notable differences in the consistency of student performance. Specifically, the variance of the concept-based group's scores decreased greatly after the teaching period, potentially indicating a higher effectiveness for teaching students of a wider range of ability. While neither method proved superior in the short term, the increased consistency of the concept-based method may indicate greater retention in the long term. Further research should investigate the long-term effects of these methods, as well as consider students' individual mathematical abilities.

RESULTS

To determine whether our hypothesis was correct, we taught two economics classes identical material using different teaching methods: one emphasized memorization of the content, while the other focused on providing additional mathematical explanations and real-life applications. The material chosen included business models of revenue, cost, and profit. The students completed a baseline test before the teaching period and a final test afterwards, with each test marked using the same criteria.

Evaluation of improvement within groups

To assess the effectiveness of each teaching method, we conducted a paired-sample t-test on the baseline and final scores (as percentages) to evaluate the improvement from the start to the end of the teaching period within each group. We performed this test to compare the baseline and final scores within a class, measure the difference, and determine whether there was a significant increase in students' understanding of the material after the respective teaching method was applied.

In the memorization-based group, the mean baseline and final scores did not differ significantly, being 55.7% (8.92 out of 16) and 56.9% (10.25 out of 18), respectively. However, the standard deviations increased dramatically, being 15.6% for the baseline test and 22.2% for the final test, representing a relative increase of 42.3%. The memorization-based group's higher standard deviation indicates greater inconsistency in student performance, suggesting significant reliance on individual memorization skills, which can vary widely. There was no significant difference in the average baseline and final scores (paired-samples t-test, $p = 0.769$, **Figure 1**).

In the concept-based group, the mean baseline and final scores were again not statistically significantly different (paired-samples t-test, $p = 0.991$), being 59.7% (9.55 out of 16) and 59.6% (10.73 out of 18), respectively. The change in standard deviations, however, did not match that of the memorization-based group, decreasing from 18.8% for the baseline test to 15.1% for the final test, representing a relative decrease of 19.7% (**Figure 1**).

Comparison of final scores between groups

To compare the effectiveness of the two teaching methods while adjusting for ability, an Analysis of Covariance (ANCOVA) was conducted on each group's final scores, with baseline scores as a covariate. This controls for students' prior knowledge using baseline scores, accounting for pre-existing differences in students' abilities and prior knowledge to accurately measure the increase in performance using their final test scores. We performed this test to determine whether one of the teaching methods was significantly more effective in improving the students' understanding of the material.

After adjusting for baseline scores within each group, the ANCOVA analysis showed no statistically significant difference between the two groups' final scores relative to baseline performance (one-way ANCOVA, $p = 0.372$, **Figure 2**). As such, neither teaching method showed a clear advantage in improving student performance.

DISCUSSION

As standardized testing becomes a formalized part of high school education, time allocation for subjects not included in these tests (such as economics) decreases. As such, in-depth explanations deemed as optional get stripped away from these curricula to accommodate for decreased teaching time. These in-depth explanations often contain links between subjects, like the relationship between concepts in economics and their mathematical origins. Removing them disconnects otherwise relevant subjects. Therefore, students are often taught to remember facts about economic variables, such as the shapes of various curves in cost and revenue diagrams, without comprehensive explanations.

Do these disconnections cause lower overall student performance? Our study aimed to answer that question by re-connecting relevant parts of mathematics and further applying economics to the real world. Our hypothesis was that students would perform better on a final test if they were taught business-economic models conceptually compared to students taught the models through memorization. Specifically, the concept-based group would include more mathematics explanations and applications, while the memorization-based group would be taught with the more traditional approach of providing students with further exercises aimed at improving recall of the content taught.

Our findings do not support our hypothesis. The non-significant one-way ANCOVA between the groups' final scores suggests that neither teaching method proved superior in the two-week period. Specifically, the memorization-based group had mean baseline and final scores of 55.7% and 56.9%, respectively, and the concept-based group had mean baseline and final scores of 59.7% and 59.6%, respectively. The lack of significance may be partly explained by the experiment's short duration, as previous studies have shown information retention continuing to decline after 31 days. However, the standard deviation of the memorization-based group increased 15.6% to 22.2% (relative increase of 42.3%),

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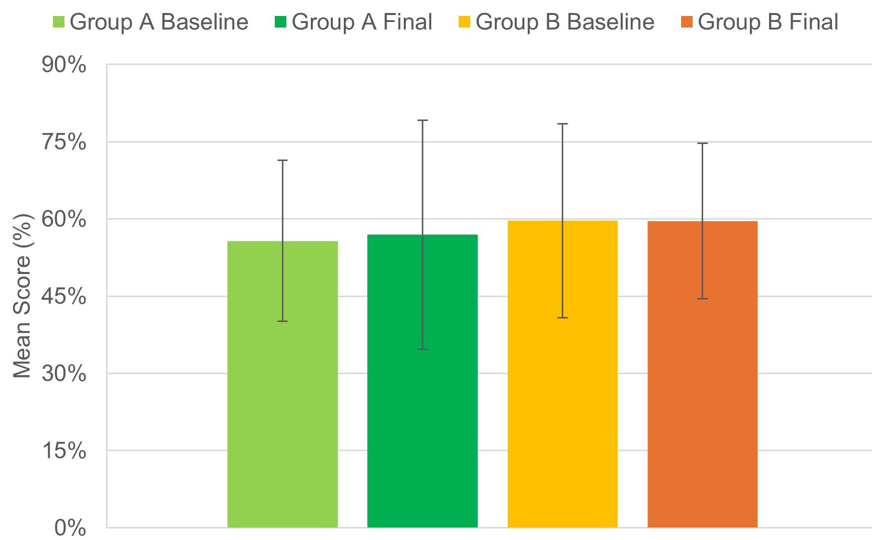

Figure 1. Comparison of baseline and final scores for the memorization-based and concept-based group. Group A was the memorization-based group and group B the concept-based. Students completed a baseline test before the teaching period, and a final test at the end of the study. Data shown as mean ± standard deviation percentage scores. Two-way paired-samples t-tests between baseline and final scores indicate no significant differences; Group A: $p = 0.769$, Group B: $p = 0.991$.

indicating greater variability, while the concept-based group's standard deviation decreased from 18.8% to 15.1% (relative decrease of 19.7%), suggesting more consistent performance among students.

The memorization-based group's increase in standard deviation shows a substantial increase in the variance of student performance, indicating greater inconsistency in the success of learning objectives. In the context of the group's memorization-based methods, this increase suggests students relied much more on their individual memorization capabilities, which can differ between students greatly (19). Because it is difficult to control for students' memory abilities compared to base mathematical skill (done by ensuring all students were passing GCSE mathematics), it is possible some students had significantly higher rote-memory abilities than others in the memorization-based group, causing the observed high variance. Due to the influence of students' memory abilities on performance, schools using primarily memorization-based methods should put emphasis on training this ability in its students.

We attributed the decreased variability in the concept-based group by 19.7% (from 18.8% baseline to 15.1% final) to the concept-based methods making it easier for students of all academic levels to remember taught material. The added emphasis on graphical explanations in conjunction with mathematics, such as entry-level calculus used to explain the gradients of curves, allowed students to remember concepts both verbally and visually, increasing the ease of information retrieval; this is called dual coding.

Our study provides a unique contribution to the field of interdisciplinary education. One previous study showed results similar to our hypothesis, where integrating mathematics into economics education increased student critical thinking skills and learning outcomes, whereas another study advocated for memorization-based learning being superior to concept-based methods for student performance. While both studies focused directly on student performance, our findings highlight the difference in consistency of performance between methods, rather than a difference in performance itself.

We theorize that our study was inconclusive in finding a direct difference between student performance in part due to its short two-week timescale. According to the Ebbinghaus "forgetting" curve, which models how quickly people forget information, there is an initial rapid drop in retention of information that continues to drop even two months after instruction (18). As such, repeated testing of students over a multi-month study period would give a better indication of long-term retention rates for each method. A longer timescale would also be more indicative of the typical high school learning process, as information taught is examined months later in a graded final exam. Additionally, a larger sample size may also make the difference in methods more measurable.

Moreover, while our study incorporated students' level of education in economics with the baseline test, we did not control or account for students' mathematical ability or knowledge. By explaining the behavior of the business-economic models, the concept-based group's teaching aimed to utilize elaborative interrogation, a learning strategy where students question the explanations for the content to attain a deeper understanding. This is only successful if the knowledge base (mathematics, in this case) is well-developed (20). If further studies are conducted into incorporating mathematics further into parallel subjects, individual students' mathematical skill must be considered.

Further research should investigate the long-term effects of these teaching methods over several months to more closely replicate the high school learning process. Additionally, future studies should control for students' individual mathematical and memory abilities to clarify which method is most effective for students at each level of ability. This is because, for example, focusing on mathematical explanations may favor students with a higher level of mathematics, and memorization-based methods could be most useful for students with better memory

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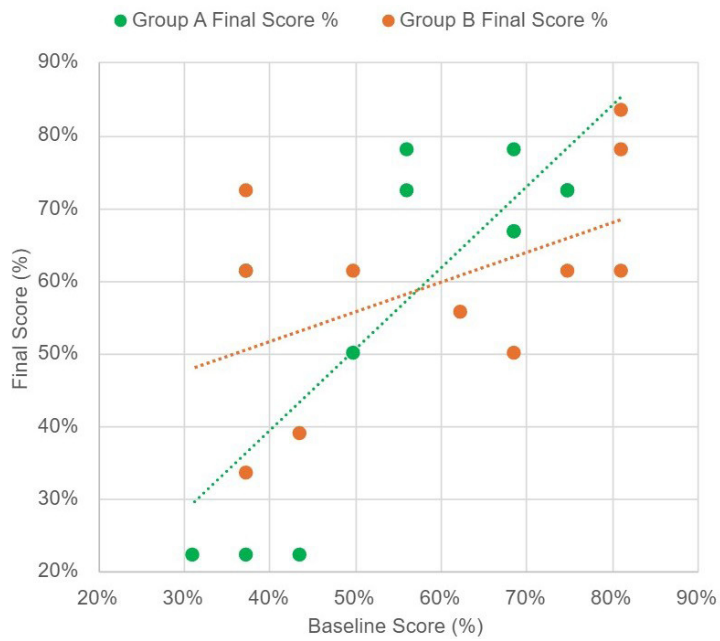

Figure 2. Comparison of final test scores with baseline scores. Group A was the memorization-based group and group B the concept-based. Percentage final scores of both groups against the corresponding percentage baseline scores, with trendlines showing linear fit. One-way ANCOVA shows no significant difference between groups, $p = 0.372$.

abilities. Additionally, the demonstrated interest of students for each method should be considered, as motivation can affect learning outcomes and performance.

The generalizability of our research is also limited due to its narrow student population. The small sample size of two classes, combined with students attending a private school in a major European city, means that this study may not be entirely applicable to schools from different socioeconomic areas. Future research should be conducted in a variety of schools to determine the effectiveness of both methods with the resources available in each case. Results may also differ in countries utilizing other school systems, educational priorities, and curricula, which should also be investigated. Research should also explore other high school subjects to see which subjects are best suited for conceptual teaching methods.

Despite its limitations, our research provides insight into the effects of connecting key mathematical concepts to parallel high school subjects like business-economics. While neither the memorization method nor the conceptual method proved superior in the short term, the concept-based method appeared to make learning more consistent among students of all levels, potentially improving long-term retention of the material. Further research into the long-term effects of these methods would be required to confirm these findings and improve the teaching methods used in high schools for students of all academic levels.

MATERIALS AND METHODS

Participants

Both groups received eight one-hour lessons over two weeks, which were conducted in the same classroom with identical learning materials. The study material's focus on graphs and the relationships between economic variables allowed for the implementation of deeper mathematical explanations through calculus and algebra, differentiating the conceptual teaching method from the standard curriculum. Students were also expected to memorize formulae and the names of various graphical data points, potentially increasing the effectiveness of the memorization-based method. Specifically, the baseline test assessed prior knowledge of micro- and business-economics taught in IAS (International Advanced Subsidiary) Economics, such as demand, costs, and revenue. The final test assessed the new content taught over the two-week teaching period (not including the additional mathematics taught to the concept-based group). The lesson schedules differed across the groups, but both groups were taught eight hours in total and had a comparable amount of homework to complete outside of class. The baseline test served as a means to account for individual students' abilities in economics, while the final test scores would measure how much new material students had successfully learned over the teaching period.

For the teaching period of the study, we selected two classes of 11 and 12 International A-Level (IAL) economics students, 7 and 9 of which also studied IAL mathematics, respectively. The students were of mixed genders and 16–18 years old. Each student had completed their GCSEs the year prior, including passing GCSE mathematics, to ensure a sufficient background to understand the mathematical explanations in the concept-based materials. The teaching period took place at the end of the academic year, so each student had also studied the first year of IAL economics before participating in the experiment. This ensured that all students had similar pre-existing knowledge of economics, as well as an interest in the subject (these students chose to take IAL economics as an elective). Students attended a fee-paying private secondary school in a major European city. The students were from diverse geographic backgrounds, including Eastern and Western Europe, North and South

America, South Asia, and the Middle East. One group was randomly selected to focus on memorization-based learning, while the other group would focus on concept-based learning.

Baseline test

At the start of the first lesson, each student completed a baseline test to measure their prior knowledge of the subject. The baseline test covered revenue, cost, and profit at varying levels of difficulty (**Table 1**) to give an accurate assessment of each student's knowledge of business-economics, as well as basic micro-economic models of supply and demand (taught previously). The baseline tests were all marked using the same marking criteria by the same marker to ensure scoring was consistent among students.

Teaching period

The lessons covered the revenue, cost, and profit sections of the IAL Economics Unit 3, 2018 specification. All students always had access to a copy of the course textbook to read and follow along, notebooks for taking notes, and a whiteboard for the teacher to illustrate explanations. The only difference between groups was that, in the conceptual-based group, the teacher gave more graphical illustrations on the whiteboard while providing more detailed mathematical explanations. The choice of topic was motivated by two factors: first, the study material contained significant graphical content, allowing for mathematical explanations to be easily incorporated into the program; second, the study material did not already include all relevant mathematical explanations, making it easier to integrate additional explanations.

Both groups had the same instructor during the teaching period to eliminate variability in the educational skill of different instructors. The instructor had a master's degree in mathematics and was also pursuing a PhD in STEAM (Science, Technology, Engineering, Art and Mathematics) education, giving her the necessary background to teach the additional mathematical explanations in the concept-based group. The instructor's experience with both mathematics and education likely had a positive influence on her ability to deliver the concept-based method, especially in making complex ideas more accessible. The concept-based group was taught economic models with an additional emphasis on mathematical explanations and real-life applications from outside the curriculum to provide students with a deeper understanding of the content. Specifically, this included defining and explaining relationships between variables such as elasticities, marginals, averages, and totals; derivations of taught graphical models using basic calculus and algebra; and providing real life applications where possible.

The memorization-based group was only taught content covered by the IAL Economics Student Book 2 textbook in chapters 4, 5, and 7 (revenue, costs, and profits respectively), with a greater emphasis on doing practice questions and worksheets based on questions from past versions of the IAL exam to solidify memorization, including primarily multiple-choice, calculation, and short-answer questions. Some questions were taken directly from past tests, while others were designed by the instructor to test specific concepts.

Final test

In the final lesson of the two-week period, students completed a final test to assess their reception of the newly taught content. The final test questions (**Table 2**) covered the taught content at a variety of levels, ranging from questions about basic knowledge to questions requiring critical thinking and deeper understanding to solve. The questions were designed to reflect the original learning objectives of the business-economics content by including content on revenue, costs, profits, and graphs. To fairly assess both groups, the test contained both questions with factual recall, like definitions, and questions on mathematical concepts, like relationships between gradients of variables. Both groups took the same test to measure any difference in students' performance across the two methods. Similar to the baseline test, all final tests were marked against the same set of criteria by the same marker so scoring was consistent.

Statistical analysis

To evaluate improvement from the start to the end of the teaching period, two-tailed paired-samples t-tests with significance levels of $p < 0.05$ were conducted on each group's baseline test and final test scores. This test was done to determine if the respective teaching methods led to statistically significant improvements in students' understanding of the material.

To compare final test scores between the two groups while adjusting for individual student ability, an ANCOVA test with a significance level of $p < 0.05$ was conducted on the final scores between groups, with each group's baseline scores as a covariate. ANCOVA was chosen as it can adjust for students' prior knowledge and ability using the baseline scores, hence measuring a relative increase in performance and not favoring the group with naturally stronger students.

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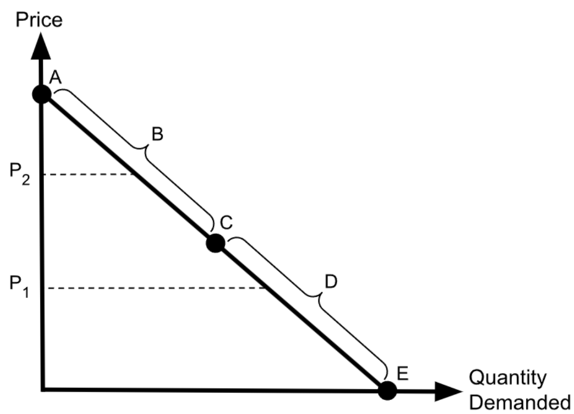
APPENDIX

Baseline test
1a. Briefly (1 sentence) define marginal revenue.
1b. Briefly (1 sentence) define average fixed cost.
1c. Briefly (1 sentence) define break even.



2a. When demand for a product is elastic, should a firm increase or decrease the price of its products to increase revenue?
2b. If a firm is currently producing at price point P1 which is in segment D, should the firm increase or decrease its price to increase revenue?
2c. Conversely, if another firm is producing at price point P2 in segment B, should the firm increase or decrease its price to increase revenue?
2d. Using your previous 2 answers, at what points and/or segments is revenue maximized?

3a. A carpenter makes chairs and sells them for 100 Euros each. The total cost column shows how much it costs for the carpenter to make the number of chairs shown in the output column. Complete the table given below:

Output	**Total Revenue**	**Marginal Revenue**	**Total Cost**	**Marginal Cost**	**Total Profit**
0	0	-	0	-	0
1	100	100	80	80	
2			140		
3			200		
4			300		
5			500		
6			800		

3b. What is the price elasticity of demand for the chairs?
3c. If the carpenter wants to make as much profit as possible, how many chairs should he make?
3d. What is the relationship between maximum profit and marginal cost & revenue?
3e. As you can see, total cost does not increase by the same amount each time. What could cause the cost of chair production to increase at a greater rate (real life example), and what is this effect called?

Final test
1a. A business has increasing linear total revenue in relation to output. Which one of the following describes their marginal revenue: rising; constant; negative; falling.
1b. The table shows the total costs of a battery manufacturer at different levels of output. Which one of the following is the average variable cost at 300 units: £15; £27; £29; £44.

Output	Total costs (£)
0	4 500
100	8 000
200	10 700
300	13 200
400	15 300

1c. Between which of the following outputs do diminishing returns start to set in: 1-2 units ($16-$19); 3-4 units ($22-$27); 5-6 units ($33-$40); 6-7 units ($40-$48).

2a. The demand for a product is such that the price (in $) is equal to 10 - (quantity). For each level of quantity from 0 to 10, calculate the total revenue and Price Elasticity of Demand.
2b. On graph paper, plot the firm’s demand and total revenue curves.
2c. When is total revenue maximized?
2d. How might firms be able to increase their levels of total revenue?

3. Fill in the table below.

Output	TFC	AFC	TVC	AVC	TC	AC	MC
0	100	-	0	-	100	-	-
1	100	100	10	10	110	110	10
2	100	50	16		116		
3				7			5
4			32		132		11
5		20			145		
6			62				

4a. Fill in the missing words: marginal cost can be defined as the _____ in total cost from the production of the _____ unit of output.
4b. Fill in the missing words: marginal _____ can be defined as the change in total _____ from the sale of one more unit of output.

5a. The marginal cost curve slopes upwards because of which of the following: diminishing marginal utility; diminishing marginal returns; technological inefficiency; economic inefficiency.
5b. When average cost is falling, which of the following must marginal cost be: falling faster than average cost; less than average cost; either greater, equal to, or above marginal cost; not falling.
5c. At which of the following points does minimum marginal cost occur: when total product is maximized; when marginal product of the variable factors is minimized; when factors are combined in their best possible proportions; when the average product of the variable factors is at a maximum.