JUMP MATH APPROACH TO TEACHING FOUNDATIONS MATHEMATICS IN 2-YEAR COLLEGE SHOWS CONSISTENT GAINS IN A RANDOMIZED FIELD TRIAL

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Abstract

Many first year college students struggle with foundational mathematics skills even after one semester of mathematics. JUMP math, a systematized program of teaching mathematics, claims that its approach, though initially designed for K-8, can strengthen skills at the foundations college math level as well. Students in sixteen sections of Foundations Mathematics at a college in Canada were randomly assigned to be taught with either the JUMP math approach or a typical teaching approach. Students were measure before and after on their competence (Wechsler test of Numerical Operations) and attitudes (Mathematics Attitudes Inventory) to identify any improvements. Results showed that students in JUMP classes had modest, but consistently higher improvements in competence when compared to students in non-JUMP classes, even after controlling for potential confounding variables, while improvements in Math Attitudes showed no differences.

Keywords: Randomized Field Trial, College Math, JUMP Math, Effectiveness

Introduction

The College Math Project (CMP) has confirmed what many involved in math education at the post-secondary level in Canada and elsewhere already knew: despite the importance of math skills in predicting success for students within the college system and beyond, too many students continue to experience poor outcomes, with over 30% considered “at risk” after completion of their first college math course (Orpwood et al, 2010). One potential solution is to teach foundations college math using the JUMP approach. The Junior Undiscovered Math Prodigies (JUMP) approach to teaching mathematics has a strong theoretical foundation and has shown some dramatic successes at the elementary school level (Lambeth, 2006). It uses guided discovery in order to help students improve their math skills alongside a careful scaffolding of ideas. Its potential for college math had not been thorough assessed, particularly through randomized trials.

The Randomized Controlled Trial method has provided strong evidence for assessing the effectiveness of interventions in many fields including math education (Scheaffer, 2007, Clements, 2008). Even though it is considered the ‘gold standard’ in educational research it is a rarely used tool (Golfin, 2005; Cook in Boruch, 2001). The goal of this research project is to use a Randomized Field Trial in order to investigate the effectiveness of teaching using the JUMP approach in as natural a setting as possible. This presentation will describe the design and results of such a randomized field trial of the JUMP math program in a college setting.

Background

The JUMP approach to teaching mathematics is founded on the principal that everyone has the ability to do well in mathematics (Mighton, 2003), that mathematics can be successfully decomposed and decontextualized for learning (Anderson, 2000), and that unassisted discovery does not benefit learners, whereas feedback, worked examples, scaffolding, and elicited explanations do (Alfieri, 2011). JUMP has been showing signs of success both anecdotally and in unpublished research (Brock, 2005; Lambeth, 2006; Solomon, 2011) in improving mathematics skills in the Grade 1-8. However, there has yet to be a peer reviewed study published confirming these findings. Maciejewski (2012) conducted a pilot study on the JUMP math program at a Canadian College. Though findings were inconclusive, they provided the impetus for redesigning the JUMP materials for the foundations mathematics course in the college setting and for further examining the effectiveness of JUMP therein.

Improving math education is important as math, specifically basic numeracy, is an essential skill for college graduates and all citizens. Human Resources Skills Canada (HRSDC) is interested in supporting Canadians in developing skills that will help them lead quality lives, especially in times of transition. In particular, there is an interest in ensuring that Canadians develop the numeracy skills needed in our highly volatile economy. With the support of JUMP and HRSDC funding, this research study was initiated with the stated aim and title *Understanding Individual Numeracy: How are we doing? Does it matter?* This presentation will focus on one aspect of this HRSDC funded research project: What is the impact of the JUMP Math numeracy education intervention program on student achievement at the college level?

Context

<u>The setting</u>: Business, Hospitality and General Arts and Science (GAS) divisions within a large urban college in Canada. This college has no math department and no standard first year foundations math course. The JUMP approach was implemented in the Fall semester of 2011 during which time pre- and post-data was collected.

<u>Courses</u>: Each division has its own approach to teaching foundations mathematics: e.g. in Business, students typically receive three or four hours of instruction per week, while in Hospitality, all students have only two hours of instruction per week. All foundations math courses in this study were pass/fail in nature.

<u>Course Content</u>: Course content varies by division as well. However, the level of difficulty would not be far beyond the Grade 8 level in the province in which the college was located.

<u>Materials</u>: JUMP math classes were provided with a set of three professionally bound booklets, published by JUMP. Based in part on the findings of Maciejewski (2012), the JUMP math Grade 8 workbooks were revised to suit the more mature nature of college students and were based on course outlines. Non-JUMP students had to purchase their textbooks as usual.

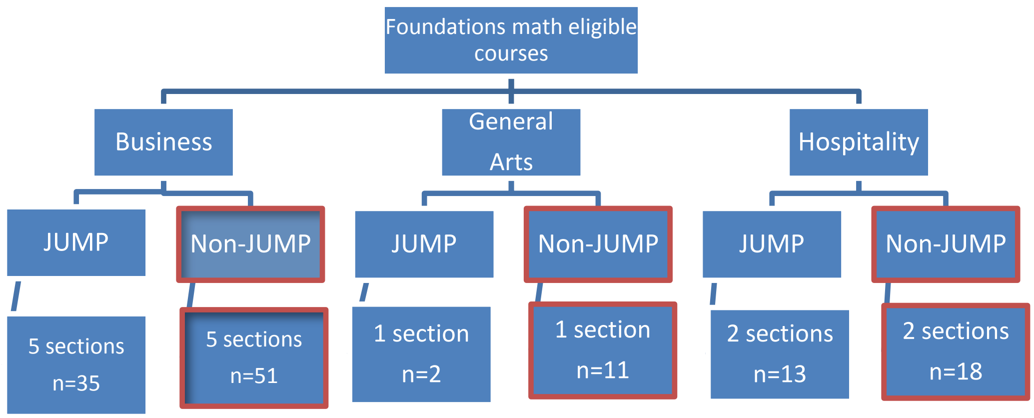
<u>Students</u>: Participants in the study were first year students from the three aforementioned divisions: Business, Hospitality, and GAS. Each registered student had demonstrated a need for mathematics upgrading either through failure of an assessment test or by a self-declaration of unpreparedness.

<u>Teachers</u>: Teachers were assigned to JUMP vs. non-JUMP sections randomly in all but two of eight pairs of classes: one pair of Business classes and the pair of GAS classes. All teachers in participating sections signed letters of informed consent. JUMP math teachers received a two-day training session and a third two-hour session during mid-term. Non-JUMP teachers received training in other contemporary teaching approaches, equivalent to the JUMP training in terms of duration. Teachers teaching the JUMP approach were not passionate and experienced JUMP teachers, and with only two days of training before start of semester cannot have been fully aware of all of the nuances of teaching using the JUMP approach.

<u>Sections (Classes):</u> The randomized field experiment approach included a total of 16 sections (classes), with eight sections in which the JUMP approach to teaching foundations math was used by the teacher and eight sections in which a non-JUMP approach was used (see Figure 1). Student placement in their respective sections was controlled by the registrar’s office at the

college, and varied by division. However, neither the Registrar's office, nor the students knew about the teaching approach in various sections before the first class.

Figure 1: Visualization of Structure with number of participants by division and approach.



Design

Unit of Analysis: The unit of randomization is the section. (Scheaffer, 2007. pg. 37) Nevertheless most of the exploration and discussion will focus on comparing JUMP vs non-JUMP students. Potential confounding of section will be accounted for by stratification and use of ANCOVA analysis.

Randomization: Randomization was accomplished through assigning of a teacher to JUMP vs non-JUMP using a coin flip. Six of eight pairs of classes had teachers assigned to JUMP vs non-JUMP randomly. Of the two not assigned randomly, one teacher in hospitality had developed his own non-JUMP materials and asked to teach non-JUMP one in General Arts and Science had some experience with JUMP and asked if he could be assigned to a JUMP section. Thus randomization is partial.

Population: There were 31 'eligible sections' i.e. sections for which the JUMP math content would be suitable ($n_{students} \approx 1000$). That number was reduced to 16 individual sections (See Figure 1) through purposeful selection based on logistics and scheduling.

Population frame I: Potential student participants were those registered on class lists of the 16 selected sections in both Week 2 (during pre-testing) and Week 14 (during post-testing). $n_{students} = 430$

Population frame II: Subset of frame I - 'active students'. Active students were those that were on the class list at the end of semester and had not dropped out. Students who had a zero GPA at the end of semester, failed all courses in that semester and did not return in the next semester were deemed not active. $n_{students} = 412$. This list was used in order to establish generalizability of results.

Dependent variable 1: Improvement in math achievement was captured using the Wechsler test of Numerical Operations (Wechsler, 2009). The Wechsler test is norm referenced for adults and is validated for pre-post test use with a minimum 12 week time span. Sixty-two test questions cover numerical computations from basic arithmetic to simple derivatives. Pre and post-test scores were collected, entered and verified, then raw scores were converted to standardized scores from which percentile improvement was calculated, based on Wechsler (2009) norms. Improvement was also calculated as gain scores to account for the fact that students who scored

higher in the pre test had less room for improvement (Scheaffer, 2007 pg. 41). The standardized gain score is calculated as $(x_2-x_1)/(\text{max score} - x_1)$.
Dependent variable 2: Minnesota Mathematics Attitude Inventory (MAI) pre- and post-test scores in 6 dimensions: Perception of Mathematics Teacher (Te), Anxiety Toward Mathematics (Anx), Value of Mathematics in Society (Val), Self-concept/confidence in Mathematics (SeC), Enjoyment of Mathematics (Enj), and Motivation in Mathematics (Mot). (Welch, 1972)
Independent variable: JUMP Math teaching approach was used in 8 sections with a control set of 8 non-JUMP sections.
Possible confounding variables: Categorical: division, day of week, time of day class held, number of times class held per week, sex, highest education completed, work status, years since most recent math course, highest level of math taken prior to Sept. 2011.
Measurement: age, Baseline standardized Wechsler and baseline percentile rank (from Wechsler pre-test), baseline MAI for each of 6 dimensions.
Institutional data: Pass rates, GPA scores, year of birth (YOB), and admission status were collected through the Office of Institutional Research. For those with zero GPA, Winter 2012 semester academic standing was collected in June 2012.
Data Collection: Letters of informed consent, demographics, Wechsler pre- and post-tests and MAI pre- and post-tests were all obtained on paper in both Weeks 2 and 14 (one post-test took place in Week 15). Teachers were not involved in the data collection process. An incentive draw was held in Week 14 in each of the 16 sections with the winner receiving a $50 gift certificate to the college bookstore.
Ethics: Research Ethics Board (REB) approval was received for all aspects of the project.
Analysis: Data Analysis was conducted using SPSS-19. Similarities between JUMP and non-JUMP sections at baseline were established to account for incomplete randomization. External validity was assessed by comparing participants and non-participants in relevant characteristics. Comparison of JUMP vs non-JUMP with respect to outcomes was examined alongside comparisons by Division and correlations with possible confounding variables. Finally ANCOVA analysis was used to assess the level of statistical significance of any differences in student outcomes between JUMP and non-JUMP.

Findings:

Participation rates in the pre-test was 295/433 = 68.13%; pre and post-tests: 130/433 = 30.02%. Section specific participation rates for both pre and post-tests ranged from 0% to 70.6%
Student participation was voluntary for the pre- and post-tests, thus the possibility of self-selection bias was investigated. Participants (pre and post) were compared to non-participants in the following: pass rates {participants were 1.25 times more likely (95% C.I. = 1.16, 1.36) to pass the course than non-participants}, semester GPA scores {participants had a significantly higher GPA (mean 2.46 vs 2.16, p= 0.006, 95% C.I. for the difference = 0.1, 0.5)} age (mean 21 vs 20.7, p = 0.468), and admission status { rates of 'directly from high school' were similar in participant vs. non-participants (86.2% vs 87.2%, p>0.05)}.
GPA was not found to be correlated with percentile improvement (r=0.049, p=0.584) nor with standardized gain scores (r= 0.033, p=0.706), thus any self-selection bias with respect to GPA was minimal at best.
It seems that there is a slight bias towards participants being marginally stronger students than non-participants, but there is no evidence that being a stronger student is related to higher improvement scores.
Students' demographics and baseline characteristics in JUMP and non-JUMP math sections were equivalent (all p>0.079 as shown in Table 1), as were students across divisions (all p>0.08) and

course sections (all $p>0.08$).. This similarity of JUMP and non-JUMP groups allows for comparison despite less than perfect randomization procedure.

Table 1: Equivalence of JUMP and non-JUMP students in selected baseline characteristics

approach used by teacher		age	highest edn	#years since math taken	Std score pre	Percentile pre	Te	Anx	Val	SeC	Enj	Mot
non-JUMP	Mean	21.35	1.29	3.70	87.77	28.50	23.92	14.50	21.52	14.45	16.56	8.39
	Std. Dev	5.24	0.73	5.71	14.96	26.36	3.33	3.49	3.55	3.91	4.65	2.46
JUMP	Mean	22.53	1.21	3.53	86.10	22.12	24.74	13.28	22.30	14.76	16.98	8.93
	Std. Dev	7.27	0.53	3.74	10.34	18.35	4.27	4.00	3.81	3.38	4.32	2.52

Correlation of baseline measures with outcomes of interest: Three baseline measurements were found to be weakly correlated with outcomes. Correlation of Attitude dimension Value of Mathematics in Society (Val) with Percentile improvement was positive ($r=0.26$, $p<0.05$) and with gain scores ($r=0.23$, $p<0.05$). Correlation of pre-test predictors with outcomes were weak and negative, with percentile improvement: ($r = -0.213$, $p=0.015$) with standardized gain scores: ($r = -0.213$, $p=0.015$). This indicates a possibility of covariance between the MAI dimension Val with improvement scores, and between Wechsler pre-test scores and improvement scores, which suggests the use of ANCOVA for controlling these potential covariates when examining the impact of JUMP on these outcome scores.

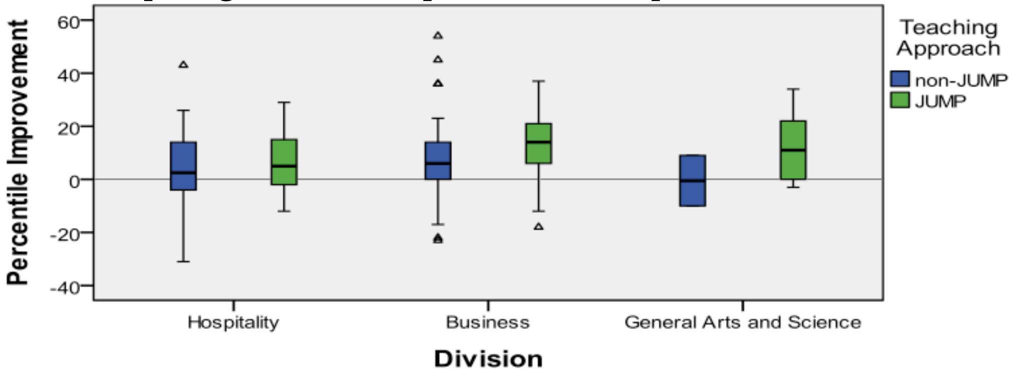
Comparing improvements in Wechsler test of numerical operations: JUMP vs non-JUMP
Mean scores for improvement in the Wechsler score were greater than zero both in percentile (95% C.I: 6.66, 11.68) and in standardized gain score (95% C.I: 0.042, 0.075). Comparison of improvements in Wechsler test showed that JUMP students' mean improvements were higher than non-JUMP students (see Table 2, and figure 2) overall, and when stratified by division.

Table 2: Comparison of percentile improvement JUMP vs non-JUMP stratified by Division

Division	approach used	Mean	JUMP – non JUMP differences % (cohen's d)	Std. Deviation	Median	N
Hospitality	non-JUMP	3.56	109% (0.27)	18.1	2.5	18
	JUMP	7.46		12.0	5.0	13
Business	non-JUMP	7.95	75% (0.41)	14.6	6.0	51
	JUMP	13.91		12.8	14.0	35
General Arts & Sciences	non-JUMP	-.50	n/a (0.91)	13.4	-0.5	2
	JUMP	12.64		12.6	11.0	11
Total	non-JUMP	6.60	85.6% (0.39)	15.5	6.0	71
	JUMP	12.25		12.6	12.0	59

Results for gain scores were similar to those demonstrated for percentile improvements herein. Furthermore, results were similar when stratified by other potential confounders (day of week, time of day class held, number of times class held per week, sex, highest education completed, work status, years since most recent math course, highest level of math taken prior to Sept. 2011).

Figure 2. Comparing Percentile improvements Jump vs. non-JUMP stratified by Division.



All correlations of improvement in Wechsler scores with possible confounding variables had r<|0.1|, except Val (r = 0.26, p = 0.004) and pre-test scores (r = -0.213, p = 0.015). These variables were included as covariates in the ANCOVA.

ANCOVA analysis to control for variation in division and section/teacher confirms that teaching approach has a modest effect on percentile improvements in the Wechsler test (see Table 3) Results for the effect on gain scores were similar.

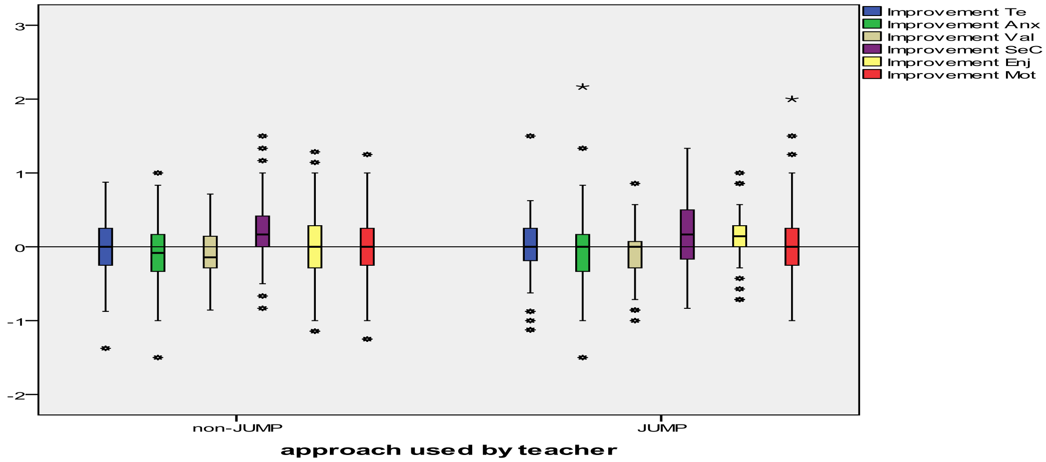
Table 3: output from ANCOVA.analysis with outcome: percentile improvement

Factor	**F-value**	**Degrees of Freedom**	**P-value**	η^2
Approach	6.384	1,22.6	0.019	0.22
Values Math in Society (from MAI)	5.955	1,103	0.016	0.055
Percentile_pre-test	3.936	1,103	0.050	0.037

Teaching approach was significantly related to percentile improvement in the Wechsler test of Numerical operations F(1, 22.59) = 6.384, p=0.019, η^2= 0.22. This confirms the modest and consistently higher improvements that were found in exploration.
2 covariates also demonstrated statistically significant, but weak effects: results for Val: F(1, 103) = 5.96, p=0.016, η^2= 0.055, and percentile pre test score: F(1, 103) = 3.94, p=0.050, η^2= 0.037. Results for gain scores were similar

Comparison of improvements in Math Attitudes Inventory in JUMP vs non-JUMP students:
There were no notable differences in improvement in any of the dimensions of the Math Attitude Inventory (Figure 3). In fact, only two of the Dimensions of the MAI had mean improvements that are non-zero: Val 95% C.I.=(–0.16, –0.02), and SeC: 95% C.I.=(0.09, 0.27).

Figure 3: Comparing JUMP to non-JUMP in MAI improvement scores



Discussion:

Though the differences are modest, the JUMP math teaching approach has shown that it was more effective in helping foundations math students improve their competence in numerical calculations than current approaches used by teachers at George Brown College.

Baseline comparisons showed that JUMP and non-JUMP groups were sufficiently similar before the intervention to allow for comparisons. Furthermore, with exploration techniques and ANCOVA analysis the threat of potential confounding variables has been diminished and results demonstrate that of all the potential factors teaching approach had the strongest effect (p=0.019, η^2= 0.22).

Despite the natural setting, partial randomization, and minimal training of teachers, improvements in standardized gain-scores and in percentiles on the Wechsler of numerical operations testing are consistently higher in students with the JUMP approach.

These differences in improvement in competence (Wechsler test) were not seen in measurements of attitudes (MAI).

This study took place in one college institution. Generalization beyond this college requires additional research demonstrating either similar patterns across institutions or evidence that foundations math students in other institutions are similar to those at this college. Secondly, despite accounting for many possible confounders, there remains the potential of a self-selection bias. Methods for collecting data that fit within the Canadian ethics policy guidelines TCPS2 and yet increase the participation rate are needed for these kinds of trials in the future.

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