3-15-2012

Using Cost-effectiveness Analysis to Evaluate School of One

Fiona Hollands

Hollands, Fiona, "Using Cost-effectiveness Analysis to Evaluate School of One" (2012). *Center for Benefit-Cost Studies of Education*. 30.
https://repository.upenn.edu/cbcse/30

Using Cost-effectiveness Analysis to Evaluate School of One

Abstract

This paper applies cost-effectiveness analysis to a blended learning math intervention for middle school students, School of One (recently renamed Teach to One: Math), to assess whether it is a productive use of education funds.

Keywords

educational technology, cost-effectiveness

Disciplines

Economics | Educational Assessment, Evaluation, and Research | Education Economics

Paper Title Using Cost-effectiveness Analysis to Evaluate School-of-One

Author(s) Fiona M. Hollands, Columbia University

Session Title Evaluating the Effectiveness of Technology Initiatives on Student Achievement

Session Type Roundtable Presentation

Presentation Date 4/14/2012

Presentation Location Vancouver, British Columbia, Canada

Descriptors Program Evaluation, Instructional Technology, Computers and Learning

Methodology Mixed Method

Unit Division H - Research, Evaluation and Assessment in Schools

Using Cost-effectiveness Analysis to Evaluate School of One (So1)

Fiona Hollands, Ph.D.
Center for Benefit-Cost Studies of Education
Teachers College, Columbia University
fmh7@tc.columbia.edu

March 15th, 2012

Objectives

While some researchers (e.g. Bates, 2005; Figlio, Rush & Yin, 2010; Rice, 2012; USDOE, 2012) argue that we know little about the costs or the effectiveness of online or blended education, as compared with traditional face-to-face education, it is important to use what *is* known to make decisions with respect to resource allocation among types of delivery. This is especially urgent given current fiscal constraints and rapidly proliferating state policies embracing and encouraging these newer modes of education.

This paper applies cost-effectiveness analysis, as developed by Levin and McEwan (2001), to one particular blended learning intervention, School of One (So1) (http://schoolofone.org/), a much publicized program developed by the New York City Department of Education, which is currently being marketed nationally as Teach to One: Math. The program budget for So1 in Fiscal Year 2011 was $7.7 million and it served 1,500 middle school students. In this paper, national prices are used to estimate what it would cost for a middle school of 480 students to replicate the program. Subsequently, evidence of the program's effectiveness in improving middle school math achievement is reviewed in order to assess whether it is a viable use of scarce education funding which merits being scaled up further.

Perspectives

Defining online and blended instruction

Many states, districts, schools and colleges perceive online and blended learning as a means to reduce overall costs while simultaneously increasing access to educational opportunities (Foundation for Excellence in Education, 2010). However, what constitutes online or blended learning varies dramatically in different situations so that generalizing about costs or effectiveness is misleading. Instead, it is important to define the intervention clearly before attempting such evaluation.

Internet-based learning has been incorporated to varying degrees in a wide range of instructional programs and courses. At one extreme of this range, a student's education at a brick-and-mortar school is replaced by enrolling in an online school, also known as a "virtual school", "cyber school" or "eSchool". According to the International Association for K-12 Online Learning (iNACOL), an online school is a "formally constituted organization (public, private, state, charter, etc.) that offers full-time education delivered primarily over the Internet" (iNACOL, 2011, p. 7). Watson, Murin, Vashaw, Gemin and Rapp (2011) estimate that 250,000 students were enrolled in full-time online schools at the K-12 level in 2010-2011.

More commonly, traditional schools are providing online learning, also known as "virtual learning", "e-learning" or cyber-learning", in the form of online courses to supplement existing face-to-face instruction. Watson, Murin, Vashaw, Gemin and Rapp (2010) define online learning as "instruction via a web-based educational delivery system that includes software to provide a structured learning environment." (p. 9). Queen and Lewis (2011) report 1,816,400 enrollments in distance education courses in K-12 school districts in 2009-2010. This count includes students who enrolled in multiple courses and in some off-line courses therefore the number of individual students participating in online courses would be lower.

In other instances, Internet-based learning is combined with traditional face-to-face delivery in what is termed "blended" or "hybrid" learning. Horn and Staker (2011) define blended learning as "any time a student learns at least in part at a supervised brick-and-mortar location away from home *and* at least in part through online delivery with some element of student control over time, place, path, and/or pace" (p.3). They further split blended learning into four models: rotation, flex, self-blend and online driver.

No comprehensive data have been published indicating how many students are participating in some form of blended or hybrid learning but Staker (2011) wrote profiles of 40 different "emerging models" which served a total of approximately 665,000 students. It is probable that there is a significant overlap in the number of enrollments quoted for full-time online schools, distance education and blended learning because some online schools, e.g. Florida Virtual School, provide blended options to their students. School of One falls into the category of blended learning interventions following a rotation model where, according to Horn and Staker, "students rotate on a fixed schedule between learning online in a one-to-one, self-paced environment and sitting in a classroom with a traditional face-to-face teacher…The face-to-face teacher usually oversees the online work." (p.4).

Effectiveness of online and blended instruction

Numerous studies have compared the effectiveness of online and blended learning interventions with traditional face-to-face instruction. Three meta-analyses summarize much of this research: Cavanaugh, 2001; Cavanaugh, Gillan, Kromrey, Hess, and Blomeyer, 2004; Means, Toyama, Murphy, Bakia, and Jones, 2009, revised 2010. However, Figlio *et al.* (2010) describe the evidence-base regarding the benefits of online versus face-to-face education as "tenuous at best" (p.4) because of weak methods. Additionally, relevance to the K-12 community is limited because most studies address higher education contexts.

In 2001, Cavanaugh synthesized the results of 19 studies of the effectiveness of interactive distance education at the K-12 level. She found that, overall, students learning through two-way audio-videoconferencing, e-mail or the Web, performed marginally better on measures of academic achievement than students learning by traditional classroom instruction only. However, a standard test of statistical significance did not confirm any advantage (or disadvantage) of interactive distance learning over traditional instruction. However, this meta-analysis has limited relevance to the current online learning environment because only one of the 19 studies involved use of the Web. Additionally, as only one third of the studies in the meta-analysis were experimental and only 10% assigned students to treatment or control conditions at random, the internal validity of the underlying studies is weak.

Cavanaugh *et al.*'s 2004 meta-analysis of the effects of distance learning on K-12 student outcomes included 14 web-delivered K-12 distance education programs studied between 1999 and 2004. Despite reviewing thousands of abstracts of distance learning studies, the researchers were able to identify only 14 studies that met their criteria, only one of which was a published article while the others were reports and dissertations. While effects on student academic achievement were slightly lower for the distance education conditions than for traditional instruction, the difference was not statistically significant.

The most recent meta-analysis, sponsored by the U.S. Department of Education (Means *et al.*, 2009, revised 2010), included 99 studies comparing the learning outcomes in online and blended learning instruction with traditional face-to-face instruction. The study concluded that blended instruction is more effective than conventional face-to-face classes for older learners (undergraduates and adults). However, the researchers emphasized that treatment conditions for the online and blended learning situations studied often included additional learning time, extra materials and opportunities for collaboration, raising the likelihood that one or more of these variables in instructional delivery might account for the positive impact on outcomes, as opposed to the blending of online and face-to-face instruction. The positive effects were greater when the online instruction was collaborative or instructor-directed as opposed to situations where online learners studied independently. Pure online learning was found to offer no significant advantage over face-to-face instruction. Positive effects were not found at the K-12 level but this conclusion was based on only five studies that qualified for inclusion in the analysis. The authors conclude that their findings support the strategy of redesigning instruction to incorporate additional learning opportunities.

More recently, a number of states, e.g. Minnesota and Colorado, have conducted evaluations of their K-12 online learning initiatives to provide accountability to their state legislatures. In Minnesota, enrollment in online courses quadrupled from 2006-2007 to 2009-2010 but course completion rates for full-time online students dropped from 84% to 63% (Office of the Legislative Auditor, State of Minnesota, 2011). Full-time online students in 11th and 12th grade dropped out of school at a much higher rate than Minnesota students as a whole. For 12th grade students, 3%

of all students across the state dropped out in 2009-2010. For part-time online students, who mostly took online courses at school to supplement traditional courses, the dropout rate was less than 1%. However, for full-time online students the rate was 25%. Some of the difference can be attributed to demographic characteristics, for example, only 66% of full-time online students stayed at the same school throughout the 2009-2010 school year while 95% of students statewide stayed in the same school. Only 1% of full-time online students were gifted and talented compared with 9% of students statewide. Full-time online students were more likely to be white and female than students statewide but did not differ in levels of special education or eligibility for free or reduced-price lunch.

A 2011 study by Heppen *et al.* in 68 mostly rural schools in Vermont and Maine investigated the impact of expanding access to Algebra I for 8th grade students by offering an online course in schools that would not otherwise offer Algebra I. The study showed that in schools offering the online course, students performed better on a test of algebra at the end of the academic year than students in comparison schools who did not take Algebra I. While this finding indicates that an online Algebra I course has positive educational outcomes, it does not compare delivery of Algebra I online with delivery face-to-face and therefore cannot help us determine whether students taking a traditional Algebra I course would have performed the same, better or worse than the online course-takers.

In summary, much of the research that does exist is focused on online rather than blended learning and very little experimental research on either has been done at the K-12 level. Perhaps because online learning can easily be delivered at scale and is readily defined, there has been more motivation to evaluate such interventions. Blended learning interventions are highly variable in structure and therefore harder to define. Their reliance on a face-to-face component has also made it harder to scale any one particular model.

Costs of online and blended instruction

Very few studies attempt to compare the costs of face-to-face instruction with online or blended instruction and none have been conducted using a rigorous cost analysis methodology. Two studies (Cavanaugh, 2009 and Anderson, Augenblick, DeCesare, & Conrad, 2006) addressed costs of online learning. A recent study by Battaglino, Haldeman, and Laurans (2012) addressed costs of both full-time virtual schools and of blended learning models.

Cavanaugh (2009) reports on a survey by the Center for American Progress of 20 virtual school directors in 14 different states. Compared with the average per pupil expenditure in public schools for 2007-2008 of $10,297 (http://nces.ed.gov/fastfacts/display.asp?id=66), the self-report survey indicated an average annual cost of $4,310 per full-time online student in 2008. The apparent savings are enormous. However, while this comparison may seem attractive for states facing slashed education budgets, the services offered by traditional schools far exceed what such online schools provide. As Cavanaugh notes, traditional schools provide not just academic courses but also transportation and nutrition services, school counselors and nurses, college guidance, libraries, media specialists and resources, clubs, activities and professional development services. Comparisons of traditional schools with virtual ones must factor in the costs of losing these services or providing alternate ways to access them.

In an earlier study, Anderson, Augenblick, DeCesare, and Conrad (2006) convened panels of online program providers to estimate the operating costs of virtual schools. While reported costs ranged between $3,650 and $8,300 per full-time-equivalent student, the authors concluded that, on average, virtual schooling costs are on par with traditional brick-and-mortar schools when similar services are being provided, excluding transportation and capital costs. The authors acknowledge that these estimates need to be refined to be relevant to specific conditions in a particular state or district.

In 2012, Battaglino, Haldeman, and Laurans estimated average costs and a range of costs for rotation and flex blended learning models and full-time virtual schools in the United States based on information collected in interviews with 50 entrepreneurs, policy experts and school leaders. It is unclear how these interviewees were selected and how representative they are of virtual and blended school models throughout the United States. It is also not clear how the authors ensured that costs were comparable across localities and time. The authors identify five major cost categories:

i) labor (teachers, aides, administrators, instructional technology staff, professional development);
ii) content acquisition (courseware, a content management system, and the cost of purchasing and shipping materials to students);
iii) technology (computers/tablets, webcams, document cameras, printers etc.) and infrastructure (hardware, software, connectivity, storage, servers);
iv) school operations (e.g. facilities, transportation);
v) student support services (e.g. guidance counselors, special education services).

They estimate total costs per student at a hypothetical 500-student full-time virtual high school of between $5,100 and $7,700. Examples cited of virtual full-time schools include Florida Virtual School, K12 Inc. and Connections Academy but the cost estimates provided are not associated with specific schools or resource requirements.

A hypothetical 500-student middle school providing blended instruction is estimated to cost $7,600 to $10,200 per student per year. Examples listed of blended instruction include Rocketship Education, Carpe Diem, School of One (although it is a math program rather than a school) and KIPP Empower LA, which all follow rotation models; and flex models such as AdvancePath or Flex Academy.

Again, estimates are not attached to any one example. The authors note that their estimates do not include the cost of student services that districts may need to provide if they are not offered by a virtual school, e.g. special education services.

Of the five cost categories, Battaglino *et al.* (2012) deem content acquisition to be the most variable depending on whether the content and content management system is free or low-cost. Open-source teacher-created content, such as Khan Academy, and free content management systems, such as Moodle, result in the lowest content costs. Off-the-shelf online content such as courses offered by K12 Inc. offer a middle ground in terms of cost while customized content created by districts, states or schools is usually the most expensive given the high labor costs. Clearly the scale to which content purchases or development can be applied is a significant driver for the cost per student.

The authors compare their estimates for online and blended schooling with the cost of traditional schooling using an NCES figure of approximately $10,000 average per-pupil costs, not including central administrative costs, for elementary, middle and high schools in the United States. They conclude that, in order to assess the productivity of “technology-rich” education models, we need to review results, or effectiveness, as well as the costs but they note that the relevant effectiveness data is yet to be gathered.

USDOE (2012) similarly acknowledges that the dearth of high quality effectiveness data on online learning precludes any serious attempts at quantifying its contribution to educational productivity. However, USDOE identifies nine ways in which online learning might improve productivity: broadening access to learning opportunities; engaging students in active learning; individualizing and differentiating instruction; personalizing learning; making better use of teacher and student time; increasing the rate of student learning; reducing school-based facilities costs; reducing salary costs; realizing opportunities for economies of scale. The report concludes that in order for educational stakeholders to be able to make decisions leading to greater productivity, they need information from studies that “follow rigorous methodologies that account for a full range of costs, describe key implementation characteristics and use valid estimates of student learning” (p.viii).

In all three cost studies described above, cost estimates are based on self-reported information from online education administrators or other individuals not directly involved in the implementation of the interventions. None of the estimates represent the costs of a specific, identifiable intervention using either budget numbers or actual expenditures. There is also no attempt to balance costs against benefits or actual student outcomes. Rice (2012), in her review of Battaglino *et al.* (2012), indicates that the strength of the analysis could be improved by: employing rigorous cost analysis methods such as Levin and McEwan's (2001) ingredients approach; identifying several promising models to use as the basis of establishing cost estimates; and addressing issues of effectiveness in addition to cost in order to be able to assess productivity. These are in line with the recommendations provided by

USDOE (2012). The following investigation into costs and effectiveness of School of One aims to provide one such analysis.

Methods

Cost-effectiveness analysis aims to facilitate efficient use of educational resources (Levin & McEwan, 2001). Given a target objective, for example, increasing 6th grade math scores in a district by 10%, cost-effectiveness analysis can identify the lowest cost alternative to achieving this objective. The process involves assessing the costs of various interventions that aim to improve math scores and reviewing the evidence on effectiveness to determine whether the 10% improvement objective can be met. Alternatively, given a fixed budget, a cost-effectiveness analysis can indicate which intervention is expected to increase math scores the most.

To conduct a rigorous cost analysis of any educational intervention, Levin and McEwan (2001) propose the ingredients method for identifying costs. The various components of a program are identified by reviewing program documents, interviewing personnel involved in the development and delivery of the intervention, and observing the intervention in a typical field situation. These components will fall into categories such as: personnel, which often accounts for about 75% of the costs of any educational intervention; facilities; equipment and materials; other inputs such as insurance and electricity; and client inputs such as transport costs.

Levin and McEwan's (2001) ingredients method was followed to estimate costs of School of One (So1), a blended learning intervention for math instruction being used by 1,500 students across three New York City middle schools in 2010-2011. First, program documents available from the New York City Department of Education's official website were examined for descriptions of the program. A general web search was conducted for reports and media articles describing implementation. Secondly, the program was observed in action on a regular school day, during a session open to the public, at one of the three middle schools using the program. Finally, e-mail and verbal exchanges with a co-founder of So1 helped clarify a number of operational issues. From these sources, a list of ingredients necessary to implement the program was compiled. Subsequently, costs of each ingredient were estimated, primarily based on national market prices for items such as teacher salaries, teacher professional development, hardware and software. Additionally, interviews with a technology director at a private school in Manhattan, a suburban public school district superintendent and assistant superintendent provided some specific cost figures for services that are not readily obtained through public sources, e.g. costs of internet access and wireless connectivity for an entire school.

Much of the $7.7 million 2011 budget for So1 was related to the development of a complex technology platform. Development costs would not be directly relevant to a decision-maker simply considering replication of the program, except to the extent that development costs are often partially or fully recouped in a content or service licensing fee. To provide useful information to decision-makers considering replication of So1, the list of ingredients and their associated costs were used to estimate the new costs per pupil that a typical 480-student middle school would incur if substituting its traditional math program with So1. The cost estimates for So1 were submitted to the founder for verification but he declined to either confirm or correct them, noting that the model is still under development. Additionally, with the current effort to market So1 nationally as Teach to One: Math, cost information is probably considered proprietary, competitive information.

In addition to estimating costs of the program, existing studies evaluating the effectiveness of So1 were examined to determine whether the costs per pupil could be associated with an improvement in educational outcomes, as compared with traditional face-to-face or "business as usual" instruction.

Cost Data

School of One is a recent initiative of the New York City Department of Education. Initially piloted in 2009-2010 as an afterschool program, a summer program, and, briefly, as an in-school alternative to the regular math program, it has now been fully integrated into the school day at three public middle schools to provide highly individualized daily math instruction for 1,500 students in place of traditional face-to-face instruction. Students spend math periods of 70 minutes a day in one of eight modalities: learning with software, independent work, peer tutoring, learning with a remote tutor online, small or large group instruction with a face-to-face teacher, small group collaboration, and integrated learning projects. Around 10 of these minutes are spent daily completing an individual assessment that allows a computer-based "Learning Algorithm" to determine how each student is progressing along a math skills map. Each student's personalized daily lesson plan or "playlist" is generated by the Learning Algorithm system and displayed on terminals as students enter the classroom.

Annual replication costs for a middle school using the So1 system are estimated based on a population of 480 students. It is assumed that four groups of 120 students each work with So1 for 70 minutes per day, five days a week, 36 weeks a year. It is assumed that four fully certified math teachers and two assistant/student teachers would be employed regardless of whether So1 is utilized or students are taught traditionally i.e. there is no initial difference in teacher labor costs. Additionally, it is assumed that the school already has Internet access for all students and wireless connectivity. The costs considered here are marginal costs i.e. additional to the existing running costs of the middle school.

Any school adopting So1 that is not already wired would need to factor in these costs, which appear to vary significantly depending on school location and scale. For example, the technology director of one Manhattan private school serving 640 students reported paying $1,500 - $1,600 per month in 2011 for Internet access

($28-$30 per student over the entire year) while the superintendent of a small suburban public school district in New York reported paying $50,000 per year for Internet access for 5,400 students spread across 5 schools ($9.26 per student per year). Wireless connectivity is a further cost consideration. The Manhattan school paid $30,000 for a Cisco wireless network, including a wireless controller and 40 access points. The technology director estimated he could amortize the costs over a four-year period ($11.72 per student per year or $187.50 per access point per year). At the suburban school district, wireless connectivity cost $78,000 for a 1,100-student high school with 50 access points ($17.73 per student per year assuming four year amortization or $390 per access point per year).

New costs for the first year that are directly associated with replicating So1 are estimated for: space remodeling; an in-house digital content manager; professional development; hardware; expected licensing fees for School of One content and access to the Learning Algorithm; and virtual tutoring. Note that remodeling and hardware costs can be amortized over a number of years. Tutoring is treated separately because it appears to be the highest cost item, accounting for 50% of the estimated cost of the program. Adjustments to the amount of tutoring used, if flexibility is offered by the program developers, will significantly affect the analysis. Costing assumptions, sources and calculations are provided for each item to allow readers to re-calculate costs to reflect local prices and conditions, to modify the assumptions for a sensitivity analysis, or to accommodate local regulations. Headings reflect dollar amounts rounded to the nearest $100.

$232,400 in school remodeling costs to open up a space of 4,320 square feet to accommodate 120 students with 120 laptops or personal computers.

Space regulations for classroom sizes vary slightly across states and are not written envisioning such large spaces at the K-12 level but, for example, Texas Administrative Code requires 36 square feet per student for a computer classroom and 28 square feet per student for a general classroom. http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=T&app=9&p_dir=F&p_rloc=138259&p_tloc=14963&p_ploc=1&pg=2&p_tac=&ti=19&pt=2&ch=61&rl=1036 . Current California Code of Regulations, Title 5, Section 14030(g)(1)(A) states that classrooms for grades 1 through 12 be a minimum of 960 square feet http://www.cde.ca.gov/ls/fa/sf/title5regs.asp. With an average class size in California for 6th grade of 26.2 students this equates to 36.6 square feet per student. http://www.cde.ca.gov/ds/sd/dr/cefteachavgclssize.asp. An allocation of 36 square feet per student is used for this analysis totaling 36 x 120 = 4,320 square feet.

According to the 2011 School Construction Report (School Planning & Management, 2011), the national median for cost of middle school construction is $215.14 per square foot. http://www.peterli.com/spm/pdfs/SchoolConstructionReport2011.pdf. Assuming that remodeling existing classroom space to create a single, large, technology-ready space would cost only one quarter of this amount, depending on the existing electrical capacity, the remodeling cost would be \$215.14/4 = \$53.79 per square foot. For the School of One space, the total remodeling cost would be \$215.14/4 x 4,320 = \$232,351.20.

School building costs are typically amortized over 10 - 30 years (e.g. The State of Connecticut requires straight-line amortization over 20 years for school building projects costing over \$2 million and over 10 years for projects costing less than \$2 million. New York State requires school building amortization over 15, 20 or 30 years). For this analysis, the remodeling costs are amortized in a straight line over 10 years as it is assumed that remodeling would occur more frequently than full-scale renovation or new building costs: \$232,351.20/10 = \$23,235 per year.

\$31,000 for Professional Development

Costs of professional development include payments to teachers for overtime hours and trainer fees. Three types of professional development are considered here:

1) One week prior to the start of the school year for the 4 teachers and two teaching assistants in how to use the So1 Model to teach mathematics.

Following Odden, Archibald, Fermanich and Gallagher's (2002) cost framework for professional development, teacher compensation is estimated based on annual salary plus benefits divided by number of contract hours per year. In this analysis the hours are calculated as 36 weeks x 5 days x 6 hours or 1,080 hours. NCES 2009-2010 reports a national average public secondary school teacher salary of \$54,505 http://nces.ed.gov/programs/digest/d10/tables/dt10_082.asp
and benefits of 23% (NCES reports benefits to teachers in 2006-2007 for a few states, which range from 17% – 29% of salary
http://nces.ed.gov/pubs2010/tcs2007/tables/table_22.asp. The midpoint, 23%, is used here). The teacher cost per hour is calculated as (\$54,505 x 1.23) /1,080 = \$62.08 per hour. For 4 teachers over one week this would amount to 4 teachers x 5 days x 6 hours x \$62.08 = \$7,449.60.

Mean assistant teacher salaries in elementary and secondary schools in 2010 were \$25,120 (http://www.bls.gov/oes/current/oes259041.htm#nat) and benefits of 23% are also assumed. Cost per hour = \$25,120 x 1.23/ 1,080 = \$28.61 per hour. For 2 assistant teachers over 1 week this would amount to 2 teachers x 5 days x 6 hours x \$28.61 = \$1,716.60.

Training rates vary depending on the provider but typical professional development providers charge \$1,100 - \$1,600 per day (e.g. Read 180 professional development). Assuming the So1 trainer cost is \$1,200 per day for 5 days, the total cost would be \$6,000. Costs of any materials provided would be additional but are not included here.

Total for this one week training would be \$7,449.60 + \$1,716.60 + \$6,000 = \$15,166.20.

2) Ongoing weekly professional development for the math teachers. Again following Odden *et al.'s* (2002) cost framework for professional development (2002), if the professional development takes place for 1 hour per week after school hours: 4 teachers are reimbursed at \$62.08 per hour x 36 weeks = \$8,939.52 and 2 assistant teachers are reimbursed at \$28.61 x 36 weeks = \$2,059.92. Total for the 6 individuals = \$10,999.44.

It is assumed that this ongoing professional development would be provided by the in-house digital content manager at no additional cost beyond his/her existing salary.

3) The in-house digital content manager is assumed, during regular work hours, to receive 4 days of continuing professional development from So1 personnel at a cost of \$1,200 x 4 days = \$4,800.

Total costs for professional development = \$15,166.20 + \$10,999.44 + \$4,800 = \$30,965.64.

\$80,000 for an in-house digital content manager

The current implementations of So1 employ a full-time in-house digital content manager to provide ongoing technical support and professional development for the teachers and to interface with the So1 developers. Salary for digital content managers is assumed at the national average of \$65,000 http://www.simplyhired.com/a/salary/search/q-digital+content+manager/l-USA + 23% estimated benefits (assuming the same benefits as teachers, explained above) = \$79,950.

\$126,200 in Hardware costs

Hardware costs include 120 personal computers or laptops, four printers, one projector and two 48" monitors for displaying student playlists. These costs are amortized over three years.

Prices based on web listings for K-12 buyers of products such as DELL (including tax, delivery and a 3 year warranty):

120 computers including basic software and networking at \$1,000 each = \$120,000
Projector at \$1,000
Four printers at \$800 each = \$3,600
Two 48" monitors at \$800 each = \$1,600
Total = \$126,200

Amortizing over 3 years results in annual costs of $126,200/3 = $42,067.

$148,800 Expected Content/Licensing Fee to So1

While it is not yet clear how users of School of One (or Teach to One: Math) will be charged for the program, it is likely that a school-wide licensing charge payable to So1 would provide access to the Learning Algorithm, all content, student data reports, and daily individual student playlists.

There are no comparable market rates publicly available for such a service therefore the licensing fee is estimated based on the purchase at market rates of an online math course. For example, K-12 Inc. charges $310 per student for a year-long 6th grade math course of 180 sessions, each 60 minutes long, without teacher support https://ecomm.k12.com/ecommerce/public/courseDetails.xhtml?cid=301105. For 480 students this would amount to $148,800. While schools are likely to get discounts from individual rates for a site-wide license, So1 provides more than a pre-packaged online course because the Learning Algorithm processes student assessments every day in order to assign each student a personalized playlist for the next day. These additional services provided by the Learning Algorithm are likely to cost at least as much as any discount equivalent.

As further reference points, Battaglino *et al.* (2012) estimate that an off-the-shelf online course with no teacher support costs $75 per student per semester (equivalent to $150 for a year-long course) and $200 - $400 per student per semester with instructor support ($400 - $600 per year). Davis (2012) reports that Florida Virtual School offers full-service half-credit courses outside Florida for $400 per student. For a full year course this would equate to $800 per student. So1 licensing costs should fall somewhere between the $150 and $800 extremes given that it includes no teacher support for the students (except virtual tutoring calculated separately below) but does provide services not offered by typical virtual schools and online courses.

$324,000 for virtual tutors

One of the eight learning modalities offered by So1 is virtual tutoring. At any one time during the math class, except during the 10-minute assessment session, some fraction of the 120 students works individually with online tutors. Assuming 15 tutors are engaged four hours per day with students, 180 days per year at $30.00 per hour, this amounts to $324,000. Online tutoring rates vary depending on the qualifications and geographical location of the tutors (some services depend on tutors from countries such as India and the Philippines where labor costs are far lower than in the United States). In the United States, market rates for online tutoring services such as tutor.com are $39.99 per hour or, for Smarthinking, $35.00 per single hour and $120 for four hours. A rate of $30.00 per hour per tutor is assumed in this analysis for a total of $30 x 15 tutors x 4 hours per day x 180 days.

Note that no costs have been included for percentage of a principal or other administrator's time devoted to the program or inclusion in professional development, but these should be considered on a case-by-case basis at each replication site. The first year costs described above are summarized in Table 1, which shows the cost of each component for the entire school of 480 students and the cost per student. The total cost per student is estimated at $1,352 although it should be noted that the virtual tutoring component is by far the largest cost, at $675 per student. If this option were eliminated, the cost per student would drop to $677. Other savings may be realized if textbooks are no longer required, if the So1 professional development replaces some or all of the regular math or technology professional development provided, or if the role of the digital content manager can be modified to replace existing technology support staff in the school. In subsequent years, provided teacher turnover is low, the So1 professional development costs can be assumed to decrease significantly.

Table 1 Estimated marginal costs of replicating the School of One Program at a middle school of 480 students

Component	Cost per annum for school of 480 students	Cost per annum per student to nearest $
Space Remodeling *	$23,235	$48
Digital content manager/technology support	$80,000	$167
Professional development**	$31,000	$65
Hardware***	$42,067	$88
School of One license	$148,800	$310
Virtual tutoring	$324,000	$675
Total	**$649,102**	**$1,352**

* Cost amortized over 10 years

** If staff turnover is very low, it is arguable that some of the training would not need to be repeated a second year and could be amortized over a period of 3 years.

** Cost amortized over 3 years

Evidence of effectiveness

Having estimated the cost of the program per student, the second part of the cost-effectiveness question is whether So1 has a large enough impact on student outcomes, compared with traditional instruction, to justify the extra costs. The currently available evidence is limited to studies of So1 pilots in summer school, afterschool, and briefly as an optional in-school alternative to the traditional math program. Each type of implementation will be associated with a different set of costs. The latter implementation aligns most closely to the cost analysis assumptions described above although the evaluation of effectiveness was based only on two months of exposure to the program.

An evaluation of the summer school pilot found that 80 rising 7th graders who were exposed to So1 for four hours a day, five days a week for five weeks (a total of 100 hours or the equivalent of 4/5 of a regular year of math instruction) gained an average of 28.2% from pre-test to post-test scores (Light, Reitzes & Cerrone, 2009). Lack of a comparison group prevents determination as to whether this gain was the same, less or greater than would be achieved by traditional teaching methods. Additionally, the summer program was highly resource intensive, employing 10 adult educators and three high school interns for 80 students.

During the 2009-2010 school year, three middle schools invited students to opt into an afterschool pilot of So1 from February through May. A total of 600 students participated and an internal evaluation by The New York City Department of Education's Research and Policy Support Group (2010) concluded that math test score improvements for So1 users, compared with the students who did not opt in, were significantly higher in one of the schools. The afterschool program was supplemental to the regular math program provided during the school day so that this study does not allow a comparison between the regular program and So1 as a substitute. Additionally, given the opt-in nature of student selection, motivation could not be excluded as a significant confounding variable.

The one school in which a significant gain was documented substituted the regular in-school math program with So1 for all sixth graders from May through June, 2010. Test scores at the end of the two-month period were compared with those of students who had not participated in the afterschool version of So1 in the other two schools and were learning math traditionally. The evaluators of this implementation found that math test scores for So1 users showed greater growth over the 2 months than the scores for students in the comparison group. Specifically, Measures of Academic Progress Rasch Unit (MAP RIT) scores increased 1 point for the So1 users and decreased 0.8 points for the students learning traditionally. However, given a relatively small sample size (76 students in each group) this difference was not statistically significant.

Breakeven analysis for cost-effectiveness comparison

To calculate a cost-effectiveness ratio of So1 to compare with traditional math teaching requires both costs of each program and effectiveness data, ideally from an experimental study which measures math achievement gains for students using So1 with a control group of students who are learning math traditionally. The two groups of students should be well matched on as many variables as possible including starting scores, demographic characteristics and recruitment process into the study. The evaluation study for the in-school implementation of So1 described above (New York City Department of Education Research and Policy Support Group, 2010) is not ideal in that it only covers a 2 month period, the comparison group is not well matched to the treatment group and no statistically significant math test score gain was found for So1 users. Additionally, because the comparison students actually lost ground over the two-month study period, a cost-effectiveness ratio would make little sense.

For demonstration purposes, an alternative approach (suggested by C. Belfield, personal communication), is presented in the following calculations which provide a rough breakeven analysis indicating how much So1 would need to improve MAP RIT scores in order to justify the extra costs associated with the intervention i.e. to be cost-effective compared with traditional math teaching.

According to Northwest Evaluation Association (NWEA), the developers of the MAP test, the national average gain in MAP RIT scores over 36 weeks is 6 points for 6th grade students (http://www.nwea.org/sites/www.nwea.org/files/resources/2011_Normative_Data_Overview.pdf). Using the national average cost of K-12 education at $10,297 per student, and assuming that the math program at a school accounts for 15% of the total costs, each point of gain in MAP score costs:

($10,297 x 15%)/6 points = $257.

The cost analysis in this paper indicates that So1 adds a further $1,352 cost per student to the costs of a regular math program. To be cost-effective, So1 would need to improve MAP RIT scores by more than:

($10,297 x 15%) + $1,352) /$257 = 11.27 points over 36 weeks.

NWEA (2008) reports standard deviations in the range of almost 6 points for students scoring at the levels of the students in the schools evaluated (average pre-intervention scores were 227 for the So1 students and 221 for the comparison students). This means that 68% of students are expected to show gains of 0-12 points over 36 weeks. A gain of 11.27 points for every student would appear highly ambitious.

Conclusion

The inconclusive evidence on effectiveness from the So1 pilot program evaluations suggests that the estimated costs of $1,352 per student for So1, above and beyond the costs of traditional face-to-face math teaching, may not be currently merited on the basis of cost-effectiveness analysis. However, cost-effectiveness of the program would be best judged by determining the actual costs and effectiveness of a full year in-school implementation and comparing this with the costs and effectiveness of traditional math instruction for a similar population of students. The breakeven analysis presented above indicates that So1 would need to improve math test scores at almost double the rate of the average math program in order to be cost-effective.

Current measures of effectiveness are narrowly focused on test score improvements and do not allow for the possibility that online or blended learning helps develop additional skills that are valuable to the learner and might contribute to future success at both school and in the workplace. Broader measures of effectiveness might capture positive trends that are not currently perceived. Additionally, experiments such as So1 might be cast as worthwhile research and development in the field of education and could lead to new methods of teaching and learning that are cost-effective once expanded to include other subject areas, delivered at scale or used to reduce teacher labor costs by replacing teachers to some extent with technology. However, unless it can be shown in a rigorous randomized control trial that So1 (or Teach to One: Math) is significantly more effective than traditional face-to-face teaching in terms of improving student educational outcomes, it does not appear to be a cost-effective alternative to traditional math instruction.

Significance

Without rigorously assessing both costs and effectiveness, many education decision-makers believe that online and blended learning is "cost-effective" because they see it as a means to save money while maintaining educational opportunities for students. In order to improve decision-making regarding school resource allocation, the research community needs to provide better information about the costs of online and blended learning interventions and about their impact on educational outcomes, relative to traditional face-to-face instruction. Using Levin and McEwan's (2001) well-established ingredients method, this paper models a detailed estimation of replication costs that would be experienced by schools replacing their traditional math instruction with the So1 model. Subsequently, the existing evidence of effectiveness is reviewed to assess whether the additional costs of the intervention can be justified by improved student performance. In situations where rigorous studies comparing a new intervention with "business as usual" or alternative interventions have been conducted, cost-effectiveness ratios can be calculated to allow comparison of the alternatives and selection of the most cost-effective. The logic followed in this paper can be applied to other online or blended learning interventions to help education decision-makers make better-informed resource allocation decisions.

References

Anderson, A., Augenblick, J., DeCesare, D., & Conrad, J. (2006). *20/20 Costs and Funding of Virtual Schools*: Augenblick, Palaich & Associates. Retrieved from: http://www.inacol.org/research/docs/Costs&Funding.pdf

Bates, A.W. (2005). *Technology, E-learning and Distance Education* (2nd ed.). New York: Routledge.

Battaglino, T.B., Haldemann, M., & Laurans, E. (2012) The Costs of Online Learning
Washington DC: Thomas B. Fordham Institute. Retrieved from: http://www.edexcellencemedia.net/publications/2012/20120110-the-costs-of-online-learning/20120110-the-costs-of-online-learning.pdf

Cavanaugh, C. (2001). The effectiveness of interactive distance education technologies in K-12 learning: a meta-analysis. *International Journal of Educational Telecommunications 7*(1), 73-88.

Cavanaugh, C., Gillan, K., Kromrey, J., Hess, M., & Blomeyer, R. (2004). The effects of distance education on K–12 student outcomes: A meta-analysis. Naperville, IL, Learning Point Associates. Retrieved from: http://www.ncrel.org/tech/distance/k12distance.pdf

Cavanaugh, C. (2009). *Getting Students More Learning Time Online: Distance Education in Support of Expanded Learning Time in K-12 Schools* Washington, DC. Center for American Progress Retrieved from: http://www.americanprogress.org/issues/2009/05/pdf/distancelearning.pdf

Davis, M. R. (2012, March 12). Examining the Florida Virtual School. *Education Week* Retrieved from: http://www.edweek.org/ew/articles/2012/03/15/25florida.h31.html?intc=EW-TC12-EM

Figlio, D. N., Rush, M., & Yin, L. (2010). *Is it live or is it Internet? Experimental estimates of the effects of online instruction on student learning* (NBER Working Paper 16089). Cambridge, MA: National Bureau of Economic Research. Retrieved from: http://www.nber.org/papers/w16089.pdf?new_window=1

Foundation for Excellence in Education. (2010). *Digital Learning Now!* Retrieved from: http://www.excelined.org/Docs/Digital%20Learning%20Now%20Report%20For%20Governors.pdf

Heppen, J.B., Walters, K., Clements, M., Faria, A., Tobey, C., Sorensen, N., & Culp, K. (2012). *Access to Algebra I: The Effects of Online Mathematics for*

Grade 8 Students. (NCEE 2012–4021). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education. Retrieved from: http://www.air.org/files/REL-NEI_Virtual_Algebra_12-13-11_AIR.pdf

Horn, M.B. & Staker., H. (January, 2011) *The Rise of K-12 Blended Learning* Mountain View, CA: Innosight Institute Retrieved from: http://www.innosightinstitute.org/innosight/wp-content/uploads/2011/01/The-Rise-of-K-12-Blended-Learning.pdf

International Association for K-12 Online Learning (2011) *The Online Learning Definitions Project.* Retrieved from: http://www.inacol.org/research/docs/iNACOL_DefinitionsProject.pdf

Levin, H., M., & McEwan, P. J. (2001). *Cost-Effectiveness Analysis: Methods and Applications* (2nd Ed.). Thousand Oaks, CA: Sage.

Light, D., Reitzes, T., & Cerrone, M. (2009) *Evaluation of the School of One Summer Pilot: An Experiment in Individualized Instruction.* Retrieved from: http://www.schoolofone.org/resources/edc_2009_eval.pdf

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009, Revised 2010) *Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies.* Washington, DC: U.S. Department of Education. Retrieved from: http://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

New York City Department of Education Research and Policy Support Group (2010) *School of One Evaluation – 2010 Spring Afterschool and Short-Term In-School Pilot Programs.* Retrieved from: http://www.schoolofone.org/resources/so1_final_report_2010.pdf

NWEA (2008) *RIT Scale Norms for Use with Measures of Academic Progress.* Retrieved from: http://pickens.it.schoolfusion.us/modules/groups/homepagefiles/cms/374410/File/MAP/Norms2008.pdf?sessionid=0f88735

Odden, A., Archibald, S., Fermanich, M., & Gallagher, H. A. (2002). A cost framework for professional development. *Journal of Education Finance, 28*(1), 51–74.

Office of the Legislative Auditor, State of Minnesota. (2011) *Evaluation Report: K-12 Online Learning.* Retrieved from: http://www.auditor.leg.state.mn.us/ped/pedrep/k12oll.pdf

Queen, B., and Lewis, L. (2011). *Distance Education Courses for Public Elementary and Secondary School Students: 2009–10* (NCES 2012-008). U.S. Department of Education, National Center for Education Statistics. Washington, DC: Government Printing Office.

Rice, J.K. (2012). *Review of "The Costs of Online Learning."* Boulder, CO: National Education Policy Center. Retrieved March10, 2012 from http://nepc.colorado.edu/thinktank/review-cost- of -online.

School Planning and Management (2011*) The 2011 School Construction Report.* http://www.peterli.com/spm/pdfs/SchoolConstructionReport2011.pdf

Staker, H. (May, 2011) *The Rise of K-12 Blended Learning: Profiles of Emerging Models* Mountain View, CA: Innosight Institute Retrieved from: http://www.innosightinstitute.org/innosight/wp-content/uploads/2011/05/The-Rise-of-K-12-Blended-Learning.pdf

(USDOE) U.S. Department of Education, Office of Educational Technology. (2012) *Understanding the Implications of Online Learning for Educational Productivity,* Washington, D.C. Retrieved from: http://gsehd.gwu.edu/documents/users/juliestella/implications-online-learning.pdf

Watson, J., Murin, A., Vashaw, L., Gemin, B., & Rapp, C. (2010). *Keeping Pace with K-12 Online Learning: An Annual Review of Policy and Practice.* Evergreen, CO: Evergreen Education Group. Retrieved from http://www.kpk12.com/cms/wp-content/uploads/KeepingPaceK12_2010.pdf

Watson, J., Murin, A., Vashaw, L., Gemin, B., & Rapp, C. (2011). *Keeping Pace with K-12 Online Learning: An Annual Review of Policy and Practice.* Evergreen, CO: Evergreen Education Group. Retrieved from http://kpk12.com/cms/wp-content/uploads/KeepingPace2011.pdf