The Preparation of Secondary Pre- service Mathematics Teachers on the Integration of Technology, a Report

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Abstract. *Are we preparing our pre-service secondary teachers to properly use the capabilities that hand-held graphing technology (HHGT) provides? To answer this question, we first established criteria on how the integration of HHGT, without CAS, expands the study of mathematics at the secondary level. A test based on the established criteria was initially administered four years ago to three intact groups consisting of 46 preservice secondary teachers from three universities in the Midwest of the USA. We compare the results with those obtained the last two years with two additional intact groups. Students were also asked to answer a survey where they rated their knowledge on the established criteria. In this presentation we will share the criteria and a sample of the test questions used as well as the results which point to the need for changes.*

Six years ago we decided to start researching whether or not we, in the USA, are taking full advantage of the main capabilities that hand-held graphing technology (HHGT) without Computer Algebra Systems (CAS) offers, to provide secondary students with the best possible preparation for calculus. We decided to focus on two key aspects of teaching that can (should?) be deeply affected by the integration of this technology, the content taught and the didactical approaches used in the mathematics classroom.

Initially, we raised many questions such as: do our textbooks respond to the changes that should take place? Beyond the traditional content of secondary mathematics, what new relevant concepts can be taught and which of those are being taught? What mathematical tools and representations are provided to our students? Which of the different approaches now available to solve problems are being introduced? Likewise, how has the integration of HHGT impacted the way we teach and the way our students learn mathematics? How much inquiry is taking place in our mathematics classrooms? Have exploration and discovery become a regular activity of our students? Are our pre- and in-service teachers prepared to integrate these changes in the classroom? Some initial results (Quesada & Smith, 2008; Quesada & Renker, 2008; Quesada & Dunlap, 2011) seem to indicate that we have much room for improvement.

To answer some of the questions raised we first decided to establish criteria postulating how the integration of technology might affect the addition of new content, approaches, and tools, and the didactical methods used at this level. We established the following principles to guide our decisions:

I. Content should be determined based on accessibility at the level taught, and on the importance of the current applications that facilitates.

II. Approaches used should favor the maximum flexibility to solve problems using the different representations and tools available.

III. Didactical Methods should be research-proven to maximize student learning (inquiry-based, hands on, team work, self-reflection/metacognition…)

Based on principles I and II, we selected the following possible changes on content affecting pre-calculus:

a) Continuous functions should be studied as families, each family with a root or parent function from which the rest of the functions in the family can be obtained via basic transformations like $f(x)+a,\ f(x+a),\ -f(x),\ a\cdot f(x),\ f(ax),\ |f(x)|,$ and $f(|x|)$.

b) Linear and nonlinear regression are now accessible in Precalculus, hence data sets from real life examples can now be modeled using functions from each family.

c) Data can be provided (or collected from basic experiments on motion, heat, light, sound…, using simple devices attached to the HHGT), and modeled using appropriate functions.

d) Additional properties that can be added to the study of continuous functions (before calculus):

    i. Finding local extrema, with intervals where the function is increasing or decreasing, as well as finding the range of continuous functions studied,
    ii. Modeling and solving optimization problems,
    iii. Determining irrational zeros–(completely factoring polynomials over the real numbers),
    iv. Estimating solutions to transcendental equations and inequalities,
    v. Exploring the local and end behavior of functions,
    vi. Solving optimization problems,
    vii. Modeling real data via linear and nonlinear regression.

e) Matrix capabilities of HHGT makes it possible for:

    i. Important matrix applications such as networks, cryptography, transformations, traffic flow, Leontiev input-output model…, to find their way into the secondary curriculum.
    ii. Obtaining directly the *ref* and the *rref* of a matrix allowing for a more in-depth study of systems of linear equations.

To properly study these concepts some collateral ideas are needed and must be included in the curriculum:

f) The concept of *"*complete graph*"* is essential,

g) Increased familiarity with basic properties and shapes of graphs of the basic families of continuous functions, including possible turning points of polynomial graphs,

h) Determining the local & end behavior of functions graphically or numerically via sequences,

i) An informal introduction to the rate of growth within and between families of continuous functions.

As the proper use of the four operations calculator calls for an increase on mental calculations, the proper use of HHGT must call for an increase on sketching, hence students must be exposed to:

j) The effect of the parity of zeros and of vertical asymptotes on graphs,

k) A working knowledge of the Fundamental Theorem of Algebra and of the Intermediate Value Theorem is essential,

l) The expected shape of basic families of continuous functions and the effect of transformations on their graphs.

The latest models of HHGT have incorporated two new environments, a spreadsheet and dynamic geometry software, with the capability of recognizing any user-defined variable in any subsequent environment. These resources further allow expanding the traditional approach to the study of families of continuous functions with the aforementioned properties. Moreover, since technology enables students to revisit problems from different perspectives based upon the depth of their mathematical knowledge, it is possible to use a spiral approach with some of these concepts, like optimization, through different courses preceding calculus (Quesada and Edwards, 2005).

Then, we developed a test containing mostly conceptual questions for evaluating the comprehension of these concepts. The test, based on the established criteria, was administered four years ago to three intact groups consisting of 46 pre-service secondary teachers from three well-recognized universities in the Midwest of the USA. Students were also asked to answer a survey where they rated their knowledge on the established criteria (Quesada & Dunlap, 2011). In this report we compare these results with those obtained this spring semester in the pretest and pre-survey by an additional intact group of pre-service secondary math students.

Table 1: *Participant Content Evaluation*

Descriptive Statistics						
	N	Min.	Max.	Mean	Std. Dev.	Variance
Pre Test Overlap 2008	46	.18	.87	.4781	.18544	.034
Pre Test Overlap 2012	15	.26	.67	.4373	.11727	.014
Pre Test 2012 System of Equations #17 - 19	15	.00	.93	.3189	.29201	.085

Paired sample t tests were performed on the results from the pretest. As seen in table 1, the mean score of the 2008 (M=48%, SD=.18544) classes was better than the 2012 (M=44%, SD=.11727) class, however, it was not statistically significant at the .05 level, $t(59) = 0.798$, $p = .428$.

The results of the "Participant Self Evaluation Survey on Experience with Technology, Standards and Teaching Strategies" Both groups acknowledged on the survey having an incomplete preparation on: i) Solving problems using nontraditional tools such as lists, sequences, recursion, ii) Solving transcendental equations & inequalities, iii) Finding the local & global behavior of functions via approximations, iv) modeling using nonlinear regression, v) Matrix applications, and vi) Using CAS and/or Math Software. The 2008 group had slightly better grade point averages (GPA) overall and in mathematics. In addition, they claim to have more familiarity with methodology: teamwork, newer approaches using technology, inquiry-based lessons, the proper use of calculators, and dynamic geometry software (DGS). The 2012 group claimed to have more familiarity with scientific and graphing calculators.

Table 2: *Participant Self Evaluation Survey Related to Workshop Strategies*

Likert scale: 1. Not at all 2. Very little 3. Some 4. Proficient 5. Very proficient

Pre-Survey results	**Avg 2008**	**Avg 2012**
GPA	3.59207347	3.423142857
GPA in math	3.48901913	3.271071429
Familiarity with the Ohio Academic Content Standards and Benchmarks.	3.36817227	3.285714286
Familiarity with the Common Core State Standards and 8 Math. Practices		2.42857143
1. Experience with teamwork	4.08571429	2.678571429
2. Familiarity with the newer mathematics approaches using technology	3.04761905	2.357142857
3. Familiarity with the concept of inquiry-based lessons.	3.40952381	2.60714286
4. In how many math courses have you developed inquiry-based lessons.	2.69183673	2.21428571
Proficiency incorporating the Internet into the teaching of mathematics		
In how many math courses have you experienced metacognition (reflection)?		2.21428571
5. Proficiency Incorporating the proper use of calc. into topics found. Calculus	3.74829932	2.92857143
6. The use of nontraditional tools such as lists, sequences, recursion to solve different problems?	2.68675470	2.50000000
7. The consistent interplay of the algeb., graph., and numer. representations	3.19911965	3.14285714
8. Solving transcendental equations	2.54853942	2.46153846
9. Solving transcendental inequalities	2.51844738	2.23076923
10. The local behavior of functions via approximations?	3.02192877	3.00000000
11. The global behavior of functions via approximations?	2.73957583	2.57142857
12. Treating each family of functions as coming from a root, via transform.?	2.65994396	2.07142857
13. Modeling real data using nonlinear regression for each family of continuous functions?	2.42312925	1.92857143
14. Matrix applications (Networks, Markov, Transformations…)	2.63513405	2.50000000
15. Asking questions such as "when will the answer be at least (at most) some number?" rather than just asking "when will the answer be some number."	3.17478992	2.78571429
16. Scientific Calculators	1.95102041	3.78571429
17. Graphing calculators	3.06666667	4.21428571
Graphing calculators with CAS		1.85714286
18. Math Software, which one (Maple, Mathematica, MATLAB, etc.)	2.00196579	2.00000000
19. Dynamic Geometry Software (Cabri, Geometers Sketchpad, Etc	2.91441076	1.35714286

We broke these questions into 3 categories for regression. The first five numbered questions were grouped under exposure to methodology. As can be seen from the correlation chart in table 3, there is a positive correlation, but it is not significant. Questions six through 15 were grouped in the second category under proficiency with integrating technology. As shown in Table 3, there is a positive correlation (.881) that is significant, $p = .001$. The third category of exposure to technology consisted of questions 16 through 19, and we found that there is a slight positive correlation, but it is not at all significant.

Table 3: Results of comparing correlations between similar '08 and '12 categories

		SurveyMethod08	SurveyMethod12
I. ***Exposure to Methodology***	Pearson Correlation	1	.853
	Sig. (2-tailed)		.066
	N	5	5
II. ***Proficiency integrating technology***	Pearson Correlation	1	.881**
	Sig. (2-tailed)		.001
III. Exposure to technology	Pearson Correlation	1	.026
	Sig. (2-tailed)		.974
	N	4	4

Conclusions

Preservice teachers' performance on the test questions and learning outcomes indicate that there is still a lack of exposure to selected topics in their preparation to become teachers. This is corroborated by the self-evaluation of both groups on the chosen topics. Clearly we are not taking full advantage of the range of capabilities that HHGT offers. Do the topics we teach respond to a conscious decision based on their relevance and accessibility, or are we still teaching content and methods based on tradition? Are math educators and math faculty who teach these students knowledgeable and aware of the possible impact that HHGT facilitates on teaching and learning concepts, approaches, and methods? Can we overcome in one semester the traditional approach followed in many math classes?

The regular use of HHGT by inservice teachers in their classrooms does not seem to have contributed to an improvement in the scope of what they teach. Therefore, new and more advanced technologies will probably not help either, unless we improve the preparation of preservice teachers on the proper integration of technology.

References

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