DOCUMENT RESUME

ED 313 244 SE 051 054

AUTHOR	Steinberg, Melvin S.; And Others
TITLE	Genius Is Not Immune to Persistent Misconceptions: Conceptual Difficulties Impeding Isaac Newton and Contemporary Physics Students.
INSTITUTION	Massachusetts Univ., Amherst. Scientific Reasoning Research Inst.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	SRRI-235
PUB DATE	87
GRANT	NSF-MDR8751398
NOTE	25p.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Concept Formation; *Force; *Mechanics (Physics); *Misconceptions; Physics; *Science History; *Scientific Concepts; Scientific Methodology; Scientific Research; Scientists
IDENTIFIERS	*Newton (Isaac)

ABSTRACT

Recent research has shown that serious misconceptions frequently survive high school and university instruction in mechanics. It is interesting to inquire whether Newton himself encountered conceptual difficulties before he wrote the "Principia." This paper compares Newton's pre-"Principia" beliefs, based upon his writings, with those of contemporary students in the areas of impetus force and centrifugal force. The paper emphasizes the retarding effect on Newton's development of inappropriate but deep-rooted models at a qualitative level, and the extent to which his experience suggests the necessity for students to struggle conceptually in order to construct the models employed by physicists. Lists 9 references. (YP)

ED313244

GENIUS IS NOT IMMUNE TO PERSISTENT MISCONCEPTIONS: CONCEPTUAL DIFFICULTIES IMPEDING ISAAC NEWTON AND CONTEMPORARY PHYSICS STUDENTS

SRRI #235

Melvin S.Steinberg

Physics Department, Smith College, Northampton, MA 01063

David E. Brown and John Clement

Scientific Reasoning Research Institute

University of Massachusetts, Amherst, MA, 01002

Preparation of this paper was supported in part by

National Science Foundation grant MDR8751398

ABSTRACT

Recent research has shown that serious misconceptions frequently survive high school and university instruction in mechanics. It is interesting to inquire whether Newton himself encountered conceptual difficulties before he wrote the *Principia*: (a) Did he have serious difficulties? (b) If so, were they difficult to overcome? We shall present evidence from Newton's writings of affirmative answers to both questions.

Newton's development of his system of mechanics was hampered by a persistent belief in "the force of a [moving] body" from 1664 to 1685. His belief in centrifugal force was an additional restraining factor that remained intact until Hooke's intervention in 1679 and weakened only gradually over the next two years. Three additional years passed before the resulting successes weakened his commitment to impetus sufficiently to permit conceptualization of mass as an inert surrogate.

This paper will compare Newton's pre-*Principia* beliefs with those of contemporary students in the areas of impetus force and centrifugal force. We shall emphasize the retarding effect on Newton's development of inappropriate but deep-rooted models at a *qualitative* level, and the extent to which his experience suggests the necessity for students to *struggle* conceptually in order to construct the models employed by physicists.

INTRODUCTION

Studies of physics students' reasoning about the relationship of force to motion have demonstrated that they harbor misconceptions which can interfere with learning and which are surprisingly resistant to change. Consider, for example, the following data from high school and university students in typical settings:

(1) Among a high school group asked to compare force magnitudes exerted when a bowling ball strikes a bowling pin, only 5% thought the pin exerts as much force on the ball as conversely. [Brown and Clement (1987)] These and the data below are from questions asked <u>after</u> instruction in mechanics had been completed.

(2) Only 29% of university physics students correctly drew the single, downward force of gravity acting on an ascending coin tossed in the air. In 90% of the incorrect answers the students drew force vectors acting in the direction of motion that are fictitious from the physicist's point of view but are strongly reminiscent of the impetus beliefs of medieval theorists. [Clement (1982)]

(3) Only 7% of high school physics students correctly indicated the single, centripetal force acting on a stone twirled horizontally over one's head in horizontal circular motion (ignoring gravity and air resistance). 71% indicated there would be an outward centrifugal force acting on the stone, 67% that there would be a force in the direction of motion of

the stone, and 48% that both of these forces would be acting on the stone. (New data: sample size = 87)

The beliefs exhibited in these examples are sources of difficulty at the level of basic conceptual understanding of the material. Their existence suggests that the concepts instructors are trying to impart are being misunderstood at a qualitative level, in addition to any difficulties that arise with quantitative formulation. What we wish to discuss in this paper is the extent to which Newton's thinking was hampered by similar inappropriate conceptions, and the extent to which he had to struggle to free himself from them.

The conceptual framework for dynamics which Newton set forth in his Principia is based on the assumption that the effect of a force acting on a material object is to change the speed and/or direction of motion. The immense success of this framework during the last three centuries has made its usefulness to mature professionals very clear. For the uninitiated, however, there is a problem of comprehension: The framework can be made one's own only if the possibility of motion without force is accepted. That state of mind is very difficult for students to achieve, because of a deep-rooted conviction that motion implies a force that causes it. [Clement (1982)]

Newton's writings before the Principia reveal the same problem, and the important question for us is: Why did he take so many years of intermittent and often intensive effort to overcome it? We have been intrigued by the evidence that Newton's progress was blocked by a web of interconnected misconceptions. Impetus was the key barrier that he had to overcome in order to write the Principia, with several others playing strong supporting roles. We feel that the long term persistence of this major misconception in so gifted a person says something important about the magnitude of the cognitive change that students must negotiate with themselves in order to understand Newtonian mechanics. Bringing the details to light may yield insights that can benefit the design of instruction. Conversely, research on students' cognitive difficulties may help make Newton's developmental path more intelligible.

There are at least four ways in which parallels might be drawn between Newton and present-day students with regard to conceptual difficulties: (a) the specific qualitative misconceptions; (b) whether these significantly impede progress; (3) how they impede progress, if in fact they do; and (4) how these difficulties are overcome. In this paper we focus on the second question and touch on the first and fourth questions, leaving the third and its overlap with the others for future papers. To anticipate our conclusion: We find that Newton's progress was indeed significantly hampered by qualitative conceptual difficulties that strongly parallel those found in students. We also discuss how, with the help of others, he finally broke through to the profound insights embodied in the Principia.

THE PERSISTENCE OF FORCE AS PROPERTY

What Newton called "the force of a body" is the intuition that a moving body is a reservoir of force. Our investigations of students' misconceptions indicate that this idea can have two aspects:

IMPETUS -- the idea that motion which occurs without assistance from an external propelling agent is sustained by an internal motive force

TRANSFER -- the idea that one body may give up some of its impetus force to another during impact

As an example of the transfer misconception in a student before instruction, consider the following reply to a question about a moving ball striking a stationary ball: "The force from the moving ball would be transferred to the stationary ball, so the force would move from the moving ball to the ball that wasn't moving." Another student said: "...the only force that would be transferred would be that which the stationary one could absorb before it moves..."

The persistence of transfer after instruction can be seen in the following data. When given the choices below for describing the impact of a cue stick on a cue ball, 65% of high school physics students selected choice (1):

(1) The cue stick transfers force to the cue ball.

(2) The cue stick exerts a force on the cue ball, but does not transfer force to the cue ball.

(New data: sample size = 87)

The invention of impetus seems to be a response to the mindset that motion without the intervention of externally applied force requires an explanation. The impetus idea is used in the transfer idea: Collisions can be perceived as providing evidence for transfer, and belief in transfer supports belief in impetus.

The earliest evidence for the transfer-of-impetus conception in Newton appears in a notebook dated 1664, when he was 21 years old and in his third year at Cambridge University, in a passage titled "On Violent Motion" in which he employs transfer to explain projectile motion: [Herivel (1965) p.123]

> This motion is not continued by a force impresst [from the outside] because the force must be communicated from the mover into the moved ....

To our knowledge, the transfer aspect has not been explicitly discussed in previous descriptions of Newton's conceptual development.

The above statement is very much in the spirit of Descartes, whom Newton had been reading. We interpret the agreement with Descartes as making intuitive sense to the young Newton, rather than as assent to authority, because the belief expressed here persisted for two decades despite continuing serious disagreement with Descartes about relativity of motion. "On the issue of [Descarte's] relativism", writes Westfall, "which smacked of atheism in Newton's view, he continued to shout his defiance until his dying day." [Westfall (1980) p.415]

Newton made considerable headway against the impetus idea in 1665-66 by focussing on relationships involved in the impact of two bodies. However, this progress was soon followed by a cripling setback when he reimbraced the impetus concept. In this section we describe these periods of progress and relapse in Newton's thinking.

In a passage in the Waste Book titled "Of Reflections", he recognized that changes of speed and direction are dynamically important, and that these changes are effectuated by forces originating outside the affected body. [Westfall (1980) p.146]

> Soe much force as is required to destroy any quantity of motion in a body soe much is required to generate it; & soe much as is required to generate it soe much is alsoe required to destroy it.
>
> .... equall forces shall effect an equall change in equall bodies.... For in loosing or getting ye same quantity of motion a body suffers ye same quantity of mutation in its state, and in ye same body equall forces will effect a equall change.

As part of this promising elaboration of the force concept, Newton also explored the two-body interaction forces required to maintain the whole-system center of mass in motion at constant velocity. "Examining what he called 'ye mutual force in reflected bodies', he concluded that each one acts equally on the other and produces an equal change of motion in it. To those who had tried to understand impact through the force of a body's motion, this conclusion had appeared patently false.... Newton appears to have reached it by realizing that every impact can be viewed from the special frame of reference of the common center of gravity of the two bodies.... Newton never forgot this conclusion. It contained the first adumbration of his third law of motion..." [Westfall (1980) p.147]

With good beginnings toward the second and third laws at age 22, what about the first law? In a cursory reading it is easy to imagine that Newton had also arrived at the principle of inertia: [Westfall (1980) p.145]]

> Every thing doth naturally persevere in ye state in which it is unlesse it bee interrupted by some externall cause.
>
> [A] body once moved will always keepe ye same celerity, quantity and determination of its motion.

Statements like these plainly deemphasize internal force compared to external, but they do not rule out the continued presence of a latent impetus concept.

Westfall points out the developmental importance of Newton's early realization that force must be associated with changes of velocity: "Here was a new definition of force in which a body was treated as the passive subject of external forces impressed upon it instead of the active vehicle of force impinging on others." However: "All of the possibilities inherent in the insight did not appear immediately to the young man who had earlier accepted the idea of a force internal to bodies which keeps them in motion. It is clear to us that the earlier notion was incompatible with the principle of inertia and his new conception of force. It was not at first equally clear to Newton. Instead of rejecting the idea of internal force outright, he attempted to reconcile it with the new concept he was developing." [Westfall (1980) p.146]

What happened, in our view, is that Newton began to interpret force exerted from the outside as force transfer: [Westfall (1980) p.146]

> The force wch ye body (a) hath to preserve it selfe in its state shall bee equall to the force wch [pu]t it into yt state; not greater for there can be nothing in ye effect wch was not in ye cause nor lesse for since ye cause only looseth its force onely by communicating it to its effect there is no reason why it should not be in ye effect wn tis lost in ye cause.

We shall return later to the question of why Newton retreated from externally impressed force to force transfer. For the present, we wish only to point out that impetus did indeed remain a viable concept in Newton's mind for another two decades. This is clearly articulated in the manuscript De Motu which he sent to Edmond Halley in the fall of 1684, much of which later found its way into the Principia. The translation from the Latin reads: [Westfall (1980) p.411]

> I call that by which a body....endeavors to persevere in its motion in a right line the force of a body or the force inherent in a body.

By its inherent force alone, every body procedes uniformly in a right line to infinity unless something extrinsic hinders it.

Note that Newton wrote these lines _after_ his pioneering work of 1680 in which (a) at Hooke's suggestion he began to think of the Sun as exerting an attractive force on a planet, conceived as an _action_ that continually deflects the latter's motion from the straight line it would otherwise travel, and (b) returned to his idea of 1665 that force is associated with _changes_ of speed and direction. In this work he was able to identify major features of the force responsible for planetary motion: (1) Kepler's equal areas pattern of orbital motion was found to be a consequence of the force being directed always toward the Sun. (2) An inverse square variation of force magnitude with distance from the Sun was inferred from the elliptical form of the orbits. In spite of this tremendous progress, he was not ready to give up impetus for another five years.

Of course, a person with Newton's powerful drive for conceptual coherence could not continue indefinitely to ride two horses in different directions. His meeting with Halley in the spring of 1684, at which he made known his deduction of the inverse square law of attraction of the planets by the Sun, ushered in a period of intense cognitive change. _De Motu_, which was sent to Halley after that meeting, was itself revised and then followed by two shorter papers of revisions. [Herivel, documents X(a) and X(b)] These papers reveal that Newton was thinking quite differently by the spring of 1685.

The first short paper reveals a newly acquired ability to think of rest and motion as equivalent: [Herivel, p.311]

> The inherent and innate force of a body is the power by which it preserves in its state of rest or of moving uniformly in a straight line.
>
> Force impressed on a body is that by which a body is urged to change its state of moving or resting...

The second short paper speaks with greater precision: (a) "The inherent and innate force of a body" becomes "The internal force of matter". This "internal force" is not impetus, however. Newton explains that it is [Herivel, p.316]

> the power of resistance by means of which any one body continues so far as it can in its state of rest or moving uniformly in a straight line...nor differs at all from the inertia of matter except in our mode of conceiving it.

He goes on to differentiate the new conception of "internal force" sharply from impetus:

> In fact a body only invokes this force in changes of state produced in it by another force impressed on it...

This novel idea of a force that acts only during a change of motional state appears to be a rudimentary conception of mass as an inert surrogate for impetus. Westfall describes it as "a paradoxical conception of a matter both inert and active". The vestigial use of impetus-like terminology for inertial mass persisted into the *Principia* as *vis inertiae*. [Footnote 3]

With impetus in the process of being transformed into inertial mass, the second short paper goes on to explain what is meant by "impressed force". It is

> an action excercised on a body to change its state of rest or motion. This force consists truly in the action only, nor does it remain in the body after the action.

The conception of impressed force as "action only" appears to signal Newton's victory over the intuition of transfer, and that of force as something which does not "remain in" a body seems to represent his final triumph over impetus. Force has now become something that influences motion only from the outside. A complete separation of force and motion has finally been achieved which, together with a budding conception of inertial mass, makes it possible to contemplate motion without force.

Newton set out in 1665 to modify his early conception of force as a property associated with motion into a form suitable for expressing action by one body on another. Why did he cling to the impetus force idea for so many years thereafter? Why were the principle of inertia and the concept of inertial mass the last of his successes? We feel the answer lies in a deep-rooted conviction, derived from a lifetime of kinesthetic experience, that motion requires a causal explanation and that "the force of a body" is a reasonable description of the cause. Barring the way to a conception of force as an action from without was Newton's commitment to impetus and to centripetal force. The latter was linked to his belief in impetus, and appears to have played a strong reinforcing role.

IN THE GRIP OF CENTRIFUGAL FORCE

In his article on Newton's discovery of gravity in 1685, Cohen writes that Newton "had more or less accepted the inertia principle some 20 years earlier." But his progress in the direction of constructing a more adequate conception of force was halted because "Newton, like Descartes and Huygens, was so mired in the concept of centrifugal endeavor that the full implications of inertial physics were far from obvious to him." [Cohen (1981)]

Practically everyone senses, on the basis of personal kinesthetic memory, that a body revolving in a circle strives to push itself away from the center of its circular path -- and to do so more strongly when it is moving at greater speed. This palpability of centrifugal force could have reinforced Newton's belief in impetus by providing a second class of situations in which it seems reasonable to think of force as a property of a moving body. [Footnote 2] Westfall writes: "Following both Descartes and common experience, Newton agreed that a body in circular motion strives constantly to recede from the center, like a stone pulling on a string as it is whirled about. The endeavor to recede appeared to be a tendency internal to a moving body, the manifestation in circular motion of the internal force which keeps a body in motion." [Westfall (1980) p.148]

For Newton, there also appear to have been some rational aspects of the problem that were peculiar to himself: (a) During the same period (1665-66) in which he began to think of force as associated with <u>changes</u> of speed and direction caused by impact, he derived the centrifugal force law by considering elastic collisions of a moving body with the sides of a motionless polygonal cavity and letting the number of sides become infinite. (b) Moreover, as Westfall points out, belief in the reality of centrifugal force is less easily shaken by relativistic considerations than is belief in impetus force because: "Unlike the internal force of rectilinear motion, it could not be made to disappear by shifting inertial frames of reference." These conclusions could have reaffirmed Newton's waning belief in impetus force (a) through association with centrifugal force and (b) through confidence in the absoluteness of the latter.

In Westfall's summary judgement: "Every indication from Newton's papers suggests that the problems of circular motion, together with considerations external to mechanics, soon led him to reject the principle of inertia. Twenty years later, the same problems of circular motion viewed from a new perspective would be decisive in his final conversion to inertia."

Newton assumed that the centrifugal force of a planet moving in a circle is balanced by a force of external (and obscure) origin which is directed toward the Sun. Some time in the late 1660's, he substituted Kepler's third law into his formula for centrifugal endeavor and discovered that [Turnbull (1960) vol.I p.297 and vol.III p.46]

> ...for the primary planets, the endeavors of receding from the Sun will be reciprocally proportional to the square of their distances from the Sun.

This spurious quantitative success may have offered Newton temporary conviction that his balanced force model was on the right path. There is evidence as late as 1673 for Newton's hope that his finding would be worthy of professional recognition: After Huygens published the centrifugal force formula earlier in that year, Newton wrote to Henry Oldenburg, for transmission to Huygens, about his prior application of the formula. [Turnbull (1960) vol.I p.290]

The end of Newton's wandering in the desert of centrifugal force came in November 1679 when Robert Hooke, in his capacity as secretary of the Royal Society, wrote to Newton [Turnbull (1960) vol.II, p.297] inviting his opinion on Hooke's idea of

> ...compounding the celestiall motions of the planetts [out] of a direct motion by the tangent & an attractive motion towards the central body.

Newton replied immediately that he did not

> ...so much as heare (yt I remember) of your Hypotheses of compounding ye celestial motions of ye Planets of a direct motion by the tangt to ye curve...

Westfall remarks that "in a letter to Halley of 20 June 1686, he spoke of Hooke's Lectures and Collections (1678) as though he had read them when they appeared." [Westfall (1980) p.383] Thus there is evidence that Newton had actually known of Hooke's proposal for more than a year but had failed to act on it. We attribute this inaction to the continuing strength of his commitment to centrifugal force.

But Hooke's letter did indeed start Newton on the way out of his doldrums. Why was 1679 different from 1678? We suggest that the intervening year had moved Newton to a state of greater receptiveness because his encounters with alchemy had by then aroused in him a previously nonexistent capacity to imagine distant "attractions" and "repulsions" that exert force without impact. Westfall writes: "Driven, as it seems to me, primarily by the phenomena that he observed in alchemical experimentation, and encouraged by concepts that he encountered in alchemical study, Newton appeared to be poised on the brink of a further break with the mechanical philosophy, which would have major impact on his future career." [Westfall (1980) p.377]

In the course of followup correspondence with Hooke in 1680, Newton made his first progress toward a model of orbital motion employing unbalanced forces. But he did this without actually giving up centrifugal force. He argued that a body moving under the action of a central force will [Turnbull (1960) vol.I p.307]

> ...circulate wth an alternate ascent and
> descent made by it's VIS CENTRIFUGA & gravity
> alternately overbalancing one another.

A precipitous discarding of centrifugal force as a viable concept in dynamics was clearly impossible for Newton. As late as April 1681 he was continuing to experiment with its usefulness in analyzing the trajectory of a comet near the Sun. Writing to John Flamsteed, he spoke of [Turnbull (1960) vol.II p.358]

> ...the VIS CENTRIFUGA overpow'ring the attraction
> & forcing the Comet there notwithstanding the
> attraction, to begin to recede from ye sun.

By the time he wrote De Motu in 1684, Newton had permanently abandoned centrifugal force in discussions of orbital motion. Even in the Principia, however, he continued to employ it when discussing rotating liquids. [Herivel (1965) p.57]

Cohen calls Hooke's intervention "A major preliminary to universal gravity.... Newton himself said more than once that it was the correspondance with Hooke during the years 1679 and 1680 that really set him thinking fruitfully in a new way about the cause of celestial motions." [Cohen (1982)] Even so, Newton was not able to assimilate Hooke's conception all at once. Rather, his willingness to adopt Hooke's point of view appears to have grown only by degrees over the next few years, as the growth of successes using that point of view made its superiority ever more clear.

Making Hooke's conception his own required two changes in Newton: (1) A conceptual reorientation in which he set aside the centrifugal force idea and abandoned the balanced force model of circular orbits. (2) A procedural reorientation in which he learned to superpose inertial motion with motion due to an attractive force. These advances combined with Newton's earlier association of force with changes of velocity and with a new-found ability -- acquired only during the late 1670s -- to accept the possibility of action at a distance. All this made it possible for him to demonstrate enough important connections between his emerging dynamics and Kepler's laws to make him ready for the final stimulus of Edmond Halley's visit in 1684.

CONCLUDING REMARKS

In this paper we have attempted to document certain of Newton's qualitative conceptual difficulties, and to show that these presented major obstacles in his path to the Principia. But granted that these difficulties successfully impeded the progress of one of history's preeminent minds, one might still be tempted to argue that they should be of little concern in contemporary physics teaching because: (1) Newton lived in an intellectual climate in which impetus beliefs were widely held by his peers. (2) Newton had no teacher to tell him the correct perspective. We shall argue against both of these considerations.

With regard to the first point, there is strong evidence from numerous studies of contemporary students that Newtonian ideas have not filtered down to the general intellectual climate of which students are a part. In their interaction with peers who have not taken physics (and with some who have), students are faced with many of the same conceptions that Newton faced in his peers.

With regard to the second point, although Newton had no teacher in the narrow sense, he did experience strong positive outside influences, particularly from Hooke. Even when Hooke's letter pointed him in the right direction, however, Newton's prior conceptions were powerful enough to prevent his moving rapidly to a more adequate way of analyzing planetary trajectories. He needed more than five years to work through the full implications of Hooke's dynamical model.

Students appear to be impeded by their preconceptions in a similar way. A wealth of data demonstrates that simply being told about more adequate conceptions often does not have a lasting effect on their reasoning. Students appear to need to confront the conflict between old and new views directly in order to make progress. Newton's experience suggests that struggling with peer confrontation is an important part of this process, and moreover that considerable time will be required for this interaction to work its beneficial effect.

We feel that the mutual support provided by a web of interconnected misconceptions goes a long way toward explaining persistance in Newton and in students. To dismantle a system of misconceptions requires something like a revolution in one's world view, which can only be precipitated by conceptual conflict. In Newton's case, the collusion of centrifugal force and impetus force to form a system with a significant degree of coherence makes it understandable why an upheaval in his world view was necessary in order to produce the *Principia*. We plan to address coherence in students on another occasion.

We would like to raise one final issue in a tentative manner, as a question to be discussed. Might the memory of a long personal struggle help explain why Newton elected to designate the principle of inertia as a separate fundamental principle in the *Principia*? Since the first law associates zero force with constant velocity, he had the option of regarding it as being subsumed by the second law. Why then did he not discard it, as he did a number of other candidates for the status of fundamental principle which he had considered in his earlier writings? It is intriguing to consider the hypothesis of a feeling on Newton's part that to do so would have obscured a conceptual issue which had been developmentally important for him. Perhaps it will be possible for science historians to shed some light on this question.

FOOTNOTES

1. In this paper we use the term "misconception" to designate any conception that is in conflict with classical mechanics as it is understood today.

2. We intend to explore in a future paper how the centrifugal force and impetus force ideas may have interacted and been mutually supportive for Newton.

3. See Science, vol.176, p.157 (1972) for a review of Westfall's Force in Newton's Physics which argues that such terminology indicates Newton retained a true impetus concept through the first two editions of the Principia.

We wish to avoid attaching any negative connotation to the term since such naive conceptions can be complex, creative and adaptive constructions of the mind.

REFERENCES

David E. Brown and John Clement, in Joseph D. Novak ed., Proceedings of the Second International Seminar on Misconceptions in Science and Mathematics, Cornell University (1987)

John Clement, American Journal of Physics, vol.50, p.66 (1982)

I. Bernard Cohen, Scientific American, vol.245, p.166 (1981)

I. Bernard Cohen, in Zev Bechler ed., Contemporary Newtonian Research, D. Reidel Publishing Company (1982)

John Herivel, The Background to Newton's Principia: A Study of Newton's Dynamical Researches in the Years 1664-1684, Oxford University Press (1965)

Herbert W. Turnbull, The Correspondance of Isaac Newton, Cambridge University Press (1960)

Richard S. Westfall, Force in Newton's Physics, American Elsevier Publishing Company (1971)

Richard S. Westfall, The Construction of Modern Science, Cambridge University Press (1977)

Richard S. Westfall, Never at Rest: A Biography of Isaac Newton, Cambridge University Press (1980)

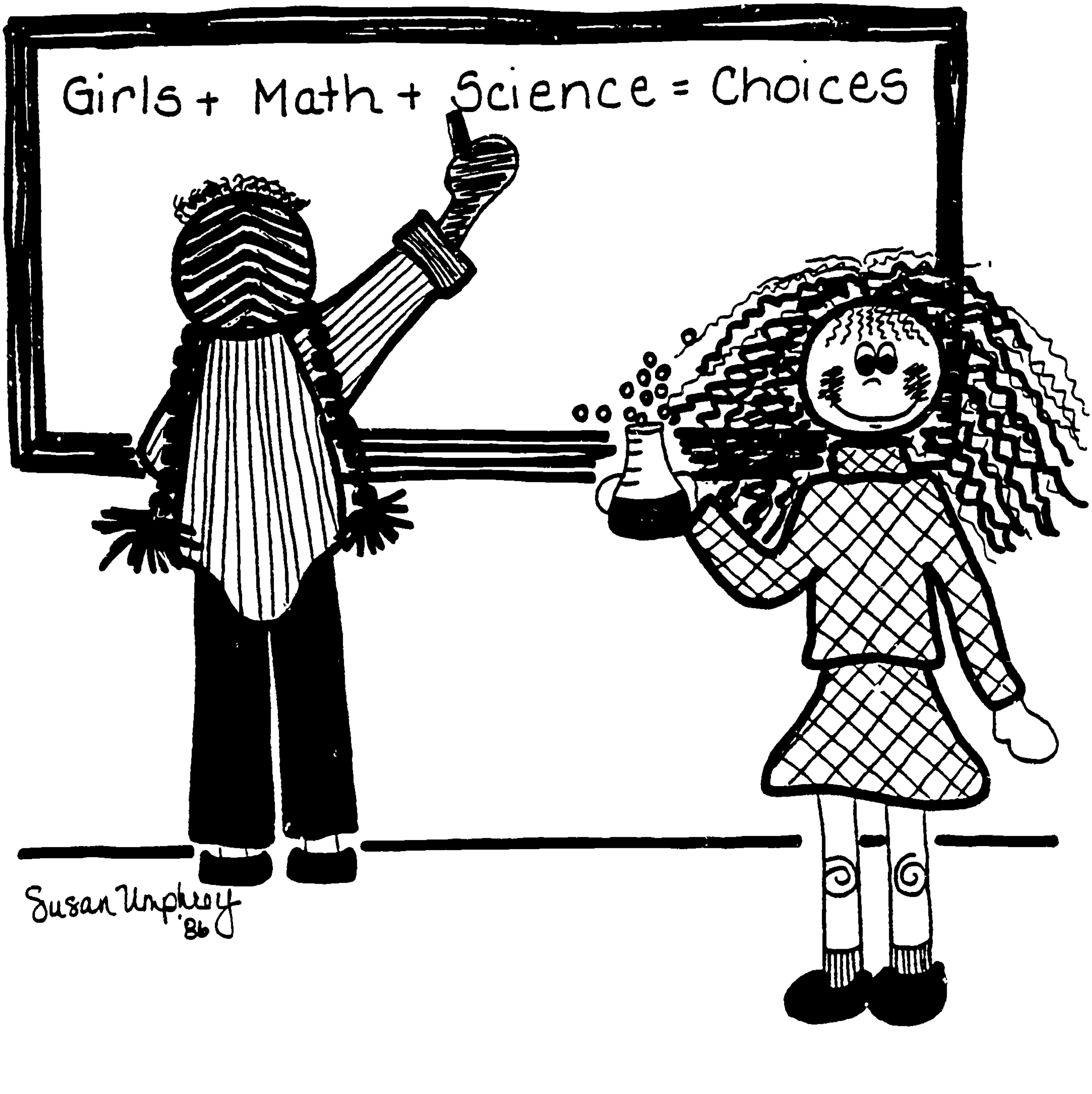
DOCUMENT RESUME

ED 313 245 SE 051 055

AUTHOR	Arbanas, Rose J.; Lindquist, Gayla R., Ed.
TITLE	Girls + Math +Science = Choices. A Handbook for Parents.
INSTITUTION	Calhoun Intermediate School District, Marshall, Mich.
SPONS AGENCY	Michigan State Board of Education, Lansing.
PUB DATE	89
NOTE	33p.; For related documents, see SE 051 051-052.
AVAILABLE FROM	Calhoun Intermediate School District, 17111 G Drive North, Marshall, MI 49068 ($2.50 plus $1.50 postage. For more than one, additional postage will be charged).
PUB TYPE	Guides - Non-Classroom Use (055)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Career Education; *Career Guidance; Elementary Secondary Education; *Females; *Mathematics Education; Parent Attitudes; *Parent Influence; Parent Materials; Parent Role; *Parent Student Relationship; *Science Careers; Science Materials; Scientific Personnel

ABSTRACT

This handbook for parents is intended to help them to stimulate their daughters' interest in career paths for young women in mathematics and science-related areas. Main topics included are: (1) problems, i.e., the dearth of women in the sciences (includes a fact sheet); (2) practical advice and guidelines; (3) activities; (4) reading materials; (5) resource information, including books, periodicals, and organizations; and (6) a selected bibliography, listing seven references. (YP)



HANDBOOK FOR PARENTS

GIRLS + MATH + SCIENCE = CHOICES

A Handbook For Parents

Rose J. Arbanas, Project Director
Gayla R. Lindquist, Editor
Susan Umphrey, Illustrator

Calhoun Intermediate School District
17111 G Drive North
Marshall, Michigan 49068

We are grateful for the insight and assistance offered by the **PARENT HANDBOOK COMMITTEE:**

Nancy Dando, Bellevue
Penny Kinter, Marshall
Sheldon Knoespel, Olivet
Arlene Lents, Battle Creek
Dick Sheffer, Pennfield
Carol Sybesma, Athens

1986 Discretionary Demonstration and Exemplary Grant
Elementary and Secondary Education for Economic Security Act (EESA)
Special Populations: Young Women
Awarded by the Michigan State Board of Education

4th Printing
1989

Table of Contents

What is the problem?

How high the sky? How far the moon? These are questions asked by children. But how many children actually go on to find the answers? And of those who do, how many are girls? Actually, the answers to the first two questions may not be important. What is important is the curiosity, the inquisitiveness, the willingness to explore what is behind them. Too often these qualities, essential to the development of scientific talent, are met with restrictions and annoyance on the part of adults, who see the exploring child as apt to get into trouble, to cause inconvenience to the adult, or, in the case of little girls, to display behavior that is not appropriately feminine.

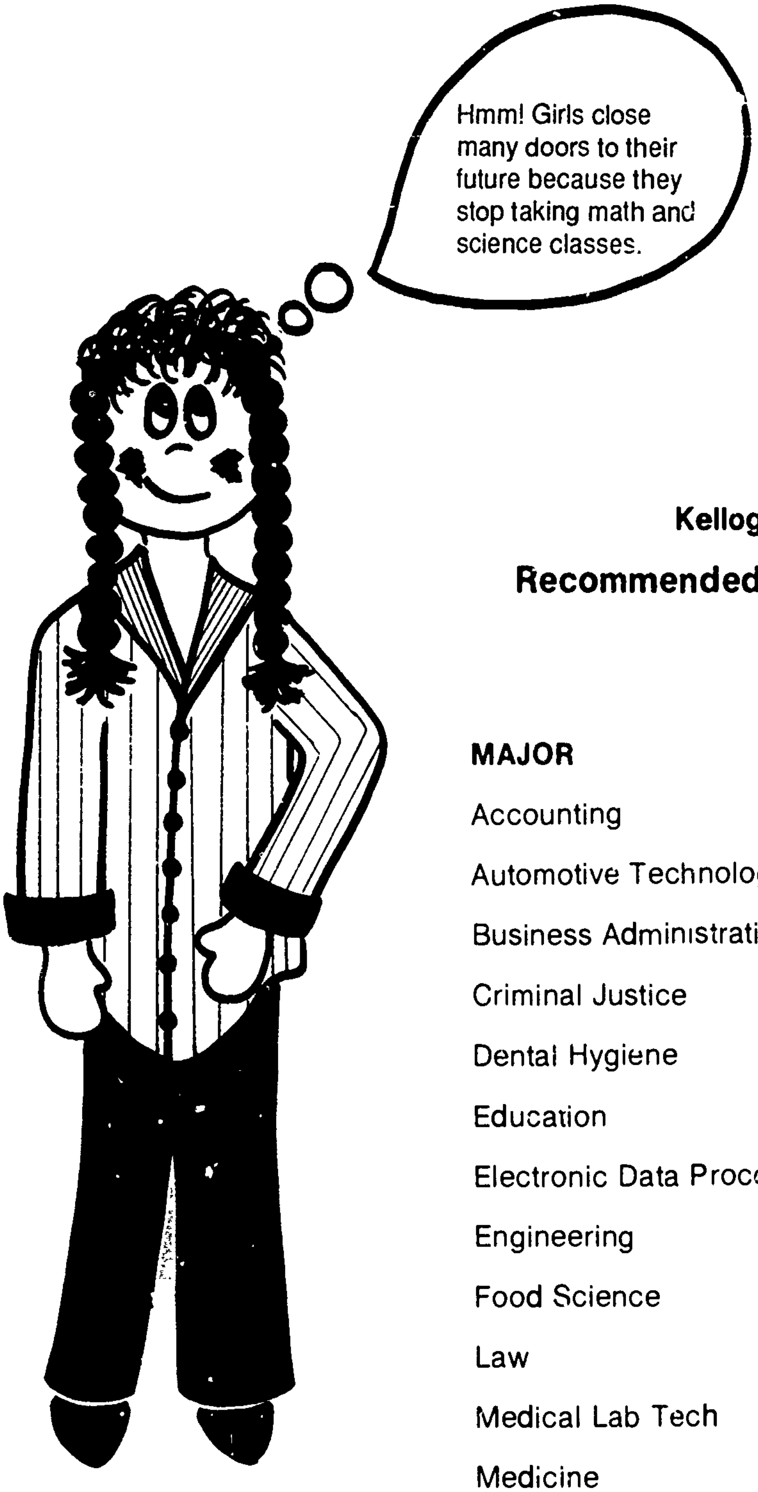
How many little girls do you know, unlike Alice, who are missing Wonderland because their minds block it out? What happened to their curiosity? Are they encouraged to be curious? Are they discouraged from exploring rabbit holes or any other strange phenomenon that passes their way? Of the approximately two million scientists in the United States, about 9.4 percent are women. Is the low number of women scientists due to a difference in abilities between the sexes? Or are there other reasons?

Science and mathematics suffer from a mystique that has caused them to be set apart from everyday life and regarded as only for the absolutely brilliant or for the eccentric who displays anti-social behavior. This mystique creates a hardship on the woman because pressures to conform are even stronger for her.

But, science is a part of our American way of life. It is part of everyday life. Adding to our scientific knowledge can, even for the nonscientist, add to our enjoyment of living and our knowledge of life. It is natural -- there is nothing mysterious about it. Learning science can be a pleasure to both sexes if it is not regarded as strictly a classroom subject and if it is not regarded as a field of study within the capabilities of only one sex.

Children should ask "How high the sky? How far the moon?" They should keep on asking these questions. They should be encouraged to ask and ask and seek and seek to satisfy their own curiosity. This should include the little Alices. "Why does water boil? Why does water freeze? How does a seed become a flower?" Our children and their minds are our most important resources.

In addition, children should meet and learn about scientists and what they do. We live in a complex, technical society. This will be increasingly so. Solving many of our future problems will require well-developed minds. Half of those minds belong to girls. Extra effort must be made to stimulate their creativity and to encourage them to be adventurous, curious and competitive. Without this encouragement, girls may grow up to find that they have not only limited their options but also cut themselves out of a larger percentage of the job market -- engineering; technical jobs; jobs requiring mathematical skills such as physics, chemistry, medicine, computer programming and accounting. These challenging jobs are also the better-paid positions.



Kellogg Community College

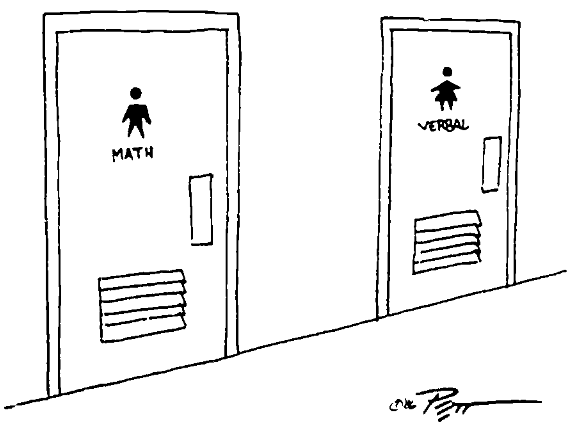
Recommended High School Years of Study

MAJOR	MATHEMATICS	SCIENCE
Accounting	3	2
Automotive Technology	2	3
Business Administration	4	4
Criminal Justice	4	3
Dental Hygiene	2	2
Education	4	4
Electronic Data Processing	3	2
Engineering	4	3
Food Science	4	3
Law	3	2
Medical Lab Tech	3	3
Medicine	4	3
Pharmacy	4	3
Physical Therapy	3	3
Social Work	3	2
Veterinary Medicine	4	3

Getting the Facts Straight

1. There is a commonly held myth that mathematics is a male domain.
2. Females can learn mathematics as easily as can males.
3. Presently, high school girls take fewer mathematics courses than do high school boys.
4. Many occupations require at least four years of high school mathematics.
5. Advanced high school mathematics courses are just as useful for girls as they are for boys.
6. Women cannot enter many occupations because they lack the necessary mathematical background.
7. Boys are more likely than girls to continue taking mathematics courses because:
   - They receive encouragement.
   - It is expected of them.
   - They believe it will be useful to them in the future.
   - They are confident of their ability to learn mathematics.
8. Girls are more likely than boys to stop taking mathematics classes because:
   - They receive little encouragement.
   - They are not expected to continue.
   - They believe they won't need it in the future.
   - They are not confident of their ability to learn mathematics.

Pett Peeves by Joel Pett



Phi Delta Kappan Magazine
Reprinted by permission

Women in the Workforce

How much do you know about working women today? Take this quiz and find out.

1. The number of women who work for pay at some time during their lives is:
   a. 3 out of 10
   b. 5 out of 10
   c. 7 out of 10
   d. 9 out of 10

2. In 1984, the percentage of women who worked because of economic need (self-supporting or husband earned less than $15,000) was:
   a. 33 percent
   b. 45 percent
   c. 56 percent
   d. 66 percent

3. Married men with non-working wives and one or more children make up what percentage of all households?
   a. 7.0 percent
   b. 26.4 percent
   c. 62.8 percent
   d. 79.3 percent

4. Women make up what percentage of the total workforce?
   a. 15 percent
   b. 24 percent
   c. 44 percent
   d. 50 percent

5. In 1982, the median earnings for men and women who worked full-time year-round were:
   a. men - $26,456 women - $24,954
   b. men - $21,542 women - $13,352
   c. men - $22,317 women - $19,942
   d. men - $20,561 women - $20,240

6. In the past decade, three-fifths of the labor force increase has been among:
   a. women
   b. minority women
   c. minorities
   d. married women

7. In 1983, fully employed, female high school graduates (with no college background) earned:
   a. more than male high school graduates
   b. less than men who did not complete elementary school
   c. more than male high school graduates, but less than male college graduates
   d. about the same as high school graduates

8. The absentee rate from work for women is:
   a. much greater than for men
   b. slightly more than for men
   c. much less than for men
   d. slightly less than for men

9. The unemployment rate of minority women compared to that of Caucasian women is:
   a. about the same
   b. less than the rate of Caucasian women
   c. 35 percent more
   d. twice as high

10. The average woman worker will work outside the home between ______ in her lifetime.
    a. 5-10 years
    b. 10-15 years
    c. 15-20 years
    d. 20-40 years

Answers

1. The number of women who work for pay some time during their lives is: **(d) nine out of ten.**

2. The percentage of women who worked because of economic need in 1984 was: **(d) 66 percent**. Most women work because they have to work. The **myth** that women work only to amuse themselves or to buy luxuries for their families is a very limiting one because it is used to justify keeping women in low-paying jobs.

3. Married men with non-working wives and one or more children in 1987 made up: **(a) 7.0 percent of all households**. Families are changing rapidly in today's society. The high divorce rate is creating many single-parent families. Also, many people are choosing not to have any children or to remain single.

4. Women make up: **(c) 44 percent of the total workforce.**

5. In 1982, the median earnings for men and women who worked full-time were: **(b) men - $21,542, women - $13,352**. The gap between the earnings of men and women continues to widen. Many explanations for the gap are given, but one of the most prominent reasons is that women are concentrated in low-paying jobs. For example, secretaries, who are usually women, make much less than construction workers, who are mostly men.

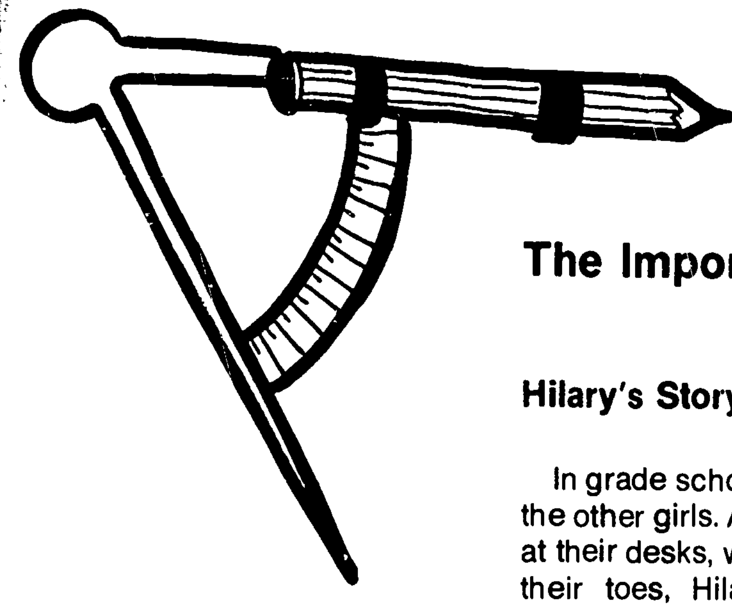
6. In the past decade, three-fifths of the labor force increase has been among: **(a) women**. Women from all backgrounds are entering the workforce.

7. In 1983, fully employed women high school graduates (with no college background) earned: **(b) less than men who did not complete elementary school.**

8. The absentee rate from work for women is: **(b) slightly more than for men**. The rates are 5.6 days a year for women and 5.2 days a year for men. This question was included to show that women are not more likely to be absent from work than men. (The statement that women are likely to be sick often is sometimes used as an excuse for not hiring women.)

9. The unemployment rate for minority women compared to that of Caucasian women is: **(d) twice as much.**

10. The average female worker will work between: **(d) 20 to 40 years in her lifetime.** Those women who expect to work only a short period of time may be in for some surprises.



The Importance of Math

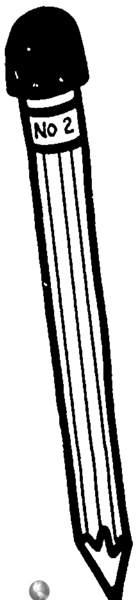
Hilary's Story

In grade school, Hilary was a whiz at math. So were many of the other girls. At times when many of the boys were squirming at their desks, wrinkling their foreheads, and trying to count on their toes, Hilary and the girls had already finished the assignment and had moved on to the extra credit questions and puzzles. Her parents hardly noticed when she brought home A's in math. It happened so often that they just took it for granted.

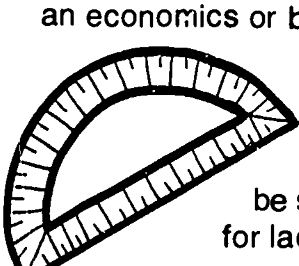
Then, sometime in junior high school, all that changed. Like her friends, Hilary seemed to lose interest in math. Her grades dropped, but she didn't really care. The boys, on the other hand, seemed to have finally caught on. They were taking all the math offered and doing well in it now.

What happened to cause this turnabout? Did the girls become dumb for some reason? Did the boys drain the girls' math ability and use it for their own, like some mad scientist in a bad horror movie? No, of course not. There isn't a logical explanation, but what happened to Hilary does happen frequently to young women. It has nothing to do with ability. If you had ability in grade school, you still have it. What you may have lost is the motivation to learn math. What you may have acquired is the notion that math is "unfeminine" or "for brains only." You may think, "No one wants to date girls who take trigonometry." If you do, that's silly.

You need to take math. Three years of high school math will give you more career options than almost any other subject. A great array of clerical jobs in banking, insurance, business and government need workers with math skills.



If you're planning to go to college, taking some math classes in high school is essential. A year of algebra and one of geometry are a bare minimum. If you have any interest in science or engineering, you ought to take trigonometry and calculus, too. Many colleges will not *admit* you without a solid math background. Most majors that prepare you for a specific high-paying career require math, although the amount and kind may differ. The math an engineer or a chemist needs is different from that an economics or business major needs. In each case the solid high school math foundation is the same. Whatever your major, one thing is certain. A knowledge of math helps you think analytically, which is an asset in any job. If you have no idea of the career you would like to eventually pursue, take math in high school to be safe. In this way you will not eliminate potential majors or careers for lack of a high school math background.



Did you know?

With math in her background a young woman graduating from high school can expect to earn $2,000-$4,000 more in her first entry level job. Math is often the key to the non-traditional jobs that pay more and offer more upward mobility.

It is a myth that people good at math can instantly come up with right answers or correct procedures.

The average yearly salary offered to a graduate with a 1983 Bachelor of Science degree in petroleum engineering was $31,044; with a Bachelor of Arts degree in humanities, $16,500.

These high-paying jobs require some college math:

- Doctors
- Nurses
- Pharmacists
- All science-related jobs.
  - Engineers
  - Physicists
  - Geologists
  - Oceanographers
  - Architects
  - Accountants
  - Computer Programmers

Over half of the jobs which are expected to increase most in number of workers by 1995 require math skills.

Math is not a talent, but a series of skills to be learned.

Mary Kay's Story

Mary Kay's friends scoffed at her interest in math and science. They said that you should just go to college to have fun and learn interesting things. Mary Kay thought differently, "I decided I wanted to be able to get a job that I'd like and that would support me just about anywhere in the country. So I went into pharmacology. It sounds boring to a lot of people, I know, but I love it. I've been working at the hospital for eight years now. I work with doctors and patients, and recently I started lecturing to nursing classes. I make more money than most women do, too. I feel bad that some of my old friends still haven't found jobs that they like. One of them, though, finally decided to start all over and is now in medical school. She's the one who was most against my studying pharmacology. Funny how things work out."

Things to think and talk about

Many parents want to know how they can help their daughters become more interested and capable in mathematics. First, you should know that **encouragment from parents** is a major factor in the choices young women make to remain in mathematics. Indeed, many successful women in nontraditional fields state that the main reason they were able to overcome barriers to their achievement in a male field was due to the early and continued support from one or both parents.

You have both the right and obligation to discuss the selection of high school courses and their relation to future career options with your daughter. Counselors are often responsible for several hundred students and cannot be expected to be current on either the employment opportunities best suited for any one student or the special needs and interests each student might have. Counselors can be urged to stress the importance of mathematics for every student; however, it still remains the parents' responsibility to ensure that their daughter is protecting her own future by becoming mathematically literate.

Specifically, parents may find it helpful to assist teachers in bringing role models into the classroom or in organizing a math/science career conference in their daughter's school. Parents who are themselves involved in scientific and technical occupations are valuable resources for the classroom teacher and should be encouraged to volunteer their talents either as role models or as contacts for female co-workers.

Parents - whether or not you are involved in math and science - you should try to:

- Provide your daughters with the same kind of toys and games that your sons receive, things to take apart and build; as well as models, puzzles, and games that develop investigative skills

- Take your daughters to visit science centers, where everyone can actively explore scientific phenomena, and on industry tours (automotive assembly plants, "inside" tours of dams, etc.) so that your daughters can see math and science in action. There may even be an opportunity to see a female role model in a non-traditional career.

- See that time and space is provided for homework and that you take an interest in the content of the homework, not just its completion.

- Provide your daughters with magazines and other literature that describe different types of occupations in an interesting manner. Clip newspaper articles on working women, and talk about them. Send for career information from large, technological industries.

- Become informed about community resources that are available to stimulate interest in math and science: nature camps, science centers, YWCA, Girl Scouts, Campfire Girls, Sea Scouts, after-school programs at the schools. Most communities have a variety of enrichment activities for students with which parents may be completley unfamiliar.

Guidelines for Growth

How do you raise and encourage your daughter?
Here are some suggestions:

PRESCHOOL:

____Dress her for activity, not sitting on the sidelines.

____Buy her building and mechanical toys (Lego, Tinkertoys, dump trucks).

____Select nonsexist day care and preschools.

____Expand sex role models. Point out and challenge the limiting stereotypes on TV.

ELEMENTARY:

____Encourage her to read; provide math puzzles, home computers.

____Take her to zoos, factories, science museums.

____ Watch for signs of boredom with school. She may need acceleration, an individualized program or a different school.

JUNIOR HIGH:

____Don't push social relations.

____Encourage her to take apart her bike and also to put it back together.

____Expect her suddenly to want to be like every other girl, but continue to encourage school work.

____Find female role models she can follow around for an afternoon.

HIGH SCHOOL:

____Insist that she keep taking math and science, even if they've become optional.

____Encourage her to focus on what she is **learning** in her classes rather than on her grades.

____Help her find good college information and nonsexist career guidance.

ALWAYS SHOW THAT YOU BELIEVE IN HER ABILITIES.

Math Autobiography Questions

A. Think back to your math experience in *elementary school*. How did you feel about mathematics?

- Did you experience mostly success or difficulty in learning math?
- What did people say when you made a mistake in math, when you did very well?
- How did your interest and ability in math compare to other students' - male and female - in your class?
- How did your elementary school teacher feel about math? Did her/his feelings influence you in any way?

B. Now recall your math experience in *junior high school*. What were your feelings about math?

- In what way had they changed since elementary school?
- If your feeling about math changed, what might have prompted the change?
- Who helped you when you had difficulty with math?
- Was your experience in math class different than experiences in your other subjects? How?
- How confident did you feel about your ability to learn math in junior high school?
- Were your math experiences in junior high school mostly successful?
- Did you experience any failure in math?
- How would you describe your feelings about math in junior high school?

C. What was your *high school* math experience like?

- Can you recall any strong feelings about math which occurred while you were in high school?

- How much math did you study in high school?
- What were your reasons for choosing to study or not to study math?
- How did your parents, teachers and counselors react to your decision regarding math?
- How confident did you feel about your ability to learn math in high school?
- Did your friends take advanced math courses?
- How did students in your school feel about girls taking advanced math classes?

D. Did you study math in *college*?

- How did you feel about it?

E. What are your feelings about math *today*?

- If you were required to enroll in a math course tomorrow, how would you feel?
- If you had to select a single memorable experience in math, what would that experience be?
- Has math or the avoidance of math been a factor in any decisions you've made about the choice of a major, a job, a career?
- How confident do you feel about your ability to learn math?

"A dog weighs 12 kg on 4 legs. What is its weight on 3 legs?"

Your Teenager and Math: You Can Make a Difference

Parents can be a big influence on their teenagers' attitudes about mathematics. If you, as a parent, have negative feelings about females' mathematical abilities, your children, from the youngest to the oldest, may have picked up that message. If you don't believe that women can learn mathemtics, your daughter may have very little confidence about her capabilities in mathematics class. How often do we succeed when we don't believe in ourselves?

SOME PRACTICAL ADVICE FOR PARENTS

1. Talk openly with your children about their feelings toward mathematics. Share your own feelings about mathematics. Did you find mathematics fun and challenging? Were you a mathematics avoider? Sometimes sharing your own feelings of anxiety or insecurity will encourage them to be more open about their insecurities. Recognizing and expressing fears about mathematics can be a major step in overcoming them.

2. Talk to your sons and daughters about their feelings toward girls and mathematics. Talk about the *myth* of male superiority in mathematics. Many girls don't do well in mathematics classes because they believe that boys are supposed to be better in mathematics than girls; they are afraid boys won't like them if their grades are higher than boys' in mathematics class. Point out to them that females can learn mathematics as well as males and that mathematics is just as important for girls as it is for boys.

3. Talk about career plans with your daughters. Point out that many occupations require a good mathematics background and that educational and career options are limited by not continuing in mathematics classes.

4. Talk about the usefulness of a good mathematics background in today's world. Whether for a job, job-training, or coping with the rapidly changing technology of day-to-day life, mathematics is something that we depend upon with growing frequency.

5. Discussing attitudes about mathematics with your children is not the only way to help improve their attitudes. Practicing what you preach is every bit as important. Ask yourself the following questions.

   a. Do you treat your sons differently than you treat your daughters when it comes to mathematics? Do you make your son "sweat it out" a little when he comes to you for help with his homework? Do you give in more easily with your daughter? The secret to success in mathematics is staying with it. If you interact differently with your son than with your daughter you may be improving you son's mathematics skills but undermining you daughter's.

   b. Do you give your sons and daughters different kinds of toys? Do you encourage them to pursue different kinds of hobbies? Many people believe that boys do better in mathematics because boys have grown up playing with more mathematical or scientific toys. Through their experiences with athletics, they are likely to learn how to keep score, add points, figure batting averages and similiar skills.

c. What kind of language do you use when referring to women and mathematics in your home? Mothers, do you say, "Ask your father," when someone asks for help in mathematics homework even though your husband may know no more math than you? Fathers, when your daughter complains about not understanding mathematics, do you say, "That's okay honey. Your mother doesn't know a thing about mathematics, and I love her anyway"?

6. Encourage your daughters to participate in mathematically-oriented games and activities - jigsaw puzzles; chess; packing things in boxes, suitcases, or cars; figuring out phone bills or per unit prices in the grocery store or monthy budgets.

7. Encourage your daughter to seek help and support if she is having trouble in mathematics class. Is there a mathematics support group she could join in your area? If not, you could help your school start one. Ask a counselor at your school about it.

8. Your children care what you think. Encourage your daughter to join the mathematics club, the chess club or the mathematics team. Give her as much encouragement as you would if she were joining the drama club or going out for cheerleading.

Remember, it's attitudes - not aptitudes - that are holding girls back from mathematics performance. Changing your attitude may make a significant contribution to your daughter's mathematical success.

- Thought Provokers -

Ask your daughter to:

- **Draw a picture of herself when she is grown up and at work.**
- **Imagine she is 30 years old. Have her describe a typical Wednesday in her life.**

Frequently Asked Questions or Comments With Suggested Responses

COMMENT:

What can I do to encourage my children to continue to study mathematics?

RESPONSE:

- Communicate to your children the message that mathematics is important and will be useful to them in the future, that an inadequate mathematics background limits educational and career options.
- Share with your children the idea that mathematics is as important for girls as it is for boys.
- Encourage your children to do well in mathematics and to ask questions of the teacher or seek extra help with problems they do not understand. Girls have as much mathematical ability as boys. Express confidence in their capabilities.
- Do not convey to your children a negative attitude toward mathematics or the stereotypic notion that mathematics is a male subject. Have the same high expectations for your daughter's mathematics achievement that you do for your son's.

COMMENT:

I have trouble understanding the mathematics homework myself. I'm not much help to my children when they are having difficulty. What can I do?

RESPONSE:

Examine your own history of mathematics learning for sources of mathematics anxiety or mathematics avoidance. Recognizing signs of the problem in yourself may help you relate more effectively to the frustration, anxiety and difficulty your children are experiencing. Encourage your children to talk about the problems they are experiencing in mathematics class and to seek help from their teacher, the mathematics resource center or a mathematics support group if such a group exists at your school. Talk to your children's mathematics teachers to insure that your children get the help they need. Don't let your own difficulty with mathematics discourage you and deter your children from overcoming their own fears and trouble with mathematics.

COMMENT:

My daughter isn't interested in mathematics-related careers. Why should we be concerned about her taking mathematics?

RESPONSE:

At this moment, your daughter may not be interested in a mathematics-related career. However, your daughter's educational and career interests may change several times before she graduates from high school or college. Having at least three years of high school mathemtics will allow her to consider a greater number of careers, training programs and college majors. It will also facilitate future career changes in our increasingly technological society. Many educational programs and careers depend on mathematics skills for entry or advanced work. Mathematics comprises one-fifth to one-half of the content on widely used employment and college entrance exams. Failure to take sufficient courses in mathematics will limit your daughter's (and your son's) educational and career options and it will hinder her opportunities to advance in the career she selects.

COMMENT:

My daughter isn't sure what she wants to do. If she continues with mathematics, I'll be pleased, but it is really up to her. I can't force her to continue to study mathematics.

RESPONSE:

Parents can be a big influence on their children's attitudes. Your children do care about what you think. The decision about learning mathematics must ultimatley be made by your daughter. However, you have a responsibility, as a parent, to provide her with accurate information or to point out where she can obtain information in order to make a knowledgeable decision. You can talk to her about the usefulness of a mathematical background in today's technological and changing world. You can point out the importance of mathematics in her educational and career planning.

COMMENT:

Do the school counselors have information on how much high school mathematics is needed for various careers?

RESPONSE:

School counselors do have books and pamphlets describing the requirements for entry into various careers and education programs. However, the amount of high school mathematics required or strongly recommended is not always stated, and many careers and majors have **hidden** mathematics requirements. Several Civil Service examinations have based one-third to one-half of their total scores on mathematics. College entrance examinations also base from one-fifth to one-half of their score on mathematics. While colleges suggest that two to three years of high school mathematics are required for entrance, they often fail to point out that having only two or three years of high school mathematics will drastically limit a students' range in choice of college majors. A knowledge of statistics, computer programming, advanced algebra, or financial planning may be required for advancement in a career or for graduate work in most areas.

COMMENT:

My daughter doesn't like mathematics and has to work harder at it than at her other subjects. Should she risk getting a low grade in it and jeopardize her chances of being admitted to a "good" college?

RESPONSE:

Low grades may have an influence on your daughter's future plans. But not having an adequate mathematics background can also lead to lower salaries, fewer opportunities for entry-level positions and less opportunity for advancement in an occupation. Her educational and career options could be **greatly limited**. There are alternatives to dropping mathematics. Some high schools are offering mathematics support groups, tutoring, mini-courses or workshops teaching varied approaches to and strategies for learning mathematics. Some people have trouble learning mathematics, not because they are unable to do it, but because they are anxious about it. Getting help with mathematics is one way of reducing their anxiety. Learning to understand the causes of their anxiety about mathematics and the ways of reducing it has helped other students improve their mathematics achievement. If your child has math anxiety, you can talk to the counselor about it. Boys, as well as girls, may find mathematics difficult and may feel anxious about it. Yet, boys are more likely than girls to persist in their study of mathematics because they seem to recognize the usefulness and importance mathematics has to their career choices and because their parents expect more mathematics study of males than females. By expressing the same support and interest in your daughter's mathematics achievement and by being as persuasive with her as you would your son, you can become a crucial element in her election of mathematics courses in high school.

COMMENT:

The importance of mathematics is being overstated. As parents we each had only two years of math, and we're doing just fine. Two years of math is adequate for most girls.

RESPONSE:

At one time, two years of mathematics probably was adequate for most people. In this decade, however, many significant changes have occurred. The growth of technology has brought about a demand for highly skilled and specialized workers. People with backgrounds in engineering, science, mathematics, statistics, computer science, accounting, business, and other technical fields are much in demand. Preparation for these fields includes three to four years of high school mathematics and additional mathematics in post-secondary programs.

WHERE THE JOBS WILL BE

10 fastest-growing occupations	Change 1986-2000
Paralegal personnel	104%
Medical assistants	90%
Physical therapists, assistants	86%
Data-processing-equipment repairers	80%
Home health aides	80%
Computer-systems analysts	76%
Medical-record technicians	75%
Employment interviewers	71%
Computer programers	70%
Radiology technologists, technicians	65%
...And 4 that will lose jobs	
Electrical, electronic assemblers	-54%
Industrial truck, tractor operators	-34%
Stenographers	-28%
Farmers, farm workers	-25%

Note Projections are among occupations with 25,000 workers or more and assume moderate economic growth *USN&WR* - Basic data U S Dept of Labor

Ten Things to Remember
The Next Time You're Avoiding Math

1. An important factor in learning math is the amount of time you spend studying it.

2. You don't have to like math to learn it.

3. Some people make mistakes in math not because they are careless or unable to do it but because they are anxious about it. Learning to understand the causes of their anxiety about math and the ways of reducing it have helped other students improve their math achievement. If you have math anxiety, learning more about it would help you.

4. Avoiding math is related to math anxiety. Putting time and energy into catching up on the math not learned in earlier courses and understanding one's feelings about math have been very effective solutions to math anxiety.

5. There is evidence that some students are less apt to contribute or to ask questions in mathematics classes. You have the right to ask for help or for clarification of a problem or math concept. Take the risk to obtain the information you need. Others in the class will follow your lead.

6. Mathematics may be a "hidden" requirement for occupational opportunities. The total score on several Civil Service examinations is based one-third to one-half on mathematics. College entrance examinations, such as the ACT and the SAT, base from one-fifth to one-half of the total score on mathematics. While colleges suggest that two to three years of high school math are required for entrance, they often fail to point out that only two to three years of high school math will limit your choices of college majors to those in the humanities, some social sciences and education.

7. Males, as a group, are not better at math than females. When females take as much math as males, there are few differences in their achievement.

8. Males have often continued in math because they are told that it is a requirement for the things they want to do.

9. Males hold most high paying and high prestige jobs in today's job market. There is evidence that males are able to enter a wider range of jobs partly because of their stronger preparation in mathematics. The higher the prestige and salary of a job, the more likely it is to require a strong mathematics background.

10. Because of the effect of past stereotyping, some people still feel that math and science are male subjects. These people may make sex-biased remarks. Seek out people who can give you accurate and unbiased information about your need for math. Remember that *Title IX* protects women's rights to equal opportunities in education.

22

Activities for your child

Sentence Completion Exercise

1. When I need help with math, I usually ask...
2. I would expect a female mathematician to be...
3. I would expect a male mathematician to be...
4. Girls who enjoy math are...
5. Boys who enjoy math are...
6. When a boy fails a math quiz, it is usually because...
7. When a girl fails a math quiz, it is usually because...
8. Girls should be preparing for careers in...
9. Boys should be preparing for careers in...
10. When a daughter graduates from high school or college, her parents expect her to...
11. When a son graduates from high school or college, his parents expect him to...
12. in math classes, teachers think the boys should...
13. In math classes, teachers think the girls should...
14. When talking about math, counselors usually think that girls should...
15. When talking about math, counselors usually think that boys should...

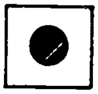
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

Laurie has always loved animals. She takes care of all of her family's pets and knows what to do when they get sick or injured. She is planning to take a lot of science and math. She wants to go to a special school to prepare for her profession.

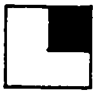
To find Laurie's job, put the right code letter over each "transformation" picture below.

CODE LETTERS

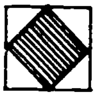
A 

E 

I 

N 

R 

T 

V 

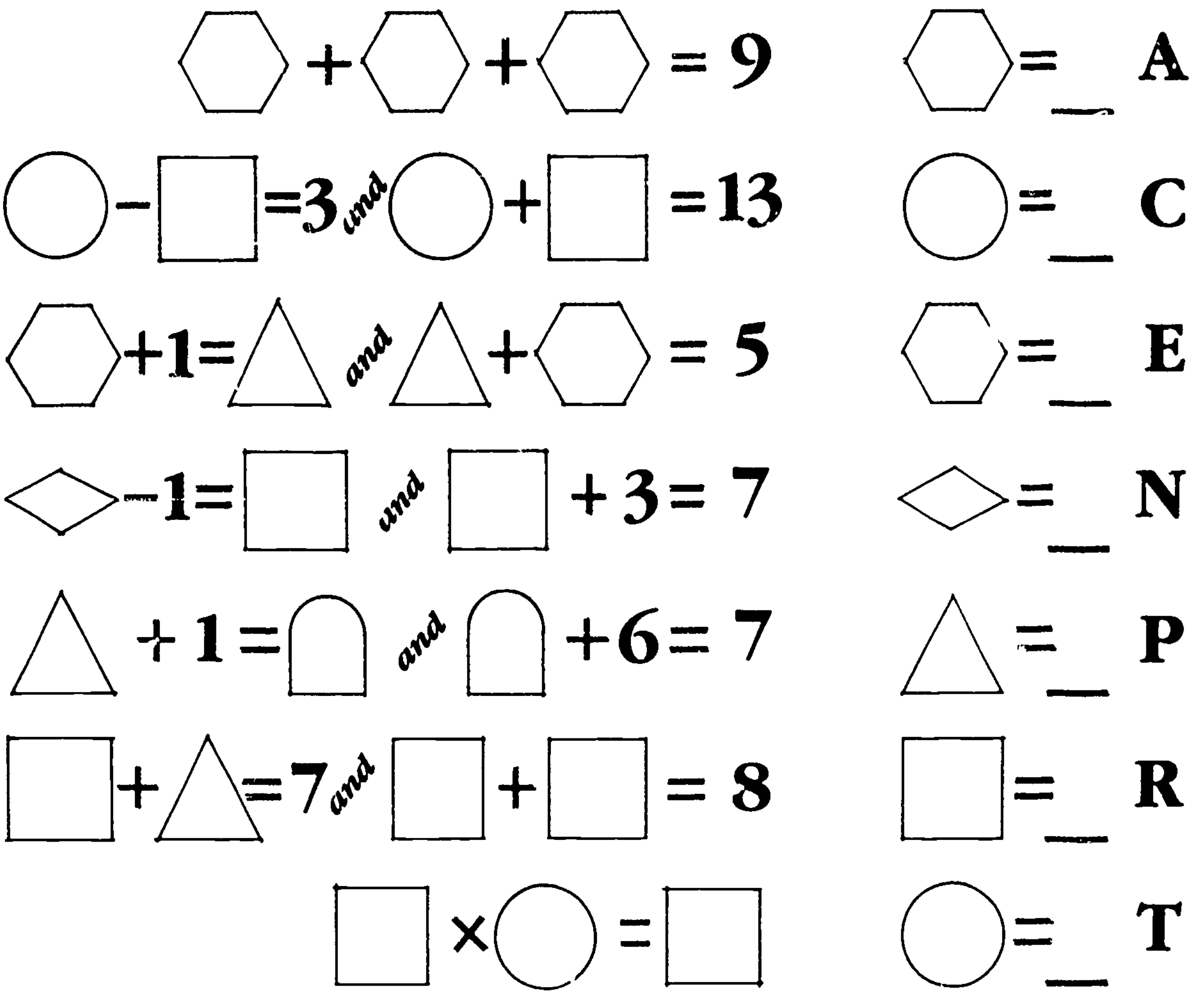
___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Louise likes building things. When she was only five years old she built a birdhouse with her mother's help. She can use a saw and a hammer, and she knows how to measure and plan ahead so she won't waste wood. Someday she wants to build a house.

In each row, a shape is always the same number. The same shape may stand for a different number in another row.

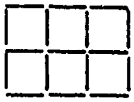
To find out what Louise's job is, put the right code letter in each blank.

CODE LETTER



___	___	___	___	___	___	___	___	___
8	3	4	0	2	5	1	2	4

TOOTHPICK PUZZLES

1. Use 17 toothpicks to construct this figure. 

   a. Remove 5 toothpicks and leave 3 squares.

   b. Remove 6 toothpicks and leave 2 squares.

2. Make this figure with 12 toothpicks. 

   a. Remove 4 toothpicks and leave 3 triangles.

   b. Move 4 toothpicks and form 3 triangles.

3. With 9 toothpicks, make this figure. 

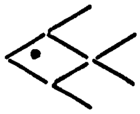
   a. Remove 2 toothpicks and leave 3 triangles.

   b. Remove 3 toothpicks and leave 1 triangle.

   c. Remove 6 toothpicks and get 1 triangle.

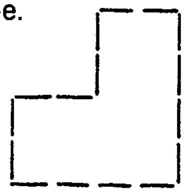
   d. Remove 4 toothpicks and get 2 triangles.

   e. Remove 2 toothpicks and get 2 triangles.

4. Use 8 toothpicks and 1 button to form a fish. 

   Move 3 toothpicks and button to make this fish swim the opposite direction.

5. Two farmers have land this shape.



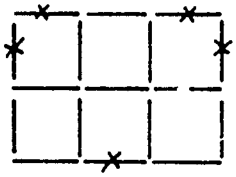
   a. The first farmer wants to divide her land evenly among her three daughters. Add 4 toothpicks to form three parcels of equal size and identical shape.

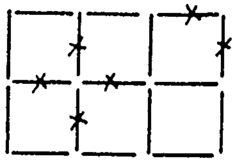
   b. The second farmer wants to divide her land evenly among her 4 daughters. Use 8 toothpicks to form four parcels of equal size and identical shape.

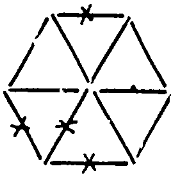
6. Use 6 toothpicks to form 4 equilateral triangles.

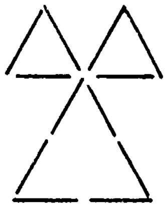
Toothpick Puzzles - Solutions

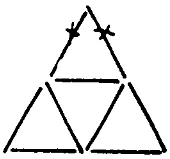
There is an "X" on each toothpick to be removed. In most cases there are several possible solutions. Only one is indicated.

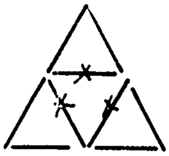
1. a. 

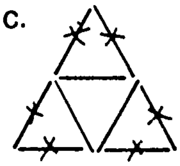
b. 

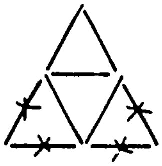
2. a. 

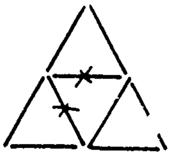
b. 

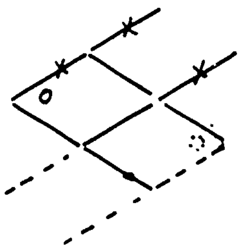
3. a. 

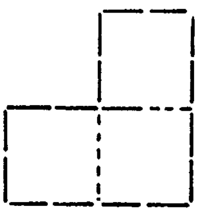
b. 

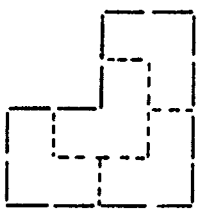
c. 

d. 

e. 

4. 

5. a. 

b. 

6. Make a 3 dimensional tetrahedron. 

Just for a laugh, here is:

Another Longitudinal Study

by Phyllis Steinmann

Once upon a time, in 1940, a research team decided to study the cooking ability of males and females to see if sex had any affect on this ability. The population chosen for the study consisted of 2,000 individuals selected at random: 1,000 were males, and 1,000 were females. Their ages ranged from 5.5 years to 6.5 years. They were observed for an average of two weeks, usually in the kitchen. It was found that both groups were equally adept at spreading peanut butter on slices of bread. Their biggest problem was when the jar of peanut butter was on the top shelf. Then the boys, who were slightly taller than the girls, had a little advantage. The major difference in the sexes was that the girls were twice as likely to put the dirty knife in the sink.

The same subjects were investigated again in 1946 when their ages ranged from 11.5 to 12.5. The large majority of girls, 65%, were able to prepare a simple meal, while only 15% of the boys had attained this skill.

The final study in the series was done in 1952 when the subjects were around 18 years old. At this time most of the females, 85%, were capable of preparing a full-course dinner, but only 5% of the males could do this.

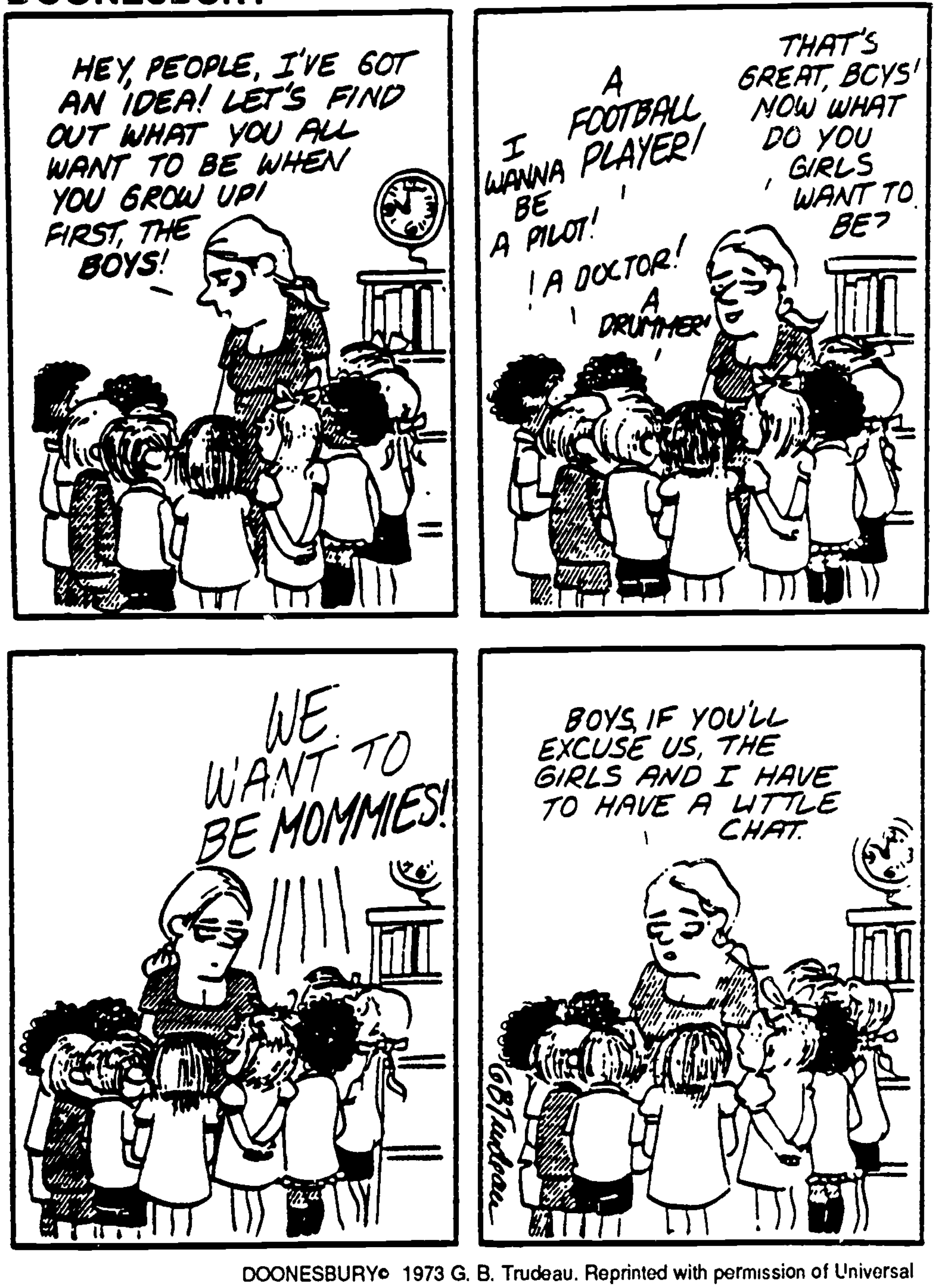
The study clearly showed that there was a great difference in the cooking ability of boys and girls. Ten percent of the sample were twins where one was male, and the other female. These siblings, brought up in the same environment, showed the same discrepancy in cooking ability. It was decided the only explanation for this situation was that the ability to cook was stronger in female genes than in male genes.

In order to confirm the findings of this study, it was repeated again in 1972 with another group of 1,000 boys and 1,000 girls. At age six, the two groups were again found to be equally able to spread peanut butter sandwiches. In 1978 at age 12, they were about equal in their ability to heat up TV dinners in the microwave oven. In 1984, neither group had developed any real cooking skills, opting to eat out at McDonald's.

The results of this study are still being analyzed. One likely conclusion is that in a matter of some thirty years the female genes have been altered, possibly caused by radiation from TV sets.

DOONESBURY

by Garry Trudeau



Where to look for more information

BOOKS:

Dotson, Fitzhugh. How to Parent. New American Library, New York, NY, 1973. An oldie, but it still offers practical advice on topics from discipline to toys.

Galbraith, Judy. The Gifted Kids Survival Guide. Free Spirit Publishers, Minneapolis, MN, 1984. Written for gifted kids, this book offers solid advice in an attractive format on how to survive being gifted. There are two volumes, one for kids under ten, the other for kids eleven to eighteen.

Kerr, Barbara. Smart Girls, Gifted Women. Ohio Psychology Publishing, Columbus, OH, 1985. An examination of the specialized needs of bright girls with recommendations to parents and teachers from preschool through professional schools.

Marone, Nicky. How to Father a Successful Daughter. McGraw-Hill Book Co., 11 West 19th Street, New York, NY 10011, 1988. An important nurturing book to help fathers communicate with their daughters.

Perino, Josef and Shiela. Parenting the Gifted: Developing the Promise. Bowker, Xerox, New York, NY, 1982. Covers a range of facts and issues of importance to parents and teachers of the gifted including such things as adolescent gifted, choosing private schools, preschool gifted and many other issues. Has extensive bibliography.

PERIODICALS:

Games Magazine
P.O. Box 10147
Des Moines, IA 50340

Gifted Children Monthly
P.O. Box 115
Sewell, NJ 08080

Popular Mechanics
515 Madison Ave.
New York, NY 10022

Science Digest
1775 Broadway
New York, NY 10019

ORGANIZATIONS:

Michigan Association for the Academically Talented (MAAT)
Mary Lou Angelotti, 2209 Belaire, Midland, MI 48640
$10.00 per year membership includes quarterly newsletter, "Gifted Perspectives."

Michigan Association of Educators for the Gifted, Talented and Creative (MAEGTC)
Robert Hayduk, 31300 Anita, Warren, MI 48093
$10.00 per year membership includes quarterly "MAEGTC Newsletter."

The Academy for the Gifted and Talented of Michigan
Richard Watson, 2100 Pontiac Lake Road, Pontiac, MI 48054
$15 individual membership includes quarterly newsletter.

Family Math Materials

Contents

FAMILY MATH Book Order Form

To order a copy of FAMILY MATH, please fill out the form and enclose a check or purchase order made payable to:

The Regents, University of California

The cost of the book is $15.00, plus $2.00 for tax and shipping within the U.S.

I would like to purchase ____________ copies of the FAMILY MATH book.
Enclosed is my check or purchase order for $____________

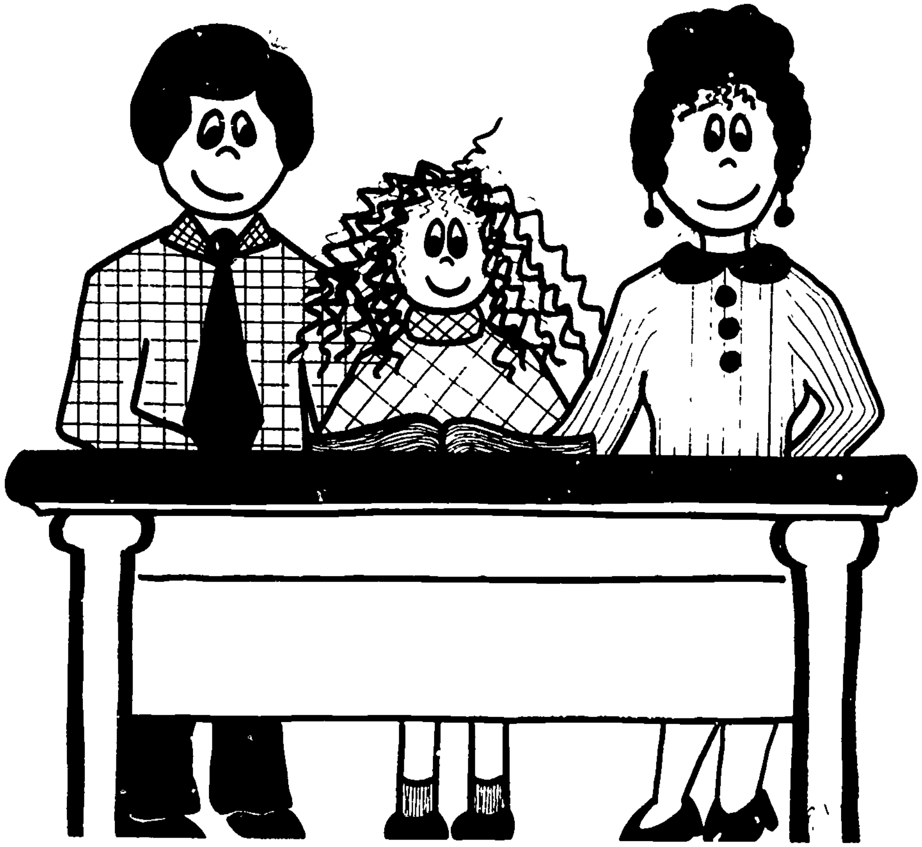
Name: ____________ Address: ____________

City, State: ____________

Zip, Country: ____________

Return to: FAMILY MATH
Lawrence Hall of Science
University of California
Berkeley, CA 94720 USA
Telephone: (415) 642-1823

Epilogue



Parents, YOU can make a difference! YOU can help your children develop positive attitudes about math and science. As a parent, you are a major role model for your children. Believe it or not, they are watching what you do, listening to what you say and paying attention to what you believe. What a compliment to you!

Selected Bibliography

CHOICES: A Teen Woman's Journal for Self-Awareness and Personal Planning, Bingham, Edmondson and Stryker.

Collegiate Employment Institute Newsletter, Michigan State University, October 15, 1987.

Downie, D., Slesnick, T. and Stenmark, J. K., Math for Girls and Other Problem Solvers, EQUALS, Lawrence Hall of Science, University of California, Berkeley.

Kellogg Community College Admissions Manual, 1986.

Multiplying Options and Subtracting BIAS, An Intervention Program Designated to Eliminate Sexism from Mathematics Education, School of Education, University of Wisconsin, Madison, 1981.

Shapiro, Robert J. and Walsh, Maureen, "The Great Jobs Mismatch," U.S. News & World Report, Sept. 7, 1987.

SPACES, Solving Problems of Access to Careers in Engineering and Science, EQUALS, Dale Seymore Publications, Lawrence Hall of Science, University of California,Berkeley.