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Effects of Quantity of Instruction on Time Spent on Learning and Achievement

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ABSTRACT

This article evaluates the extent to which quantity of instruction influences time spent on self-study and achievement. Data on both time variables and achievement were collected in a problem-based medical curriculum. The results suggest that time spent on self-study is primarily a function of the degree of time allocated to instruction. The association between these time variables may be described as a trade-off mechanism. A considerable amount of variance in achievement, 25%, is accounted for by the ratio of time spent on self-study to quantity of instruction. Hence, instruction time proved instrumental in influencing time spent on self-study and achievement. The present investigation demonstrates that raising instruction time is only effective to the extent that students spend an increased amount of time on self-study.

INTRODUCTION

In higher education learning takes normally place apart from lectures, tutorials, seminars, or any other formal classes. Teaching in higher education is often seen as an instructional process, designed to ensure that students learn outside the classroom. The primary purpose of instruction is the facilitation of learning. In the majority of classes, the amount of

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instruction time allocated to a subject area will require additional time spent on self-study to master the course's objectives. In-class instructional time is usually devoted primarily to course readings.

Research on the influence of time-related variables on the learning process has shown that time spent on learning appears to be a crucial factor in influencing achievement. In their review on the relationship between time and learning, Fredrick and Walberg (1980) found that 23 out of 25 studies report positive correlations between measures of time and learning. Depending on how time was operationalized, the association between time spent on learning and achievement resulted in correlations ranging from .13 to .71. A major focus of educational research has been how differences in achievement results among individual learners, may be explained by time spent on learning (Gettinger, 1984). More recently, increased attention is given to identifying factors in the instructional design that influence time variables and in turn achievement (Reynolds, & Walberg, 1991). In addition, studies have been conducted in the area of higher education that focus on the critical question what kind of modifications are required in the organization of instruction, to maximize the effectiveness and efficiency of time use by students and teachers (Vos, 1985; Van der Drift & Vos, 1987). Particularly the work of Vos (1985), has provided researchers with a framework to investigate the intrinsically related variables of allocated instruction time and time use by students.

The present study attempts to examine the relationships between time variables and academic achievement in higher education. The primary emphasis is on the relationship between alterable time variables in the instructional design, especially in-class instruction time and time spent on self-study. In addition, the association between time variables and achievement is examined.

TIME SPENT ON LEARNING AND ACADEMIC ACHIEVEMENT

Historically, it has been in particular Carroll's (1963) work that stimulated the development of instructional theories that stress the decisive role of time to learn (Bloom, 1976; Cooley & Leinhardt, 1980; Walberg, 1981). Carroll's (1963) model suggests a complex, dynamic interaction among learner characteristics, time factors and instructional variables. His theory maintains that individual students will master instructional objectives to the extent that they are allowed and are willing to invest the time needed to learn. His theory specifies that degree of learning is a function of time actually spent on learning and time needed to learn. Carroll stated that achievement is maximized if time spent increases to the point where it equals the amount of time actually needed to learn.

Recent studies focus in particular on the influence of time variables on achievement (Anderson, 1984a, 1985; Carroll, 1984; Gettinger, 1985; Fisher & Berliner; 1985; Karweit, 1989; Dickinson & O'Connell, 1990; Britton & Tesser, 1991). Gettinger's (1985) studies are a case in point. She conducted a series of studies in an attempt to evaluate Carroll's model in detail. She found, for example, that the ratio of time spent to time needed does appear to be strongly related with degree of learning (r = .51) and retention (r =.60). Time spent correlated .40 with degree of learning and .38 with retention. Time allocated correlated .35 with degree of learning and .30 with retention.

The apparent appeal of Carroll's model consists of identifying time-related variables affecting individual learning. Most of these time-related variables - such as perseverance, ability, aptitude and time needed to learn - can be considered as learner characteristics. Carroll's model was conceptualized as an individual differences framework. He tried to explain the degree of individual student learning of two individual time variables (time spent and time needed). However, classroom learning is also affected by variables outside the learner, such as opportunity to learn and instructional quality. Schooling is often organized to provide group instruction, with fixed time periods allocated to curricular contents. Teachers of classes do not have much time to devote to individual concerns and individual differences in time needed to learn.

Therefore, several models have been developed to refine Carroll's theory and adapt it for classroom settings. These models place greater emphasis on time factors external to the learner and incorporate features of the instructional process itself at the classroom level (Harnischfeger & Wiley, 1976; Cooley & Leinhardt, 1980; Walberg, 1981; Parkerson, Lomax, Schiller & Walberg, 1984; Reynolds & Walberg, 1991).

For example, Harnischfeger and Wiley (1976) developed a model of classroom learning based on the concept of *quantity* of education. According to Harnischfeger and Wiley (1976) the main issue is how much instruction time is used in the classroom and for what purpose, given general constraints such as maximum time available for instruction, e.g. length of school day or school year. For them, Carroll's factor of opportunity or time allowed, in combination with how time is used during instructional events, determines achievement. Harnischfeger and Wiley (1976) indeed found that in schools in which students receive more instruction, students tended to have higher achievement gains. A similar result is reported by Cooley and Leinhardt (1980). They found that Carroll's factor of opportunity in itself bears little relation to learning gain. Use of instruction time was thought to have more impact on learning than scheduled time per se.

Walberg's (1981) nine-factor theory of educational productivity represents an advancement over the Harnischfeger-Wiley and Cooley-Leinhardt models. It identifies variables that are adjustable in teaching practice to improve achievement. This theory elaborates Carroll's emphasis on time variables related to learner characteristics: perseverance, aptitude, and time needed. In addition, it incorporates the significance of variables specified by the Harnischfeger-Wiley and Cooley-Leinhardt models, which are related to features of the instructional process: instructional quality and quantity of instruction. Walberg (1981) suggests that quantity and quality of instruction are both factors amenable to intervention and may possibly lead to improved achievement. Reynolds and Walberg (1991), evaluating the educational productivity model, found empirical support for the validity of this notion. They showed that quantity of education, expressed as the sum of class attendance and hours of homework, had an almost equally large effect on achievement as the students' prior knowledge.

TIME ALLOCATED TO INSTRUCTION AND TIME SPENT ON SELF-STUDY

Research concerning the effects of allocated instruction time on time spent on learning outside the classroom, shows that allocated instruction time is a critical factor in the instructional design to enhance learning in higher education (Vos, 1985; Van der Drift & Vos, 1987). Furthermore, this research showed that time allocated to instruction has a considerable potential for influencing time spent on self-study. Vos (1985) conducted a series of detailed studies of time spent on self-study and time allocated to instruction in various higher education curricula in the Netherlands (ranging from medicine to social sciences, law, and engineering). The investigator's main interest was how to maximize time spent on self-study (hours of homework, hours spent on individual study) as a function of instruction time (hours of class attendance). He observed that differences in the amount of time spent on self-study are largely determined by the number of hours allocated to instruction. Increased instruction time resulted in more time spent on homework or self-study. However, excessive instruction time (more than twenty hours per week), actually consumed time that would otherwise be spent on homework. On the other hand, a limited number of hours (less than 10 hours per week) allocated to instruction time was associated with a lesser than expected amount of self-study, compared to self-study time spent under intermediate levels of instruction time. It was also found that diminishing returns show up when instruction time increases indefinitely, while other variables are held constant. This implies that increasing amounts of instruction time beyond an optimum may be associated with an actual decrease in time spent on self-study. It was concluded that more instruction time is not always better, because surplus of instruction time may eventually affect educational effectiveness due to lack of time for self-study.

The consequences of the Vos' (1985) studies are that self-study time, and hence, achievement, could be boosted by manipulation of instruction time. Given that instruction time and time spent on self-study are scarce resources in higher education, this may provide teachers in higher education with tools for optimizing the effectiveness of their instructional design. The present investigation applies the framework developed by Vos (1985), to examine the relationship between allocated instruction time and time spent on self-study in a medical curriculum. The second purpose of this study was to elaborate this framework and incorporate the academic achievement variable next to the time variables: allocated instruction time and time spent on self-study.

METHOD

Description of the Educational Program

The data used in the analysis were obtained from the medical school of the University of Limburg in the Netherlands. The educational approach of this medical school is based on the principles of problem-based learning (Norman & Schmidt, 1992; Schmidt, 1983). Problem-based curricula are based on the principle that students have an active role in learning. According to Schmidt (1983) problem-based learning optimizes student learning because discussing problems facilitates the activation of relevant prior knowledge which, in turn, enables students to process new information in a better way. This requires a view on higher education in which learning is more important than teaching. Consequently, self-directed learning must be stimulated explicitly and sufficient time should be available to spend on individual study. It may therefore be evident that in designing problem-based curricula opportunities are created to optimize time spent on self-study in relation to instruction time. The common model of problem-based learning at this medical school is that instruction (working in small group tutorials, skills training etc.) should facilitate learning of the assigned materials. Instruction intends to match what students will read in the assigned materials and what is tested on an exam.

The model of problem-based learning may be characterized as follows. During each course, students meet twice a week for a two hour small-group tutorial (eight to twelve students) in which problems are analyzed and learning goals formulated. Students are randomly assigned to tutorial groups. A collection of carefully constructed problems is presented to these small groups. These problems usually consist of a description of a set of observable phenomena or events which are in need of some kind of explanation. In medical education, usually a patient is described including the presentation of complaints with a number of signs and symptoms. Essential to the method is, that students' prior knowledge of the problem is, in itself, insufficient to understand it in depth. During initial analysis, dilemma's will arise and questions will come up that can be used as learning goals for subsequent, individual, self-directed learning. While analyzing a problem in a prescribed, systematic fashion, the group is guided by a tutor, usually a member of the faculty. His or her task is to stimulate the discussion, to provide students with some subject-matter information, to evaluate progress being made and to observe the extent to which each group member contributes to the group's objectives.

Each curriculum year in the first four years contains six six-week courses organized around interdisciplinary themes central to medicine. The first four curriculum years consist in total of 20 obligatory courses (required for all students) and four elective periods (allowing students to follow courses of their own choice). Approximately 130 students attended each obligatory course. Only one course per six-week period is scheduled in a curriculum year. Every course is programmed at a time schedule of about 40 hours per week. Scheduled activities usually included four hours a week of small-group tutorials, two to four hours of lectures, and two to four hours of training in medical skills. Instruction time is kept at a minimum in this program to provide for optimal opportunity for self-study.

Sample

The study included data on 65 obligatory courses - each course representing about 130 students - in five consecutive academic years. This amount is somewhat lower than theoretically possible (100 courses). Data from courses were only included in the analysis if these courses satisfied two criteria: 1) attendance rates should be available for *all* instructional activities within a course (for 10 courses attendancy data were not complete), 2) courses should be typical for a medical curriculum (e.g. biomedical or clinical courses). Application of the second criterion resulted in exclusion of 25 obligatory courses (introductory courses on problem-based learning; courses on the relationship between psychology and medicine; courses on nursing).

Variables

The independent variable in this study was *quantity of instruction* (QI). Quantity of instruction was defined as the total time per course spent on instruction: Attendance of tutorial groups, lectures, skills training and other activities. Quantity of instruction may be regarded as a curriculum planning variable: quantity of time allocated in an educational program for instruction activities. For all instruction activities percentages of attendance were available. For each instructional activity the number of instruction hours was multiplied with attendance rate for this activity. This was defined as the net amount of instruction time for an instructional activity. Quantity of instruction for a course was computed as the sum of hours spent on instructional activities (corrected for attendance rates). In the present study QI is expressed as the average quantity of instruction per week during a course.

The dependent variables in this study were *time spent on self-study* (TSS), *total time spent on education* (TTE) and *achievement.* TSS was measured by a self-report procedure. This procedure typically depends on students' recall of the amount of self-study spent over an extended time (Dickinson & O'Connell, 1990). At the end of course, one or a couple of days before the final examination, students were asked to estimate the number of hours per week spent on self-directed learning activities. Preliminary studies in problem-based curricula have shown that this method provides a reliable and valid indicator of TSS (Gijselaers, 1988; Moust, 1993). Moust (1993), for example, conducted a study on learning activities of students of the problem-based law school (also the University of Limburg, the Netherlands) using two methods of time measurement: 1) a self-report procedure similar to the one used in the present study, and 2) a log method. The log method requires students to record how much time they study during a specific time such as a day or a week. The log method has the advantage that the interval between studying and reporting is less than in self-report methods and, may therefore be less distorted by forgetting. Moust (1993) required students to record *all* their study activities and time spent on independent learning in a logbook. In addition, he required students to estimate TSS at the end of the course on the same evaluation instrument as used for the present study. The data showed that, at the course level, estimates of TSS per week were exactly the same for both methods. At the individual level both measures correlated .60. The results from Moust's (1993) study support the validity of the measurement of the dependent variable in the present study, given that under similar conditions (problem-based curricula, measurement at the course level) with similar instruments, the same estimates for TSS were found.

Total time spent on education (TTE) was calculated as the sum of quantity of instruction and time spent on self-study. That is: TTE = QI + TSS. The TTE measure reflects the total number of hours per week spent on education.

Achievement was measured by standardized objective exams. Students who attended the courses were required to take these exams, immediately at the end of the course, over the assigned readings. All exams had the true-?-false format. Test items were designed by the teachers responsible for the course. The construction of exams was such that they should be directly tied to what is contained in the assigned readings, the problems discussed in the tutorial groups, and contents of additional instructional activities in medical skills training. The major goal of the tests was to assess student's knowledge about the course contents and provide students information about their mastery of course contents. The *percentage of correct answers* for a test was the dependent variable. This score was computed by dividing the number of correctly answered items through the number of items contained in the test. Each test contained approximately 160 items, ranging from 60 - 306 items. Fifty percent of the tests contained between 143 and 189 items (mean number of items for all tests = 162, Sd = 42). The reliability of the tests was estimated through internal-consistency reliability's (Cronbach's alpha) for the %correct score of the individual tests. In the present study test reliabilities were above .80. The average reliability for tests containing more than 150 items was about .85 or higher.

Procedure

Data were collected at the individual level. For purposes of analyses, data on variables included in this study were aggregated at the course level. An additional time variable was computed for the present study. Following the theoretical framework of Vos (1985), a time spent on self-study/quantity of instruction ratio score (TSS/QI) was calculated for each course, by dividing the time spent on self-study score by the quantity of instruction score. The TSS/QI ratio score represents the time spent on self-study return to one hour instruction time: the amount of time spent on self-study given the allocated number of instruction hours. For example, a ratio of 3 for a particular course can be interpreted as follows. Given the total amount of instruction time (for instance, 10 hours scheduled instruction time per week); every hour of instruction time results in 3 hours time spent on self-study.

Regression analyses were computed to investigate the association between QI, TSS, TSS/QI and achievement scores. The ratio TSS/QI was regressed on both a linear and a natural logged form of QI. The natural log model was applied following suggestions by Vos (1985). According to Vos, the association between TSS and QI may be expressed as the following exponential function

$$(1)\ TSS/QI = ae^{-(b*QI)}.$$

TSS denotes the average net time spent on self-study, QI is the average amount of allocated instruction time, and a and b are regression constants. According to this function, an increase in QI will result in an exponential negative decrease of the ratio TSS/QI. Vos showed that his data, consisting of 18 data-points at the curriculum level, fitted this curve perfectly ($R^2 = .99$; $a = 7{,}14$; $b = .00317$).

To calculate the a and b weights for regression equation (1) applied to our data, the natural logged version of this equation was taken. This equation can be written as

$$(2)\ \ln\,[TSS/QI] = \ln\,[ae^{-(b*QI)}].$$

Equation (2) is then rewritten as

$$(3)\ \ln\,[TSS/QI] = \ln\,(a) - b(QI).$$

Equation (3) is a linear regression equation where ln(a) denotes the intercept and where b(QI) represents the slope of the regression equation. Following the solution of equation (1), the association between the ratio TSS/QI and QI was assessed by using the linear regression module of SPSS/PC.

Tests of normality of the time variables "ratio TSS/QI", "QI", "TSS", "TTE", and achievement were conducted. The values reported for skewness did not lead to rejection of the assumption of normality for distribution of the variables at $p < .01$.

RESULTS

Table 1 shows the correlation matrix between the time variables and achievement. Also the univariate statistics (mean, standard deviation, number of cases) are included. Quantity of instruction has significant correlations with the other variables, except time spent on self-study. Quantity of instruction correlates negatively with achievement. Not surprisingly, time spent on self-study correlates strongly with total time and ratio TSS/QI. A modest correlation exists between time spent on self-study and achievement. Total time is not correlated with achievement and ratio of TSS/QI. Total time correlates substantially with quantity of instruction and time spent on self-study. The ratio of TSS/QI has a strong negative correlation with QI, a strong positive correlation with total time, and a modest correlation with achievement.

The logged and linear form of the ratio TSS/QI was regressed on QI, to estimate the relationship between QI and the return of TSS on QI. The performed regression analyses followed the framework provided by Vos (1985) and Van der Drift and Vos (1987) as described in the procedure section. Figure 1 contains the results of the regression analyses in the form of a scatterplot of the ratio TSS/QI by QI and two curve fitting models.

Application of the natural log model proposed by Vos resulted in a good fit with the data : $R = -.82$, $p < .001$, $a = 5.079$ and $b = .091$. The linear model produced a nearly similar fit: $R = -.81$, $p < .001$, $a = 3.75$ and $b = -.17$.

Table 1. Intercorrelations, Means, and Standard Deviations of Variables.

Variable	1	2	3	4	5
1. QI	1.00				
2. TSS	–.06	1.00			
3. TTE	.61	.74	1.00		
4. TSS/QI	–.81	.61	–.05	1.00	
5. Achievement	–.33	.40	.10	.50	1.00
M	11.3	20.3	31.6	1.8	53.5
SD	1.8	2.2	2.8	.4	5.3

Note. The number of courses was equal to 65. QI = quantity of instruction; TSS = time spent on self-study; TTE = total time spent on education; TSS/QI = ratio time spent on self-study to quantity of instruction. Critical Value of Correlation coefficients ($N = 65$; $p < .05$) = .25.

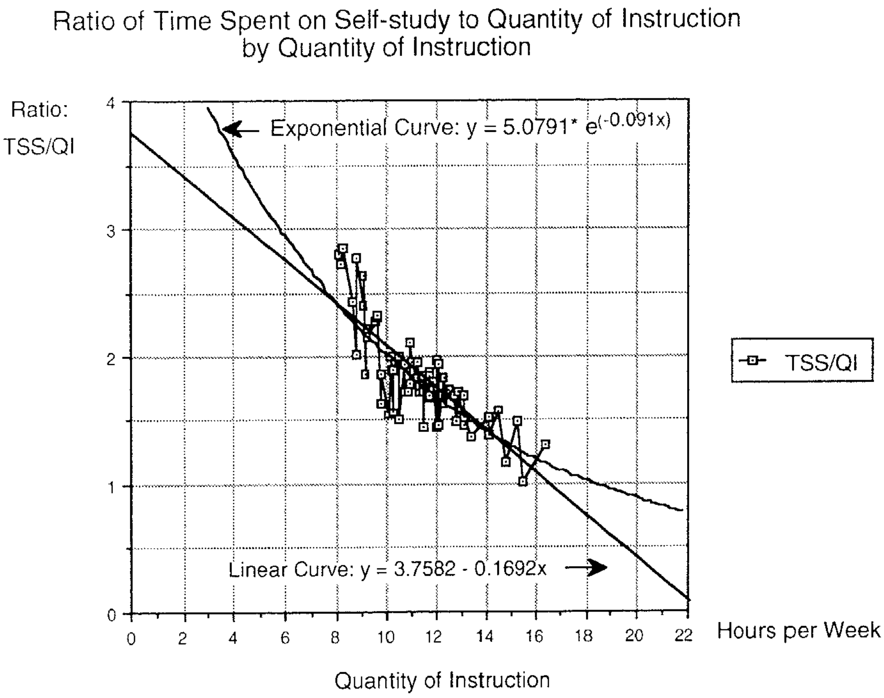

Fig. 1. Scatterplot of the association between quantity of instruction (QI) and the ratio time spent on self-study to quantity of instruction (TSS/QI), estimated with exponential and linear curve fitting.

The plotted cases clearly demonstrate diminishing returns for increased quantity of instruction (QI) to amounts of self-study time (TSS). That is: An increase in QI results in a diminishing increase in TSS/QI and, hence, in a diminishing increase in TSS. These graphs may be interpreted as follows. One hour increase in instruction time will result in less time spent on self-study for one preceding hour instruction time. For example, in Figure 1 when QI is equal to 9 hours, students will approximately spend 2.2 (= ratio TSS/QI) * 9 = 19.8 hours on self-study. Total time spent on instruction and self-study equals to 28.8 hours per week. However, when QI would, for instance, equal 17 hours per week (which is an increase of 8 hours), then the resulting increase in TSS is merely 2 hours per week. According to the data, students only spend 1.2 * 17 = 20 hours on self-study (TSS) when QI is scheduled at 17 hours per week. This results in a total time of 37 hours per week. In fact, gaining 10 more hours total time spent on education (TTE) requires 8 additional hours of instruction time.

Regression analyses were carried out to examine the relationship between time variables and achievement scores. As was shown in table 1 achievement scores correlated moderately with TSS and the ratio TSS/QI. Quantity of instruction had a moderate negative correlation with achievement. Achievement correlates negatively with QI ($r = -.33$) and correlates not significantly with total time spent on education.

Figure 2 contains scatterplots of achievement scores by the ratio of TSS/QI. This figure depicts a linear curve fitting model. Application of other curve fitting models - e.g. polynomial, exponential or logarithmic- did not provide better estimates. Figure 2 shows that an increase in the ratio of TSS/QI is associated with an increase in achievement scores. This graph may be interpreted as follows. Courses with relative high ratio's TSS/QI (e.g. greater than two), are associated with higher achievement scores. These courses are characterized by invoking about two hours per week (or more) spent on self-study for every allocated hour of instruction time per week.

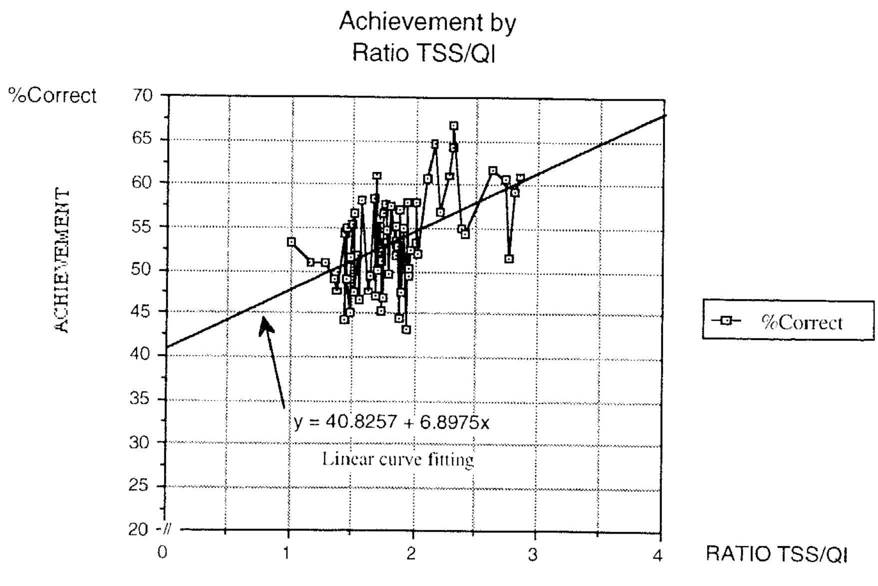

Fig. 2. Scatterplot of the association between achievement and the ratio time spent on self-study to quantity of instruction.

DISCUSSION

Research on classroom learning has documented the important role of time variables in the process of schooling. Many studies have addressed the critical question of how to maximize achievement through manipulation with time factors. Fewer attempts have been made to address the issue by focusing on the role of *quantity* of instruction and its effects on time spent on learning and achievement. The present study was designed to address this issue. Following the theoretical framework of Vos (1985) and Van der Drift and Vos (1987), the purpose of the present study was twofold. First, the relationship between quantity of instruction and time spent on self-study was explored. This part of the study may be viewed as an attempt to replicate at the course level the findings of the Vos studies. The second part of the current study sought to explore the relations among time allocated to instruction, time spent on self-study and achievement. In both studies, the ratio scores of time spent on self-study to quantity of instruction represented the key variable of analysis.

The findings of the first part of this study correspond with those of Vos (1985), and Van der Drift and Vos (1987). The exponential curve fitting model of Vos, and the linear curve fitting model both provide good estimates of the association between instruction time and the ratio of time spent on self-study to quantity of instruction. As was hypothesized, an increase of instruction time is associated with a diminishing increase in time spent on self-study. The present findings suggest that increasing instruction time indeed results in diminishing increases of time spent on self-study. Alternately, relatively few hours of instruction time are associated with higher returns in terms of time spent on self-study.

The present data suggest that student's time is a limited resource. Their time-management practice, in the medical program under scope of this study, seems to be constrained by some upper level of total time willing to spend on education: that is, participating in scheduled instructional activities plus spending time on self-study. Consequently, the relationship between allocated instruction time and self-study time may be regarded as a trade-off mechanism. Students seem to subscribe to an upper limit of total time spent on education, beyond which they do not wish, or are unable, to go. In the present study, the upper limit was equal to 37 hours per week spent on medical education. Given the upper limit of total time spent on education, the relationship between time spent on self-study and quantity of instruction is likely to be balanced. Steady increases in allocated instruction time will eventually compete with limited time resources students are willing to spend on education.

From a curriculum planning perspective, a steady increase of allocated instruction time seems to be paid for in diminishing increases on students' time on self-study. The existence of time constraints implies that allocation of instruction time should be done carefully. However, the present results suggest that careful allocation of instruction time could make it possible to maximize total time spent on education. If that is true, an efficient and effective allocation of resources for learning becomes a more feasible possibility. Therefore, the present findings underscore the need for teachers to consider the question of how to make instruction time effective, especially in relation to the required amount of self-study by students.

Vos (1985) and Van der Drift and Vos (1987) postulated an exponential model as the best description of the relationship between amount of time allocated to instruction and time spent on self-study. The present study fails to show a better fit of this model over a simple linear model. Both models had the same fit. The reason why Vos (1985) found a better fit for an exponential model may be that his data set included some curricula consisting of either an extreme low or high amount of instruction time. Our data fail to show a better fit of the exponential model, simply because among the 65 courses investigated none had less than 8 hours per week of allocated instruction time. Therefore, a linear model seems to describe the present data as good as the exponential model. It appears that future investigations would benefit from data sets including more extreme values for quantity of instruction.

The second purpose of the present study was to analyze the influence of quantity of instruction and time spent on self-study on achievement. Scores on standardized tests, containing items of the true / false format, were used as indicators for achievement. The ratio of time spent on self-study to quantity of instruction was found to correlate reasonably well (r = .50) with achievement. Time spent on self-study was somewhat .10 lower correlated with achievement: $r = .40$. The correlation between total time spent on education and achievement was zero. The correlation between quantity of instruction and achievement was equal to -.33.

These results demonstrate the importance of spending sufficient time on self-study. As such, the correlation between time spent on self-study and achievement supports Carroll's (1963) model and the findings of Fredrick and Walberg (1980). The ratio of time spent on self-study to quantity of instruction was found to produce higher correlations with achievement than time spent on self-study alone. Courses with a higher ratio tended to affect achievement scores positively. These results suggest a number of important links between educational theory and practice.

The results suggest that time spent on self-study is primarily a function of the degree of time allocated to instruction. It is therefore interesting that quantity of instruction in itself does not correlate positively with achievement. In fact, quantity of instruction is negatively correlated with achievement. This negative correlation may partly be explained by the nature of the positive relationship between TSS and achievement and the trade-off mechanism between QI and TSS. As was shown, an increase in QI results in a diminishing increase of TSS. Taken together, it is a logical outcome that the relationship between QI and achievement is negative. The positive correlations of achievement with the ratio time spent on self-study to quantity of instruction and time spent on self-study, seem to justify the conclusion that time spent on self-study has more effect on learning than instruction time as such. Why is this the case? Does it imply that students don't learn during instruction? Obviously, the present study suggests that quantity of instruction *in itself* does not facilitate achievement. There are several possible explanations for this unusual finding.

Modern cognitive psychology suggests that learning results from active construing by the learner and that instruction plays a role only to the extent that it enables or fosters these constructive activities. Transmission of subject-matter through direct instruction is, from this perspective, only of limited use. Teachers should focus on helping students acquire self-directed learning skills, if their instruction is to play any role in the learning process (e.g. Resnick, 1989; Glaser, 1991; Bereiter & Scardamalia, 1992). The present study suggests that students benefit more from time spent on self-study than participating in instructional activities. It may be possible that a substantial amount of the allocated instructional activities -in the program under scope of study- focus more upon transmission of knowledge than upon active and constructive learning activities.

A second possible explanation is that students pay only limited attention to learning tasks during instruction and shift their attention to external events (Anderson, 1984b). The classroom environment usually contains a large number of distractions carrying students' attention away from the subject-matter taught. Consequently, instruction may not facilitate learning as intended.

Total time spent on education (TTE), that is: Quantity of instruction plus self-study time, seemed fairly constant across courses and was unrelated to achievement. This leaves us with two questions: Why is TTE a constant and why is it unrelated to achievement? The results suggest that students tend to "economize" TTE; they seem not willing or able to exceed total time spent on education, beyond the point of approximately 37 hours per week. Vos (1985) and Van der Drift and Vos (1987) found a similar ceiling effect of TTE. In their studies, TTE also did not exceed the number of 37 hours per week. Their interpretation was that universities in the Netherlands do not provide extended sufficient facilities to minimize loss of potential time for self-study. Students also have to spend time on daily human routine activities, such as sleeping, shopping, and social activities. Van der Drift and Vos (1987) calculated that after extraction of these activities, the upper limit to TTE seemed plausible, although it may appear relatively low in comparison with time spent on self-study of students in campus environments elsewhere (for example Universities in the USA). To them, the only possibility to raise TTE is to introduce campus life coupled with all facilities to reduce time needed for normal daily activities.

The second question is why TTE does not predict achievement. This time variable is calculated as a composite score of quantity of instruction and time spent on self-study. Given the positive relationship between time spent on self-study and achievement, and the negative association between quantity of instruction and achievement, a zero-sum effect may be the result. Time spent on self-study and quantity of instruction are, as mentioned above, connected to each other following some kind of trade-off mechanism ($r = -.06$, $p > .05$). The nature of the TTE variable is such, that high values for TTE may both be the result of either a combination of fairly low instruction time and a high amount of time spent on self-study or the other way around. Since we know that QI is negatively correlated with achievement, high TTS's may occur both with fairly high and low achievement scores, depending on the contribution of TSS to TTE.

The present study has four limitations. The first limitation is the already mentioned restriction of range in the sample concerning instruction time (minimum 8 hours per week, maximum 16 hours per week). Further research is necessary examining the effects of extreme low or high values of instruction time. The second limitation is the operationalization and interpretation of the time variables. As Anderson (1985) points out, from a measurement point of view, time is not a variable but a metric: a value on a scale representing hours spent on potential different activities. Depending on the operationalization of time, values found for this variable may have different inherent meanings. In the present study instruction time may conceptually differ from course to course. Instruction may take place as lecturing, small-group discussion or skills training resulting into different learning effects. The same problem holds for the measurement of self-study time. Does it imply memorizing, reviewing the assigned literature, or seeking answers to teacher -or text- questions? Finally, is it necessary to distinguish between instruction and self-study, given that both activities result in some kind of learning? We recognize the conceptual problem underlying the measurement of time. We also acknowledge that the present study doesn't provide detailed information about why students make certain choices in allocating study time, given the amount of instruction, or how time is used during instruction or self-study. Therefore, it seems evident that further studies are needed to provide a deeper understanding of these conceptual issues.

The third limitation is that the results may be only generalizable to a somewhat narrow student outcome (namely, achievement as measured by true-false items). However, from a perspective from ecological validity, it seems clear that this format is generally used and accepted at the Maastricht Medical School, many other medical schools or institutions for higher education. Previous studies in medical education (Norman et al., 1987; Stalenhoef et al., 1990) have shown that a high correlation exists between examinee scores in open-ended and objective questions (multiple-choice or true-false format). Different formats of written tests provided similar information about students. In conclusion, although more sophisticated achievement measures may provide better insights in students' mastery of course contents, the present measure reflects current educational testing practice justifying its use in the present study. A final limitation is that the findings for this unique group of medical students may not be generalizable to other samples of interest (e.g. students in other schools). It may be clear that further study is required for different disciplines and types of schools.

From a practical perspective, the present study offers new tools for curriculum and course designers to maximize time spent on self-study and consequently achievement. The present investigation shows that raising instruction time is only effective if students spend indeed a greater fraction of time on self-study. Excessive allocation of instruction time may consume time that otherwise would be spent on self-study. Given that student's time is a scarce resource (the amount of hours per week that students are able and willing to spend on schooling), instruction activities should be allocated in such a way that an optimal balance exists between instruction and self-study.

Taken together, the results of this study confirm the importance of spending sufficient time on learning. The amounts of time students are willing and able to engage in self-study is related to quantity of instruction. If that is true, an efficient and effective allocation of resources for learning becomes better possible. Hence, research dealing with the effects of quantity of instruction on time spent on self-study and achievement should be an area of primary interest to investigators of school learning.

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