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ABSTRACT

An ongoing research project that investigates how mathematics educators can prepare prospective and practicing teachers to cope with cultural diversity is presented. The first component of this project is investigation of the ways that students can use their cultural identities and practices in constructing mathematical ideas that belong uniquely to them through a graduate course called "Ethnomathematics." The second is the investigation of ways teachers can facilitate students' construction of such uniquely personal cultural mathematics ideas in a high school classroom. The third component is the development of a grounded theoretical framework in which to situate the two previous components using semiosic chaining. The semiotic framework developed is being applied to the work from the graduate course and to the high school project, which took place in the 1995-96 school year. Data from the graduate project consisted of student journal entries, field notes, and more than 170 student project reports collected since 1993, some of which are described. The high school project involved seven students from differing ethnic backgrounds. Evidence from these students makes a strong case that traditional mathematics teaching does not facilitate a view of mathematics that encourages students to see the potential of mathematics outside the classroom. Although their own reports indicated that students were involved in many life activities with mathematical aspects, they continued to see mathematics as an isolated subject without much relevance to their lives. Semiosic processes may be used to illustrate connections as symbol systems are constructed in a bridge between cultures. Symbolism provides possible connections between mathematical ideas frozen in academic mathematics and practices, and different symbolism would facilitate the construction of different mathematics structures and concepts with increased relevance to students from different cultures. (Contains 33 references.) (SLD)

A SEMIOTIC ANALYSIS OF STUDENTS' OWN CULTURAL MATHEMATICS

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1

Significance of the research program.

Concerns about equity in mathematics education have been coming to the fore in many countries in the world (Keitel et al., 1989). Mathematics in particular was the subject, more than any other, that was considered to be value- and culture-free: hence the view of many educators was that mathematics education had no need to take the growing diversity of student populations into account. That this position is untenable and contributes to the differential effectiveness of educational systems has been demonstrated convincingly (Bishop, 1988; Powell and Frankenstein, 1997). In countries as diverse as Brazil (D'Ambrosio, 1985), USA (Wilson & Mosquera, 1991), and Mozambique (Gerdes, in press), educators have called for the recognition not only that mathematics is a cultural product, but that the *ethnicity* (unique sociocultural history) of students can be used in a powerful way in the learning of school mathematics. Connections are advocated between mathematical content and the home cultures of learners, as well as between different branches of mathematics, various disciplines in which mathematics is used, historical roots of mathematical content, and connections with the real world and the world of work (Civil, 1995; Powell & Frankenstein, 1997). In various parts of the world, the need for such connections in mathematics education is being acknowledged and explored, e.g., in the "Realistic Mathematics" project which is ongoing in The Netherlands (Treffers, 1993).

In the USA there is a growing awareness amongst mathematics educators that "the American educational system is differentially effective for students depending on their social class, race, ethnicity, language background, gender, and other demographic characteristics" (Secada, 1992, p. 623). Situated in a broader base of multicultural education literature (Banks & Banks, 1995), recent writings show that acceptance and understanding of cultural diversity is not an option, but a necessity, for those who teach in multicultural schools (Ogbu, 1995). Ogbu's writing, in particular, suggests that the "collective identities" of minority students are complex phenomena. Without understanding of the issues, there is no guarantee that even a well-designed multicultural program will be successful in eliminating inequities (Ogbu, 1995). How then, can mathematics teacher educators prepare prospective and practicing teachers to cope with the challenge of cultural diversity in their classrooms? This paper documents an ongoing research program which investigates some of these issues. There are three components in the research, as follows.

1. Investigation of ways that students may use their cultural identities and practices in constructing mathematical ideas that belong uniquely to them, in a graduate course called "Ethnomathematics".

2. Investigation of ways that a teacher may facilitate students' construction of such uniquely personal cultural mathematical ideas, in a high school classroom.

3. Development of a grounded theoretical framework in which to situate the two previous components, using semiosic chaining in analyses based on Lacan's inversion of Saussure's model (Walkerdine, 1988; Whitson, 1997).

The first and second components involve the pioneering activity of students constructing mathematics curriculum which is based on their own cultures and shared with the class. The third component emerged from a need to situate this activity in a theoretical model which allows interpretation of the processes involved in linking mathematics in and out of school. This model resonates with an emergent perspective (Cobb, Jaworski, & Presmeg, 1996), and also with a developmental research paradigm (Gravemeijer, 1994). The first component, involving graduate students, has been ongoing since this mathematics education course was first taught in 1993. The high school research project was conducted during the 1995-96 school year. The semiotic framework is currently being used to analyze student projects from the work of the past five years. Only a few of the rich examples of student work can be suggested here, along with the methodology of the investigations.

The research described in this paper resonates with and complements that of Abreu, Bishop, and Pompeu (1997), since both programs address issues concerning home and school mathematical practices, the implemented mathematics curriculum, and investigation of ways in which the experienced mathematics curriculum may or may not resonate with home mathematical cultural practices of learners. Abreu analyzed the sociocultural organization of mathematical practices linked to school and home culture, in terms of the structure of the practice, the patterns of social interaction within practices, and prior knowledge of learners. The research described here complements Abreu's research, using a different theoretical framework. The purpose of a semiotic framework for analysis of students' projects is to investigate ways in which signs facilitate the identification by learners themselves, and their teachers, of patterns and structures in cultural practices, so that these patterns may become the basis for mathematical constructs in classrooms, thus bridging these two forms of knowledge which some scholars have described as incommensurable (Dowling, 1995).

The three components of the research program are described further in the following sections.

I. Principles for a mathematics course which takes culture into account.

I shall suggest some reasons for choosing an approach based on ethnomathematics, defined as *mathematics of cultural practices* (Presmeg, 1994), for a teacher education course which addresses cultural diversity (rather than another theoretical framework). There are other approaches to diversity and equity, such as critical race theory (Ladson-Billings & Tate, 1995; Tate, 1997) which have proved useful in addressing minority achievement in mathematics. However, for curriculum development in mathematics, because of the potential for construction of mathematical ideas which are uniquely students' own (Presmeg, 1996), ethnomathematics provides a broader and more viable framework which resonates with the "intellectual property" aspect of critical race theory, in which ownership is important. Thus for purposes of cultural course development in mathematics I have used a theoretical framework grounded in ethnomathematics. I agree with Vithal and Skovsmose (1997) that definitions of ethnomathematics are problematic (see Presmeg, in press, for further discussion of this issue). But in view of the difficulty in defining their own perspective of critical mathematics education, at this time ethnomathematics still appears to be viable as a basis for cultural curriculum development in mathematics.

Literature on the use of cultural practices in learning school mathematics (Bishop, 1988, Ascher, 1991; Civil, 1995; Nieto, 1996), along with the foregoing considerations, provided a basis for the Ethnomathematics course. The following were the principles used.

1. Each student is considered as having a unique sociocultural history; each student has ethnicity, and so does each teacher.

2. This ethnicity is a mathematical resource; mathematics may be developed from associated cultural practices.

3. Students and teachers can use their ethnicity in developing mathematical activities for sharing in mathematics classrooms.

4. Since the sharing of elements of one's cultural or ethnic practices may be a sensitive issue, those who belong to a social group of a certain culture should be involved in making decisions about who should share the mathematics of its practices, and which practices should be shared.

Students in the course (which is offered regularly) are practicing or pre-service mathematics teachers, and the principles imply that the ethnicity of learners is a resource for mathematics teachers at all levels (investigated in part II). This approach entails not only learners' cultural *backgrounds,* but their cultural *foregrounds* too (Vithal & Skovsmose, 1997), since their lived experiences and hopes for the future are taken into account. In spite of cultural conflicts (Presmeg, 1988), when the position is taken that *all* students, and the teacher, have ethnicity, the way is opened to view that ethnicity as a resource and an asset rather than as a liability in a mathematics classroom.

The research involved in this component was an investigation of ways in which graduate students could take ownership of a mathematics education curriculum (that is, make it their own, engage in *developing* curriculum) sufficiently to construct mathematical ideas from cultural practices which belonged to them in some way, and to integrate this mathematics in the curriculum by sharing both the mathematical ideas and the underlying cultural elements. An open and exploratory qualitative methodology was appropriate; data consisted of students' weekly journal entries, fieldnotes following student presentations, and students' final project reports. Analysis of the data yielded multiple ways in which students took ownership as described in the foregoing. Categories of ways in which students chose topics for their personal projects include the following.

1. <u>Looking to the past.</u> An example in this category is Debra Stocking's project, which arose out of of her family tree, which was traced back to the "Domesday Book" of William the Conqueror about the year 1083. She chose to analyze *The Mathematics in Stonehenge*, in the area of England which was the ancient family seat of her ancestors.

2. <u>Looking to the future.</u> Linda Burke chose to examine her potential future investment in the US stock market, rather than a topic from her Caribbean ancestry. Her project was *A Personal Evaluation of Stock Investment and the Mathematics Involved in the Selection of Outback Steakhouse.*

3. Looking to the present. Most of the student choices fell into this category; for example, there were many projects in each of the following subcategories:

* current American sports, e.g., *baseball* (Michael Knight), *mountain biking* (Vivian Knowles), *racquetball* (Kim Crook).

* games around the world, e.g., *Mah Jongg* - China (Lilly Sun), *dominoes* - Cuba (Isabel Tamargo and Raquel Casas), *the Dreidel game* - Israel (Amy Solomon), *contract bridge* (Curtis Ruder).

* navigation, cars, boats and planes, e.g., *traffic flow* - USA (Michael Capps), *flight navigation* - USA (Flora Joiner), *construction of boats* - Haiti (Jean Louis), *traditional navigation* - North Pacific (Denise Gardiner, from the Peace Corps).

4. Looking to national and religious practices and emblems. I have included emblems such as national flags in a category of their own (rather than including them in the previous one) since these analyses frequently involved past and present, the history of a country along with its national and religious practices and underlying philosophies, e.g., *South Korean flag* (In-Gee Lee), *Jamaican flag* (Genevieve Burke), *Gematria* - Israel (Bonnie Jeroslow), *I Ching* - China (Lilly Sun).

5. Looking to arts and crafts. This category and the following one also involve past and present practices, e.g. *Lithuanian folk textile ornamentation* (Trina del Valle), *American patchwork quilting patterns* (Ann Zamanillo, Leonda Bussell, Kim Scales) *Islamic art* (Shabana Ahmad), *Cherokee Indian artwork* (Leatisha Brown), *cuckoo clocks* - Germany (Karen Chandler).

6. Looking to music and dance. Examples include *Flamenco music and dance* (Sandra Davis), *a Jamaican folk song* (Clova Jobson), *construction and playing of the tabla* - India (Parmjit Singh), *Gospel music* - USA (Vanetta Grier).

These examples give a small taste of the rich diversity of cultural practices chosen by students in the more than 170 projects collected to date. (I am putting together an edited collection of some of these.) The significance of this research stems from the excitement generated in students as they took ownership of their personal projects and the mathematical elements of these, shared in class, and learned about mathematical elements in cultural practices authentic to their peers. The implications of this ownership factor were investigated in a high school in the second component of the program.

II The high school research project.

The purpose of the project (conducted with research assistants Stephen Sproule and Bineeta Chatterjee) was to work with students and teachers to develop viable ways of using the authentic cultural experiences of students as a resource for the learning of mathematics. Although it was envisaged that this development might include the introduction of ethnic instructional materials (as described in Zaslavsky, 1996, for example) for the learning of mathematical content in mathematics classrooms, the purpose was not to use such materials in "cookbook" fashion (i.e., as recipes), but as examples for students, of mathematics of cultural practices, i.e., of ethnomathematics. Thus an important part of the project was the development of a bank of personally meaningful student activities which had the potential for classmates to construct mathematical content at various levels. Qualitative research involving interviews with a small number of learners was suitable for the purpose of investigating authentic student activities. These interviews were video- or audio-recorded, took place on a regular basis, and were semi-structured to facilitate comparison but allow the flexibility to pursue unanticipated avenues.

This year-long project started in Fall, 1995, with seven students in a multicultural high school. The research also included observations in their Algebra II classroom, interviews with their teacher, and the teaching of one lesson which was video-recorded. Consonant with the goal of investigating cultural practices authentic to these diverse students, and their beliefs about mathematics and whether it was involved in their practices, we asked the students to talk about their Histories, Hobbies, Hopes (career aspirations), and Homelands, and mathematical ideas which they could discern in these "four Hs". The results may be summarized as follows (see Presmeg, 1996, & in press, for greater detail).

1. Students in this project entertained beliefs about the nature of mathematics which prevented them from "seeing" mathematical ideas in their own practices.

2. Nevertheless, they described rich and diverse cultural practices which the researchers considered to have potential for the construction of mathematics.

3. It was concluded that use of cultural practices in traditional classrooms requires renegotiation of both the social norms (involving patterns of social interaction) and the sociomathematical norms (involving what is taken to constitute mathematics) (Cobb et al., 1997).

Based on the evidence of the interview data and classroom observations, a strong case can be made that traditional mathematics teaching does not facilitate a view of the nature of mathematics which encourages students to see potential for mathematics in their lives outside the mathematics classroom. All but one of the students interviewed, Big Al in the final interview, perceived mathematics as a "bunch" of numbers, equations, and formulas, used to solve (school) word problems. These beliefs about the nature of mathematics persisted even after involvement in the project and the one ethnomathematics lesson. It was not possible to do more than this one lesson because the teacher felt pressured to complete the syllabus, and in fact expressed impatience that the activities had taken longer than intended. It may be concluded that introduction of ethnic and home activities into mathematics classrooms needs to be accompanied by a recognition of the value of such activities, and such recognition may involve a change of belief about the nature of mathematics, on the part of teachers as well as students. Pompeu (1992) wrote of the necessity of changing teacher attitudes in a project which attempted to integrate ethnomathematics in the school curriculum in Brazil.

In contrast to this somewhat negative conclusion about beliefs concerning the nature of mathematics, a very positive aspect of the research was the richness of the mathematical aspects of the cultural and home activities described by the high school students, even if these students themselves did not always identify these aspects as mathematical. Examples of such potentially mathematical activities were racing around barrels on horseback in Central Florida, international coin collecting, American football, basketball, volleyball and cheerleading, carpentry and housepainting.

The project, which seemed merely to scratch the surface of a much larger undertaking, does however suggests that ethnomathematics, taken broadly to encompass mathematical elements in everyday activities of students, has an important role to play in making mathematics more meaningful in the lives of students. The idea is that a cultural activity which is authentic to at least one student would be described in class by that student; then small group work and whole class sharing would be used to identify and symbolize patterns as a basis for developing mathematical concepts from the activity. For instance, one of the project students, Keri, grew up on a farm in central Florida. She described rich patterns involved in the practice of barrel racing on horseback (e.g., "hairpin", "candle", "cloverleaf"). These patterns are important for students in Keri's class, because they are part of Keri's culture; but they may not have meaning for students in other classes who do not know Keri. Mathematical principles of symmetry, distance and time, and sharing of culture, are involved simultaneously. (Incidentally, Keri herself, when asked if these activities were mathematical, replied, "Naw! Well, maybe; if you count the barrels, one, two, three, four, five, six.")

Many questions remain. For instance, should it be a case of "out-of-school mathematics on Fridays", while "academic mathematics" is taught on the other days? Contrary to this view, academic mathematics may be viewed as a form of ethnomathematics too (since distinct cultural practices are involved). This may be linked by semiosic means to cultural practices outside school, for instance in symbol systems which become the *counterpart* - acted upon as objects in their own right (Pimm, 1995) - of patterns in cultural practices (see part III). Thus there is a place in the curriculum for "mathematics for its own sake," the advantage of this broad characterization being that cultural links are not ignored. In the groupwork following our one "ethnomathematics" lesson, mathematical constructions of the high school students were of varying degrees of mathematical sophistication, and certainly not all were algebraic - and it was an Algebra II class! Many of the student constructions had potential for geometric rather than algebraic ideas. Would this matter? The questions are legion. However, the project has shown enough promise for me to believe that there is a possible didactic interface, mediated by semiosis, between cultural practices and academic mathematics, and that pursuing such an interface is of value in the search for equity and meaning. Current trends have teachers playing a greater role in the development of curricula than was the case in some countries previously (Posner, 1992). What is suggested here goes a step further, in that teachers would be facilitating the development of curriculum by students.

Dowling (1995) wrote powerfully about the incommensurability of the domains of everyday knowledge and academic knowledge, which he characterized as belonging in what he called the public domain and the esoteric domain respectively. I agree with the basic tenets of his characterization, but wish to suggest that semiosis, and in particular, the chaining of signifiers, provides a missing link between the domains, which has the potential to "open up the availability of academic discourse to all" (Dowling, 1995, p. 223), while retaining the personal ownership factor which was crucial in the first two components of this research program.

III Semiotic analysis.

This theoretical component of the program arose from the previous two components in the need for a model to use in analyzing processes used in constructing links between cultural practices and academic mathematics. In investigating factors in the discrepancy between the facility of the graduate students in making these links, and the almost total lack of perception of links by the high school students, a theoretical framework was needed in which to examine these processes in more detail. The analysis of student projects is ongoing and will be described in the presentation. There is room only for a brief sketch of the model here.

Using Lacan's inversion of Saussure's diadic model of semiosis (activity of signs; see Whitson, 1997, p. 99), it is possible to analyze chaining of signifiers which involve mathematical symbolism, leading in two or more steps from an initial signified which is situated in a cultural practice, through various symbolic signifiers, to a mathematical structure which is isomorphic to the structure of the original practice and retains some of its properties (Presmeg, 1997). As Walkerdine (1988) pointed out, resonating with Dowling's (1995) characterization, very different discourse patterns and power relationships exist in cultural practices and in mathematics classrooms: the subjectivities of those positioned in these practices are involved. The significance of a semiotic framework for analyzing the links lies in its capacity to retain, not gloss over, these differences, while unfolding structural isomorphisms which allow for the construction of mathematics. In Dowling's (1995) view, "a sign may quite easily be carried between activities, but its signification will of necessity be transformed, because it will participate, relationally, in distinctive systems" (p. 214). The chaining component in semiosis brings about several successive transformations, while retaining essential structures which are isomorphic in relationally different domains. The knowledge constructed rests squarely in the domain of academic mathematics but retains some meanings from Dowling's (1995) "public domain" in a sliding under effect, which was also illustrated in a different context by Cobb et al. (1997).

I have analyzed Marcia Ascher's characterization of the Warlpiri kinship system as a dihedral group of order 8, in terms of a semiotic model, in a different paper (Presmeg, 1997). Here I shall include only the diagram from that analysis as a first example of semiosic chaining which links cultural practice and academic mathematics.

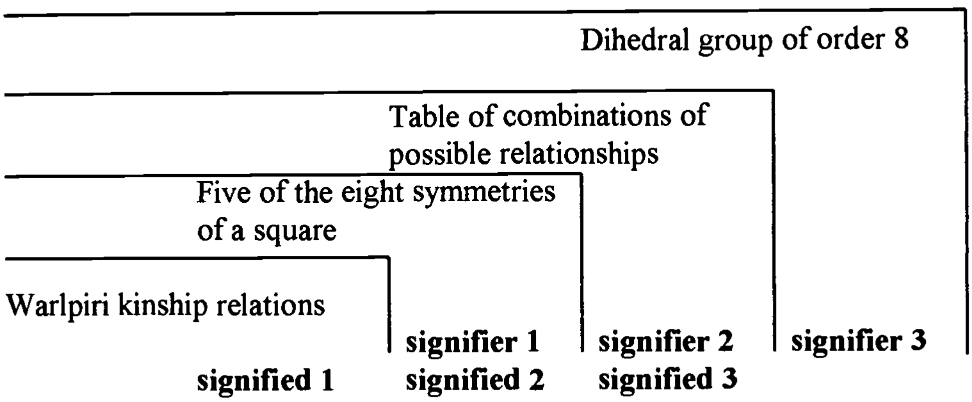

Figure 1: Chaining of signifiers in a progression of generalizations from the Warlpiri kinship system to a dihedral group of order 8.

There are increasingly abstract systems of symbolism in this example, in the sense that there is progressive distancing from the cultural practice in which the recognition of structure originated. In the use of the sides and symmetries of a physical square, say, made of cardboard (signifier) to illustrate the structure of the Warlpiri system (signified), the symbolism may not yet be of a level of generality to satisfy some definitions of academic mathematics. In the next link of the chain, the concrete square gives way to more abstract symbolism in a table. Finally, a generalized structure called "a dihedral group of order 8" becomes the signifier for this specific table, which is now no longer the signifier, but the signified, in an academic mathematical structure. Each sign in turn is subsumed under a new signifier, which belongs to a different set of cultural practices, with different goals, norms, expectations, discourse patterns, and power structures. However, because the whole sign, including signifier and signified, slides under and is incorporated in the new signifier, some of the implicit meanings and associations of the old sign with its sociocultural norms, are still present in the new sign with its own set of different sociocultural norms (Cobb et al., 1997). In this way, some of the associated personal meanings may be retained in this transformation.

What follows are two further sketches of semiotic chaining from student projects which linked personal cultural practices and academic mathematics.

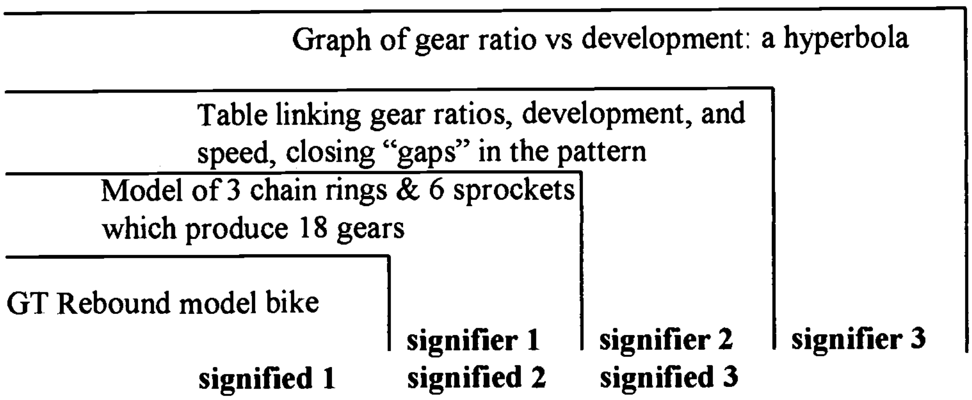

Figure 2: Chaining of signifiers in "Mountain Bike Mathematics", by Vivian Knowles.

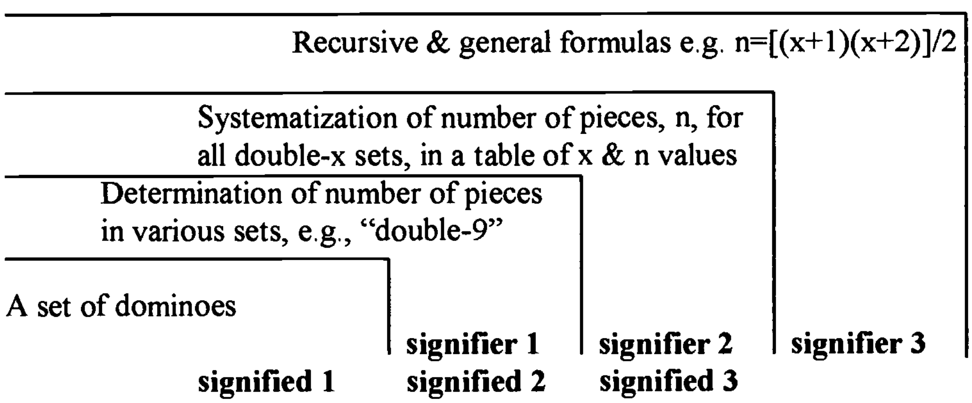

Figure 3: Chaining of signifiers in "Dominoes: A Tradition in Cuban Families" by Raquel Casas and Isabel Tamargo

In figure 3, the chain of signifiers could continue. The values of n in Raquel and Isabel's table constitute the triangular numbers, which could be signified by diagrams of various kinds. The mathematization could then be extended to other figurate numbers (e.g., square, oblong, and patch numbers), with their associated formulas and diagrams, and even to mathematical relationships between figurate numbers, all squarely in the domain of academic mathematics.

In this way, semiosic processes may be used to illustrate connections as symbol systems are constructed in a bridge between cultures. Thus, symbolism provides possible connections between mathematical ideas "frozen" in practices (Gerdes, in press), and academic mathematics. Different symbolism would facilitate the construction of different mathematical structures and concepts (Pimm, 1995; Presmeg, 1997). The role of abstraction and formalization is clear from the analysis, resonating with Noss's (1997) implied answer to his question, "Are we justified in talking about a (unique) mathematical idea represented in various ways?" He continued, "Or should we better acknowledge that there are no mathematical ideas without representation, and that a change in the mode of representation necessarily entails a change (however subtle) in the idea itself?" (p. 290).

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