Adoption of Technology-Mediated Distance Education: A Longitudinal Analysis

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Research

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Abstract

We investigated the factors that facilitated the fast adoption and utilization of Technology-Mediated Distance Education (TMDE) among higher education institutions. Our analysis was based on a rich data set on the utilization of TMDE between the 1997-1998 and 2000-2001 academic years. The analysis showed that size, public/private status, and location significantly predicted its actual adoption. Being in an urban location negatively affected enrollment in the courses at the undergraduate but not at the graduate level. While the intent to adopt TMDE correlated significantly with actual adoption, many schools that were not interested in TMDE in 1997-1998 adopted it by 2000-2001. Interestingly, late adopters utilized certain technologies as frequently as early adopters, such as synchronous Internet-based instruction and the use of CD-ROMs.

Keywords: Technology-Mediated Distance Education; E-Learning; Online Learning; Adoption

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1. Introduction

Recent developments in IT and the commercialization of the Internet have allowed many higher education institutions to reach distant audiences. According to the Sloan Consortium's survey of over 2,200 colleges and universities, nearly 3.2 million students took at least one online course during the fall 2005 term, a substantial increase over the 2.3 million reported the previous year. The additional 800,000 students is more than twice the number added in any previous year. Enrollment at the largest U.S. online college, University of Phoenix Online, rose to around 125,000 students by 2004. Business Week ranked the online college 22^{nd} in its 2004 Info Tech 100 list and stated that it was among the top 10 most profitable IT firms [4].

In addition to cyber-universities, over 400 "brick-and-mortar" institutions (including Columbia University, the University of Maryland, and Pennsylvania State University) offer master's programs completely campus-free. Such activities have made higher-education publishers more attentive to the online market; for example, McGraw-Hill Education, the third-largest U. S. college publisher, formed an Online Learning division in June 2004 to take advantage of the growing interest in online courses.

We examined various aspects of the adoption of TMDE across U.S. higher education institutions. The majority of research in this field has previously focused on analysis at the student level, attempting to understand the critical enabling role of IT in learning environments [1],[19],[20],[21],[24],[26],[28],[37],[38],[41]. Alavi and Leidner [2] noted the lack of studies that focus on the organizational and program levels. Along these lines, Ozdemir et al. [25] built an economic theory to predict the types of institutions that should be most interested in adopting TMDE and empirically tested their (static) theory using a cross-sectional data set.

2. Research Framework

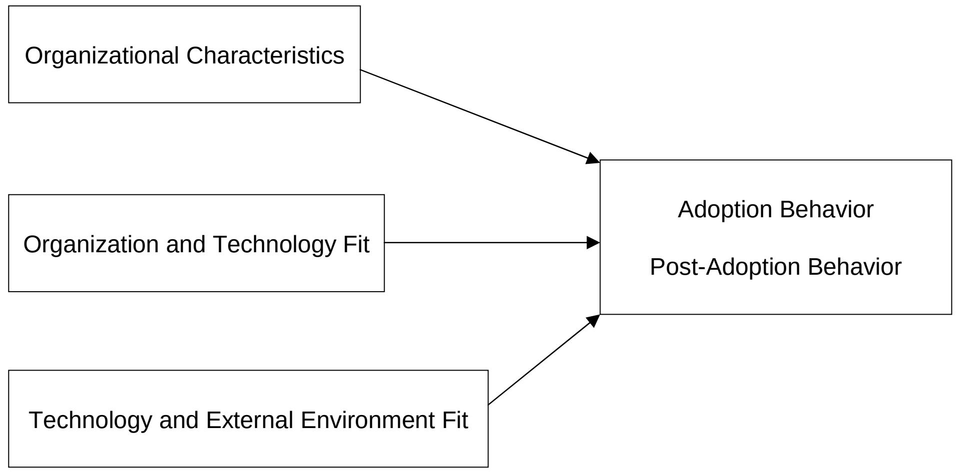
Our research was an adopter study [13] where the typical approach is to "survey organizations in some population of interest to capture data about (1) the characteristics of those organizations and their adoption contexts and (2) the timing and/or extent of adoption of one or more innovations." We used a data set to examine the adoption of TMDE in the U.S. higher education sector. Perhaps the most notable difference of this sector is its extensive heterogeneity among market participants in terms of their resources, market reach and focus (e.g., research universities *versus* liberal arts colleges), and governance and mission (e.g., public *versus* private institutions).

2.1. Factors Influencing Adoption and Post-Adoption Behavior

The literature on adoption of IT provides factors likely to influence the adoption of TMDE. The two behaviors have generally been modeled as being influenced by the same set of factors that lead to initial use [17],[31],[34],[35]. We followed the same approach, although we did allow the factors to have varying effect on the two types of behaviors.

Among the factors, the most significant include organizational characteristics, organization and technology fit, and technology and external environmental fit, all of which were included in our framework (see Figure 1).

Figure 1. Factors affecting the adoption and assimilation of TMDE



Organizational Characteristics. Prior research has consistently shown a positive relationship between organization size and innovativeness [27]. The most common reasons for this include economies of scale [18], slack resources [12], access to outside resources [3], and ability to bear adoption risks [15]. Size should also be important in our context because larger institutions are more likely to have the technology infrastructure that is essential for providing TMDE. Therefore, we included institutional size (total enrollment) as a control and expected it to have a positive relationship with both adoption and post-adoption behavior.

Organization and Technology Fit. An organization with a high propensity to innovate may still lag in adoption if the innovation does not fit its needs, strategies, resources, or capabilities. The literature on the diffusion of IT support the importance of characteristics that capture the relative fit between innovation and organization [5],[8],[29]. In higher education, public/private status can be a proxy for the fit between an organization and a technology. Generally, private institutions are smaller and tend to specialize in the provision of undergraduate teaching, whereas public institutions are larger and tend to have a broader set of goals and objectives. Consequently, the priorities and cost structures of the two kinds of institutions can vary substantially [7]. As financial support from state governments has dwindled in the past decade, many public institutions have experienced significant revenue constraints [32]. In addition, public institutions aim to serve the citizens in their states by making educational opportunities more affordable and making courses available at multiple convenient locations.

Another issue is that private institutions have had smaller classes and have provided a higher quality of education. For example, Zemsky and Oedel [39] found that students' with academic achievement and/or educational aspirations were more likely to select a private institution. Ehrenberg [11] suggested that private institutions with ample resources and excess student demand may have been less responsive to the growth in demand for higher education because of an interest in maintaining endowment per student and, hence, quality. However, it may be relatively harder for private institutions to provide quality education using TMDE, although courses provided via TMDE can still be of high-quality. Indeed, Zhang et al. [40] reported that in an e-learning environment that emphasized learner-centered activity and system interactivity, allowed remote learners to outperform traditional students. In summary, we expected that public institutions would adopt TMDE earlier and use it more than would private institutions.

Technology and External Environment Fit. Technology characteristics, the external environment, and the fit between the two may also impact adoption decisions. We took these factors into account in two ways. First, we considered the heterogeneity of institutions and educational programs. Doctoral/research institutions, master's/regional institutions, and schools that took two-year (or less) to graduate faced very different technological constraints and external environments when adopting TMDE. For example, doctoral/research institutions have more advanced technological infrastructures, compete for students nationally and internationally, and emphasize research. We thus performed our estimations for different types of institutions separately.

Second, we considered the effect of geographical location. Organizations in different locations faced heterogeneous markets for labor, third-party services, and complementary technological inputs. Normally, those that are located in urban locations are expected to innovate more.

2.2. Intention-to-Adopt versus Actual Adoption

Our second analysis was initiated to determine whether the intention to adopt TMDE correlated with actual adoption. The institutions in our data set were interviewed in the 1997-1998 academic year about their intent to adopt TMDE, and were interviewed again in 2000-2001 academic year about the extent of their adoption. This longitudinal information allowed us to control for intention-to-adopt when estimating the actual adoption behavior and see whether institutions actually followed through with their previously announced plans. The intention-to-adopt and actual adoption considered here are loosely related to TAM. The relation is loose because the original TAM [9],[10] and its subsequent modifications are based on psychological theories focused on the individual, whereas our unit of analysis is the institution.[2]

We assumed that the institutions had intended to adopt TMDE based on a cost-benefit analysis. Thus, the announced intent in the 1997-1998 academic year and the actual adoption in 2000-2001 should be highly correlated if there was little uncertainty on the forecast of costs and benefits. We defined the Actual Net Benefit of adopting TMDE as:

$$\text{Actual Net Benefit} = \text{Forecasted Net Benefit} - \text{Forecast Error}$$

[2] We thank an anonymous reviewer for valuable comments on this issue.

The forecast error depended upon the uncertainty about cost, demand, competition, and fit between the technology and the institution. In our setting, the three-year time difference between the observed intent and actual adoption was long, especially given the rapid technological advances during that period. We therefore expected Forecast Error to be high.

2.3. Utilization of Specific TMDE Technologies

TMDE can be offered using several technologies; they can be classified as audio/video (one- and two-way interactive video, one- and two-way audio, one-way live and prerecorded video) and computer-based (CD-ROM, synchronous and asynchronous Internet-based applications). Computer-based technologies such as Internet-based applications are newer and potentially more effective tools than audio/video technologies. For this study, institutions were considered to have adopted TMDE as long as they used at least one of these technologies to offer TMDE courses. Obviously, this approach may not fully reveal the underlying adoption process because adopting schools may differ in the technology they utilize. Therefore, we also employed a finer level of analysis to investigate differences among early and late adopters of TMDE.[3]

While the fixed cost to set up the infrastructure has substantially decreased lately, the marginal cost of enrolling new students is low for both. Therefore, if an early adopter had already established the necessary infrastructure and support in the form of qualified personnel and a distance education office, it was likely to continue using older technologies even after newer ones became available and economical. Its TMDE infrastructure and support would also help in the adoption of newer technologies. On the other hand, a late adopter was more likely to

[3] We called institutions that had adopted at least one TMDE technology by the 1997-1998 academic year "early adopters," whereas "late adopters" were those that had not adopted any but did by 2000-2001.

jump into the new computer-based technologies. Therefore, we expected some inertia in early adopters, but technology "skipping" by late adopters.

3. The Data

Our analysis was based on confidential data obtained from two nationally representative surveys of distance education undertaken by the NCES. Part of the Postsecondary Education Quick Information System (PEQIS) of NCES, the surveys reported the number of TMDE courses (if any) offered at each institution, the number of students enrolled in them, and the number of degrees offered via TMDE in the 12-month 1997-1998 and 2000-2001 academic years [21],[36]. We shall refer to these surveys with their starting year. A total of 5,353 (4,175) U.S. institutions were initially eligible for the 1997 (2000) PEQIS panel. The NCES stratified each panel by instructional level (four-year, two-year, less-than-two-year), control (public, private), highest level of offering (doctor's, master's, bachelor's, less than bachelor's), and total enrollment; it sorted institutions within each strata by region (Northeast, Southeast, Central, West), whether the institution had a relatively high minority enrollment, and whether research expenditures exceeded $1 million; it allocated them to the strata in proportion to the aggregate square root of total enrollment; and it sampled institutions within each stratum with equal probabilities of selection. The selected 1997 (2000) PEQIS panel consisted of 1,612 (1,610) institutions, 1,487 (1,500) of which participated, resulting in a 92 (93) percent response rate. A total of 1,149 institutions responded to both PEQIS surveys.

We supplemented the PEQIS data with institutional characteristics such as public/private status, Carnegie classifications [6], an urban indicator, and enrollment levels, which we obtained from the Department of Education's Integrated Postsecondary Education Data System (IPEDS).

IPEDS is the core postsecondary education data collection program for NCES and was built around a series of interrelated surveys that collected institution-level data in such areas as enrollments, program completions, faculty, staff, and finances. Of the 1,149 schools that responded to both PEQIS surveys, 21 schools either did not have any institutional information in IPEDS or had zero enrollment in 1997 or 2000. Eliminating these resulted in a panel (longitudinal) data set with a cross-sectional sample size of 1,128. The final sample includes institutions at the four-year, two-year, and less-than-two-year level, public and private colleges, and universities that award associate, bachelor's, master's, and doctoral degrees. The variety of institutions reflected the exceptionally complex nature of the U.S. higher education sector and its multitude of products [23]. To manage this variety, some of the analysis was considered for individual categories of schools, including doctoral/research institutions, regional/master's universities, and two-year or less-than-two-year schools. Of the 1,128 schools in the sample, 163 were doctoral/research institutions, 222 were regional/master's universities, and 386 two-year or less-than-two-year schools.

The third and final data source was the 2000 *U.S. News & World Report* rankings, which were used as proxies for education quality of doctoral/research and master's/regional universities. Published in 1999, the rankings indicated where each school stood within its Carnegie category and were based on several criteria including selectivity, faculty resources, financial resources, retention rates, and alumni giving. *U.S. News & World Report* ranked doctoral/research institutions into four tiers but did not rank them within each tier except at the top, "Tier 1." Therefore, the tier information (rather than more precise rankings) were used as the proxy for education quality for doctoral/research institutions. In contrast, master's/regional institutions were not tiered, but rather classified and ranked by region. Thus, we constructed a binary variable indicating whether a master's/regional university was surveyed by *U.S. News & World Report*. Named "Tier 1" for ease of exposition, this variable also conveyed information about institutional quality since the surveyed institutions were touted as the best within their region and category.

4. Empirical Analysis

4.1. Summary Statistics

Table 1 presents definitions of the variables. The last nine items are the TMDE technologies considered here: six types of audio/video technologies and three types of computer-based technologies. The audio/video technologies are characterized by being "one-way" or "two-way," with video technologies being either "interactive," "live," or "pre-recorded." The three possible computer-based technologies were Internet (synchronous), Internet (asynchronous), and CD-ROM.

Table 2 reports sample averages of the relevant variables for the 1997 and 2000 samples. Standard deviations are reported in parentheses for the non-indicator variables, and the last column reports p-values associated with a two-sided test of equality between the 1997 and 2000 averages. Overall, the percentage of institutions that offered at least one TMDE course increased from 59.5% to 73.8% percent over the three-year period. Interestingly, the 14 percentage-point increase in TMDE adoption was quite close to the percentage of institutions (17%) that, in 1997, reported an intent to adopt TMDE within three years. The average number of TMDE courses (per institution) increased from 22.6 to 48.3. In 1997 (2000), 15 (35) undergraduate and 7 (12) graduate courses were offered per institution, respectively. Six of the nine technologies saw increased usage in 2000, most notably the ones that were Internet-related. In 1997, 13% and

37% percent of institutions used synchronous and asynchronous computer-based instruction via the Internet, respectively, as the primary mode of instructional delivery in at least one course; these numbers jumped to 36% and 68%, respectively, in 2000.

Table 3 provides a cross-tabulation (1997 versus 2000) of TMDE offering and intent behavior among the 1,128 institutions. About two-thirds of the universities that planned to adopt TMDE in 1997 actually adopted by 2000. However, of the 192 schools that had reported an intent to offer TMDE by 2000, a subset of 32 not only did not follow through but also changed their reported intent in the second survey. Perhaps the most interesting finding was that roughly a quarter of the schools that did not offer TMDE courses in 1997 and did not plan to adopt in the next three years did adopt by 2000. This highlights the speed at which diffusion of TMDE occured among the institutions that had no plan to adopt. One could argue that the Department of Education should survey higher-education institutions more frequently.

4.2. Adoption and Post-Adoption Behaviors

In our context, adoption behavior refers to adoption by 1997, while post-adoption behavior is measured by the change of TMDE usage between 1997 and 2000 for the that adopted TMDE by 1997. A probit model was used to estimate the effects of various factors on the probability of offering at least one TMDE course by 1997. Table 4 provides the results for the sample of 1,128 schools as well as for doctoral/research institutions, regional/master's universities, and two-year or less-than-two-year schools. For each sample, the model specification includes total enrollment, the public indicator variable, and the urban indicator variable. Tier variables are also included for the first two categories of schools for which information was available. (Since "Tier 4" is the excluded category, the estimates on the other three tier variables should be interpreted as differences from "Tier 4.") The probit estimates reported in Table 4 corresponded to a given variable's marginal effect on the probability of a 1997 TMDE offering, evaluated at the mean values of all the explanatory variables.[4] For instance, in the full-sample results, an urban institution is 10.9 percentage points less likely to have offered a TMDE course in 1997 than a non-urban institution, holding total enrollment and public status constant. Standard errors are reported in parentheses.

Not surprisingly, institutional size is a significant predictor of TMDE adoption for all types of institutions. Also, the effect of being a public school is consistently positive and significant for all three institutional categories. The probability of offering at least one TMDE course in 1997 increased by almost 40 percentage points if a school was public, with the most pronounced positive increase (65 percentage points) observed for two-year (or less) schools. Finally, urban status correlates significantly (and negatively) with TMDE adoption in the overall sample. For each of the three categories of schools, the estimated effect of urban status remained ouegative but lost statistical significance (presumably due to lower sample sizes). We find similar results at the undergraduate and graduate levels.

With respect to post-adoption behavior, we included only schools that offered at least one TMDE course in 1997 and we then performed a regression analysis of the change in TMDE enrollments between 1997 and 2000. The results are reported in Table 5. The model specifications and the breakdown of institutions into categories were identical to the analysis of adoption behavior. We found that an increase of 1,000 in total enrollment was associated with an expected increase of 66 in TMDE enrollment. The enrollment in TMDE courses increased less at public universities. The coefficient for urban indicator was significant, indicating that enrollment in TMDE courses increased less in universities located in an urban setting.

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[4] These probit marginal effects were computed using the `dprobit` command in the *Stata* statistical software package. The same marginal effects are also reported in other probit regressions that follow.

The results differ to some extent across the categories of institutions. None of the coefficients were significant for doctoral/research institutions except for the Tier 3 dummy, whereas all coefficients were significant for regional/master's universities and two-year or less-than-two-year schools. We observed a slowdown of adoption at public schools in the latter two categories of schools. In fact, the expected net change in TMDE enrollment at a regional/master's university surveyed by *U.S. News & World Report* was significantly negative if the school was also public and located in a large city.

At the undergraduate level, the pattern of change in TMDE enrollment during the three year period was similar to the overall change. The coefficients were significant and had the same sign as previous analyses. At the graduate level, TMDE enrollment increased by approximately 400 for all types of institutions. The coefficients for size, public status, and urban indicator were still in the same direction but not significant. Also, the urban indicator was a significant predictor of the increase in TMDE utilization at the undergraduate level but not at the graduate level.

4.3. Intention-to-Adopt and Actual Adoption

Table 3 shows that the intention to adopt TMDE was not a good predictor of actual adoption. In the current analysis we included only institutions that did not offer any TMDE course in 1997. Probit regressions were used to estimate the determinants of TMDE adoption in 2000 within this sample and the results are shown in Table 6. To see the association between intent-to-adopt and actual adoption, an indicator variable for the intent in 1997 (*Intention97*) was included in the regressions. Two specifications were considered: one with only the indicator variable and one that also included interactions of this variable with the other explanatory variables (total enrollment, public indicator, and urban indicator).

Similar to the results for the 1997 adoption decision , the estimates for institution size and the public indicator in Table 6 were both positive and statistically significant, although the estimated effect of the urban indicator was not statistically significant. Interestingly, the expressed intention to offer TMDE courses in the three-year period after 1997 increased the probability of adoption in 2000 by 29 percentage points. When the intention indicator variable interacted with the other covariates, we found that size loses its importance for institutions that expressed an intention to adopt (a combined effect of 0.010, as opposed to 0.028 in the first specification). Furthermore, the effect of the intention to adopt on the actual adoption behavior was lower for institutions located in urban areas. In other words, among the schools that had intended to adopt TMDE by 2000, those that were located in large cities were less likely to adopt than those that were not.

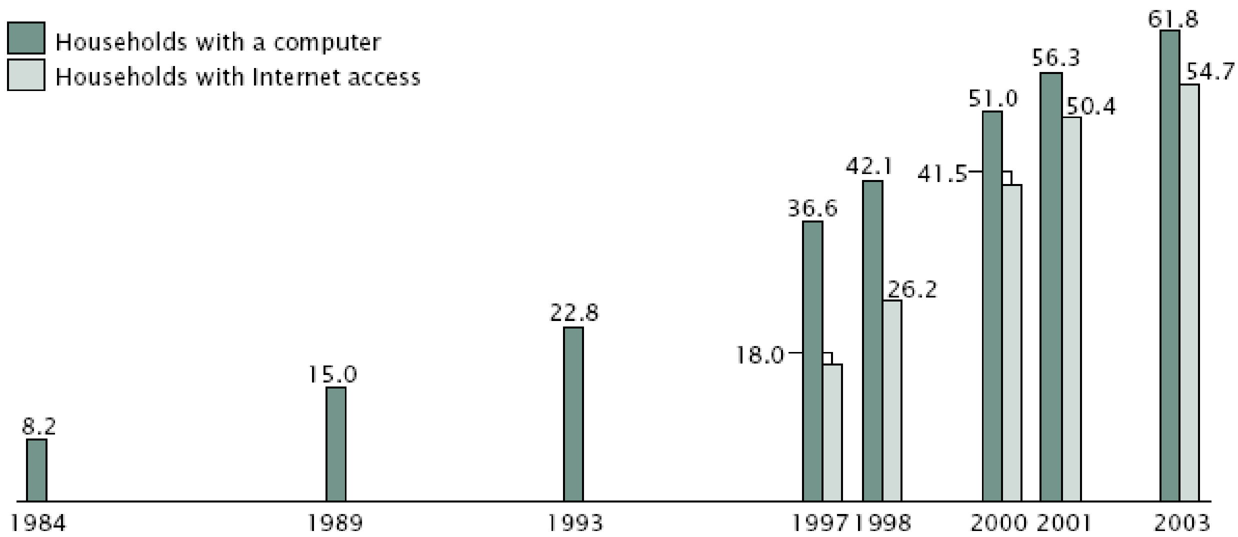
According to the regression results that include the interaction terms, the coefficient for the public indicator was higher at the undergraduate level. Compared to their private counterparts, public universities were more interested in TMDE at the undergraduate level. The expressed intention to adopt was significant at the undergraduate level but not at the undergraduate level. Also, schools that intended to adopt TMDE in 1997 were less likely to adopt the innovation at the undergraduate level if they were located in large cities. The positive effect of size for these schools was lower than that for others.

4.4. Adoption of specific TMDE technologies

Since the summary statistics provided only a limited view of the utilization of the various available TMDE technologies, we considered comparisons between: (*i*) 1997 and 2000 utilization rates of "early adopters" (i.e., those institutions that had already adopted TMDE by 1997), and (*ii*) 2000 utilization rates of "early adopters" and "late adopters" (i.e., those institutions that adopted TMDE by 2000 but did not by 1997). These comparisons are shown in Tables 7 and 8, respectively, with utilization rates for each technology and a p-value for the two-sided test of equality between the two respective rates.

According to Table 7, the technologies that found increased utilization among early adopters included: one-way live video, one-way and two-way audio transmission, synchronous and asynchronous Internet-based instruction, and CD-ROM. The largest increases occurred for the computer-based technologies (Internet and CD-ROM). Note that the period of our study coincided with the period during which computers were adopted at a large rate by U.S. households. According to U.S. Census Bureau, the rate of computer ownership increased from 36% to 56% and Internet access increased from 18% to 50% between 1997 and 2001 (see Figure 2) [33]. Essentially, Internet use had rapidly become synonymous with computer availability by the end of this period. We believe that the relative shift from audio/video technologies to computer-based technologies in delivering TMDE occurred due to such unprecedented changes in the society.

Figure 2. Households with a computer and Internet access: 1984 to 2003 (in percent)



Source: U.S. Census Bureau, Current Population Survey, 1984, 1989, 1993, 1997, 1998, 2000, 2001, 2003.

Table 8 shows that early and late adopters utilized three technologies with similar frequency in 2000: two-way audio transmission, synchronous computer-based instruction via the Internet, and CD-ROM. The other six technologies exhibited statistically significant differences in utilization rates between early and late adopters. In fact, the early adopters were significantly more likely to utilize each of these six technologies. In certain cases (such as one-way pre-recorded video), the greater utilization by early adopters suggested a degree of inertia in the way TMDE courses were delivered. On the other hand, early adopters also had more experience with TMDE technologies and greater ability to adopt many technologies at once, which would be a possible explanation for the higher utilization rates of technologies such as asynchronous Internet-based instruction.

4.5. Goals of TMDE Adoption

Since public indicator was significantly positive in many of our analyses, we further investigated the reasons for increased levels of TMDE adoption among public institutions using the responses to the questions in the 2000 survey that inquired about the goals of the adopting institutions and the barriers as perceived by non-adopting institutions. The adopting institutions were asked the importance they attribute to a set of eight goals in utilizing TMDE; these included reducing per student costs, making education more affordable and accessible, increasing enrollments, improving course quality, and meeting the needs of local employers. Institutions rated these goals as being unimportant, somewhat important, or very important. After coding "not important" with zero and the other two with one, we compared the responses among public and private institutions as well as early and late adopters (see Table 9). We found that, among the institutions that had adopted TMDE, public institutions were significantly more likely to try to achieve all these goals. This showed why the public indicator was so significant in our analyses and highlighted the different objectives of public and private institutions. In addition, we found that early adopters were more concerned with reducing per student costs, making education more accessible, improving course quality, and meeting the needs of local employers.

We also analyzed the barriers that non-adopting institutions considered as being relevant and found that the most important were "lack of fit with institution's mission" (64%), "lack of perceived need" (45%), "program development costs" (45%), and "concerns about course quality" (43%). As technology improves and more institutions adopt TMDE, the second and third barriers may disappear. One wonders whether progress will occur to a point at which institutions will be forced to change their "mission."

5. Discussion and Conclusions

We studied, in a longitudinal fashion, the organizational factors that are associated with the adoption and continued utilization of TMDE. We found that public universities adopted TMDE earlier than private pnes. The high level of importance that public institutions placed on increasing enrollments and providing affordable education may have spurred their early adoption. TMDE reduces the need for physical facilities. For example, the Ohio State University recently redesigned its core statistics course by reducing the time spent in class and offering components online, allowing the administration to register 150 more students in the class [30]. Interestingly, private institutions outpaced public institutions with their adoption between 1997 and 2000, decreasing the gap that existed in 1997.

Recent work on IT adoption suggests that the set of factors that influenced the acceptance and initial use of an innovation could differ from those that affect post-adoption behavior [16]. We find partial evidence supporting this claim since the sign of the relationship between public status and the extent of actual usage of the innovation (TMDE) reversed after initial adoption. Other factors have similar associations with adoption and post-adoption behaviors.

A consistent finding is that universities located in large cities are less likely to utilize TMDE. Typically, attending universities in rural parts of the U.S. requires most students to either temporarily relocate to the campus or incur significant travel-related expenses. An important benefit of TMDE is that it allows students to reduce travel-related expenses. In contrast, universities in large cities attract many of their students from the residents of the city. Since these students need not relocate upon admission, they do not have this advantage of TMDE. We note that this result is corroborated in other contexts involving the adoption of the Internet.

We found that TMDE had spread fast among U.S. higher-education institutions between 1997 and 2000, those offering at least one TMDE course increased from 59 to 74 percent. The diffusion was so fast-paced that even a quarter of the institutions that did not offer TMDE courses in 1997 and did not plan to adopt in the next three years did actually adopt by 2000.

Finally, the Internet was a major factor in the fast-paced TMDE adoption. More than 80 percent of the schools that adopted TMDE between 1997 and 2000 used an Internet-based technology for at least one course. Also, late adopters used a certain set of TMDE technologies (including sophisticated technologies such as synchronous computer-based instruction) as frequently as the early adopters. The major decrease in the cost of digital storage devices in the decade may have facilitated the adoption of the CD-ROM as a medium of instructional delivery.

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Table 1. Variable definitions

Variable	Definition
Institutional Variables	
Urban indicator	Whether the schools is located in a city with population above 250,000
Tier *i*	Whether the school is included in Tier $i \in \{1,2,3,4\}$ by U.S. News & World Report in 2000
Variables on TMDE Adoption	
TMDE	Whether the school offered TMDE courses
Intent	For a school that did not offer TMDE courses, whether it expressed the intention to do so in the next three years
Total TMDE enrollment	Total enrollment in credit-granting TMDE courses (includes duplicated counts of students)
Undergraduate TMDE enrollment	Total undergraduate enrollment in credit-granting TMDE courses (includes duplicated counts of students)
Graduate TMDE enrollment	Total graduate enrollment in credit-granting TMDE courses (includes duplicated counts of students)
Total TMDE courses	Total number of credit-granting TMDE courses offered
Undergraduate TMDE courses	Total number of undergraduate credit-granting TMDE courses
Graduate TMDE courses	Total number of graduate credit-granting TMDE courses
Variables on TMDE Technologies	
Two-way interactive video	Whether two-way interactive video was used as the primary mode of instructional delivery in any TMDE course
One-way video / Two-way audio	Whether one-way video with two-way audio was used as the primary mode of instructional delivery in any TMDE course
One-way live video	Whether one-way live video was used as the primary mode of instructional delivery in any TMDE course
One-way prerecorded video	Whether one-way prerecorded video was used as the primary mode of instructional delivery in any TMDE course
Two-way audio	Whether two-way audio transmission was used as the primary mode of instructional delivery in any TMDE course
One-way audio	Whether one-way audio transmission was used as the primary mode of instructional delivery in any TMDE course
Internet (synchronous)	Whether synchronous computer-based instruction via the Internet was used as the primary mode of instructional delivery in any TMDE course
Internet (asynchronous)	Whether asynchronous computer-based instruction via the Internet was used as the primary mode of instructional delivery in any TMDE course
CD-ROM	Whether CD-ROM was used as the primary mode of instructional delivery in any TMDE course

Table 2. Summary statistics

Variable	1997	2000	p-value
Institutional Variables			
Public indicator	0.61	0.61	
Urban indicator	0.23	0.23	
Total enrollment (in 1000's)	7.45 (8.11)	7.81 (8.45)	
Undergraduate enrollment (in 1000's)	6.33 (6.78)	6.66 (7.15)	
Graduate enrollment (in 1000's)	1.11 (2.22)	1.15 (2.26)	
Tier 1	---	0.11	
Tier 2	---	0.05	
Tier 3	---	0.05	
Tier 4	---	0.04	
Variables on TMDE Adoption			
TMDE	0.60	0.74	
Intent	0.17	0.08	0.00
Total TMDE enrollment	698 (1,592)	1,373 (2,873)	0.00
Undergraduate TMDE enrollment	559 (1,387)	1,132 (2,519)	0.00
Graduate TMDE enrollment	139 (582)	240 (842)	0.00
Total TMDE courses	22.6 (53.2)	48.3 (78.3)	0.00
Undergraduate TMDE courses	15.3 (31.6)	35.4 (59.6)	0.00
Graduate TMDE courses	7.3 (29.4)	12.6 (39.3)	0.00
Variables on TMDE Technologies			
Two-way interactive video	0.36	0.43	0.00
One-way video / Two-way audio	0.11	0.11	0.95
One-way live video	0.05	0.08	0.00
One-way pre-recorded video	0.34	0.36	0.19
Two-way audio	0.03	0.08	0.00
One-way audio	0.04	0.10	0.00
Internet (synchronous)	0.13	0.36	0.00
Internet (asynchronous)	0.37	0.68	0.00
CD-ROM	0.05	0.24	0.00
Sample size	1,128	1,128	

Table 3. The adoption profile of institutions

	2000-2001			
1997-1998	Offered TMDE courses	Did not offer, but planned to in the next three years	Did not offer, and did not plan to within the next three years	Total
Offered TMDE courses	648 (57%)	12 (1%)	11 (1%)	671 (59%)
Did not, but planned to offer in the next three years	123 (11%)	37 (3%)	32 (3%)	192 (17%)
Did not, and did not plan to offer within the next three years	65 (6%)	41 (4%)	159 (14%)	265 (24%)
Total	836 (74%)	90 (8%)	202 (18%)	1128 (100%)

Table 4. Adoption behavior: The probability of offering at least one TMDE course in 1997

	Overall	**Undergraduate**	**Graduate**	**Doctoral/Research Institutions**	**Master's/Regional Institutions**	**Two-year (or less) Schools**
Total enrollment	0.04**	0.03**	0.10**	0.01**	0.02**	0.02**
(in 1000's)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Public indicator	0.39**	0.46**	0.40**	0.21**	0.15*	0.65**
	(0.04)	(0.03)	(0.04)	(0.09)	(0.08)	(0.08)
Urban indicator	-0.11**	-0.11**	-0.13**	-0.02	-0.13	-0.07
	(0.04)	(0.05)	(0.06)	(0.04)	(0.09)	(0.08)
Tier 1				-0.09	-0.06	
				(1.00)	(0.08)	
Tier 2				-0.04		
				(0.06)		
Tier 3				0.03		
				(0.04)		
n	1,128	1,087	553	163	222	386
Log-likelihood	-512	-513	-278	-40	-116	-160

* Significant at 10 percent level.
** Significant at 5 percent level.

Table 5. Post-adoption behavior: Regression of change in TMDE enrollment between 1997-1998 and 2000-2001 academic years, given that schools offer TMDE course(s) in 1997-1998

	Overall	**Undergraduate**	**Graduate**	**Doctoral/Research Institutions**	**Master's/Regional Institutions**	**Two-year (or less) Schools**
Constant	920**	870**	392**	1,642	1,667**	5,784**
	(288)	(320)	(165)	(1,063)	(704)	(233)
Total enrollment	66**	88**	41	49	180**	112**
(in 1000's)	(17)	(22)	(51)	(44)	(79)	(26)
Public indicator	-550	-757*	-156	-609	-2,270**	-5,524**
	(369)	(431)	(247)	(1,427)	(868)	(127)
Urban indicator	-772**	-723**	-301	-664	-1,705**	-914*
	(301)	(299)	(212)	(645)	(749)	(544)
Tier 1				-1,469	-1,302**	
				(1,092)	(553)	
Tier 2				-995		
				(621)		
Tier 3				-1,745**		
				(586)		
N	662[ψ]	602	283	134	159	268
R^2	0.05	0.07	0.01	0.08	0.10	0.14

* Significant at 10 percent level.
** Significant at 5 percent level.
[ψ] Nine schools that adopted TMDE in the 1997-1998 academic year did not report their TMDE enrollment either in that academic year or in 2000-2001. Hence, change in TMDE enrollment can only be calculated for 662 schools (rather than the 671 schools in Table 3).

Table 6. Intention-to-adopt and actual adoption: The probability that an institution offers at least one undergraduate TMDE course in 2000-2001 academic year, given that it did not in 1997-1998

	Overall		**Undergraduate**		**Graduate**	
	Without Interaction Terms	With Interaction Terms	Without Interaction Terms	With Interaction Terms	Without Interaction Terms	With Interaction Terms
Total enrollment (in 100's)	0.03**	0.05**	0.03**	0.04**	0.06**	0.08**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Public indicator	0.34**	0.34**	0.38**	0.42**	0.17**	0.27**
	(0.06)	(0.09)	(0.06)	(0.08)	(0.07)	(0.09)
Urban indicator	0.01	0.12	-0.01	0.08	-0.02	0.03
	(0.06)	(0.08)	(0.06)	(0.08)	(0.07)	(0.09)
Intention97	0.29**	0.46**	0.22**	0.37**	0.08	0.24**
	(0.05)	(0.07)	(0.05)	(0.07)	(0.06)	(0.09)
Intention97*Enrollment		-0.04**		-0.03*		-0.07
		(0.02)		(0.02)		(0.04)
Intention97*Public indicator		0.04		-0.05		-0.18
		(0.130)		(0.12)		(0.11)
Intention97*Urban indicator		-0.24**		-0.20*		-0.09
		(0.08)		(0.09)		(0.14)
N	457	457	470	470	272	272
Log-likelihood	-240	-232	-241	-236	-171	-169

* Significant at 10 percent level.
** Significant at 5 percent level.

Table 7. Utilization of specific technologies by the early (1997) adopters.

	1997 Mean (early adopters)	2000 Mean (early adopters)	p value
Audio/video technologies:			
Two-way interactive video	0.61	0.62	0.70
One-way video / Two-way audio	0.18	0.16	0.39
One-way live video	0.08	0.12	0.01
One-way pre-recorded video	0.57	0.54	0.30
Two-way audio	0.05	0.10	0.00
One-way audio	0.06	0.14	0.00
Computer-based technologies:			
Internet (synchronous)	0.22	0.48	0.00
Internet (asynchronous)	0.63	0.90	0.00
CD-ROM	0.09	0.32	0.00

Table 8. Comparison of technology utilization between early (1997) and late (2000) adopters.

	2000 Mean (early adopters)	2000 Mean (late adopters)	p value
Audio/video technologies:			
Two-way interactive video	0.62	0.34	0.00
One-way video / Two-way audio	0.16	0.06	0.00
One-way live video	0.12	0.05	0.00
One-way pre-recorded video	0.54	0.26	0.00
Two-way audio	0.10	0.11	0.76
One-way audio	0.14	0.09	0.03
Computer-based technologies:			
Internet (synchronous)	0.48	0.42	0.12
Internet (asynchronous)	0.90	0.83	0.01
CD-ROM	0.32	0.27	0.15

Table 9. Fraction of institutions that considered various goals for adopting TMDE as "important" (2000 survey)

Goals of adopting TMDE	**Public Institutions**	**Private Institutions**	**p value for equality of means**	**Early Adopters**	**Late Adopters**	**p value for equality of means**
Reducing institution's per student costs	0.65	0.50	0.00	0.64	0.54	0.02
Making educational opportunities more affordable for students	0.79	0.67	0.00	0.78	0.73	0.24
Increasing institution enrollments	0.94	0.90	0.06	0.94	0.91	0.23
Increasing student access by reducing time constraints for course taking	0.96	0.90	0.00	0.96	0.90	0.01
Increasing student access by making courses available at convenient locations	0.95	0.85	0.00	0.94	0.89	0.03
Increasing the institution's access to new audiences	0.97	0.91	0.00	0.96	0.94	0.16
Improving the quality of course offerings	0.91	0.78	0.00	0.90	0.82	0.01
Meeting the needs of local employers	0.85	0.61	0.00	0.82	0.72	0.01