Teaching university mathematics and coaching youth soccer

MATTHIAS KAWSKI*

Department of Mathematics and Statistics, Arizona State University

This note reflects on similarities between best practice in teaching mathematics and in coaching children's soccer. The focus is on two examples: The key role, importance, and design of problem solving activities, and the necessary restraint on what kind of feedback and corrections to provide in a student centered classroom or practice. A central observation is that, in the end, learning and teaching in no matter what subject, involves the same human organ. Hence one may find helpful ideas and solutions for teaching one's subject even in domains that appear very distant. Indeed, as laid out in the author's personal experiences, sometimes it may even be easier to become aware of, understand, and improve on learning issues when experiencing them in a very different discipline.

Keywords: Problem solving, student-centered, best practices.

1 Introduction

This article presents a different twist of the popular saying [1] *“from sage on the stage to guide* (or *coach*) *on the side"*. It reflects on similarities between best practices in teaching mathematics in a student centred environment, and in coaching youth sports, with focus on children's soccer. It is strongly motivated by the very similar misconceptions about either side: The colleagues and even the instructors in the coaching licensing courses, much like the general public, thought of mathematics teaching as being mostly about supervising the memorization of recipes and drill of algorithmic procedures. On the other hand, fellow mathematics instructors and e.g. colleagues at international conferences related to mathematics education thought of coaching youth soccer as being all about repetitive drill exercises designed to shape *muscle memory*, and at older ages, about perfecting the execution of a library of predesigned combination plays. Moreover, many more experienced, and more reflective members of either side claimed that, unlike the other side, effective teaching/coaching in their own area is mainly about designing problem solving activities.

As a research mathematician, with a secondary interest in undergraduate mathematics education research, the author found that this is more than just an amusing coincidence. As a student in coaching license courses, and as a coach routinely designing activities for each practice, he observed that this is a two-way street. The two groups are very dissimilar: On one side there are university students and primarily mental exercises in mathematics. On the other side, there are consider children of ages 8 through 12, and primarily physical activities in soccer. But it is precisely this contrast that makes it even more compelling to reflect on the common principles of effective learning strategies. Almost certainly there are deep reasons why in either setting the professional organizations seem to converge on very similar recommendations. While it is fun to speculate about such deeper reasons in terms of the make-up of our brains and general learning theories, this is beyond the scope of this brief note. Instead, we shall be very descriptive and practically oriented.

* Email: kawski@asu.edu

This article does not present hard statistical data, but the author has considerable anecdotal evidence that either practice, together with abstraction and reflection, has considerably improved the effectiveness of both his mathematics teaching and his soccer coaching. This includes superior success (retention, being selected by top graduate schools, or by elite teams at the teen level) as well as numerical student teacher evaluations, and verbal feedback by players, parents, and other coaches. From the point of view of mathematics education researchers, or physical education researchers, these observations may not come as a surprise. Yet the teacher working in the ditches is often torn between heeding traditions and implementing lofty recommendations that come from education researchers and which often are considered controversial among students, parents and colleagues.

Observing the positive results of implementing the recommended principles in such different arenas has made the author feel considerably more at ease with following the recommendations, even in the presence of considerable local antagonism. He hopes that by sharing this experience, others, too will find strength to continue the path of implementing the recommendations based on research.

Since this note is primarily addressed at mathematics educators, and mathematics education researchers, the next section first gives an overview of guidelines for coaching youth soccer by the top professional organizations. This is followed by comparisons to teaching strategies in mathematics, and selected more detailed examples of teaching situations. The final section summarizes our observations, and makes a few suggestions for deeper reflection, and for looking beyond the traditional narrow disciplines for proven methods for effective teaching and coaching.

2 Coaching youth soccer in the United States

2.1 Youth soccer in the United States

Soccer is widely considered the world's most popular sport, as measured by the number of active participants and spectators. However, it has arrived in the United States only comparatively recently. At the professional level it cannot compete in the U.S. with the highly developed traditional sports with their intricate commercial networks. However, at the youth level, already in the late 1990s soccer became the number one sport (measured by number of active players) in the United States, too.

While in most parts of the world, soccer is played everywhere in the streets, parks, plazas, on the beaches with often only minimal equipment and formal organization, and still predominantly by male players, the situation in the United States is quite different.

Unlike, say, the continental European countries, in which schools and universities concentrate on academics, the United States schools and colleges have a long tradition of fielding highly competitive athletic teams. These not only usually are major commercial enterprises by themselves, but they also come with a long tradition of athletic scholarships. Given ever more sky-rocketing costs for private schools and colleges, such athletic scholarships, which may be worth thousands, even tens of thousands of dollars, are by many seen as a unique enabler for accessing a postsecondary degree. Historically, the male dominated team-sports with their huge rosters (up to a hundred players) such as American Football have been the biggest providers of such scholarships. However, in 1972, the famous *Title IX* of the Education Amendments of 1972 [2] completely changed the playing field. Among many other changes, it requires that colleges and universities give females equal access to athletic scholarships. This has resulted in the termination of numerous male sports, and the creation of many female teams. The natural counterpart to the male American Football teams are female soccer teams at colleges across the continent.

In view of this background, it may not come as a big surprise that parents are willing to invest large amounts for competitive soccer programs for their children. Typical costs for even twelve to fifteen year olds in competitive teams are anywhere from USD 1500 per year, and up, plus additional costs for interstate tournament travel.

2.2 Coaching education and best practices

Given the ensuing high demand for competitive coaching, it is natural that the professional organizations, foremost the United States Soccer Federation (USSF), have instituted carefully monitored professional training and licensing programs for coaches. The desire to compete and win at the highest levels, together with a large community of researchers in university physical education and related departments, provide ample resources for science based guidelines. A detailed discussion of the literature in this area is beyond the scope of this note. We refer to the *"Player development guidelines"* as in the USSF's "*Best Practices For Coaching Soccer In The United States"* [3], which have been written in consultation with a broad spectrum of academic researchers in kinesiology, psychology physical education, sports sociology etc. Notable primary references are [4,5], which advocate e.g. *"athlete centred coaching"* with the objective of *Developing Decision Makers*. Through the affiliated state organizations, the USSF offers a multi-tiered system of coaching education and certification courses. These start with weekend long seminars, and extend to multi-week, all day courses. They combine both theoretical and practical (on the field) instruction and examinations.

As a candidate in such courses, the author was particularly intrigued by the careful balance between technical content and pedagogy, which reminded him most strongly of the heated controversies about the corresponding proper balance between content knowledge and pedagogy in mathematics teacher education.

The lower level USSF coaching courses very much focus on pedagogical issues, what is age-appropriate, and what characterizes effective practices (a.k.a. lesson plans). The analogue of *content knowledge* plays a much smaller role: Most coaching candidates have substantial technical knowledge from an earlier career as a professional player, and continuing technical education relies strongly on constant collaboration with ones' peers. Possible mathematical analogues would be future teachers have prior work experience applying mathematics in research, industry, business, government jobs, before training to become mathematics teachers, and teachers continually learning from their senior colleagues as e.g. described by Liping Ma [4].

Both as a candidate in coaching courses and as a practicing coach, the author found many analogies with his idealized teaching of university mathematics. Many of these involve rather *common sense* issues about a dignified treatment of the students/players, dealing with physical limitations (available space and time), the importance of a deep understanding of how different topics are interrelated and how this affects the order in which they can be learnt, etc. However, this note shall focus on two specific examples: The primacy of *problem solving activities* and clear *focus* on *one topic at a time* with strictly tailored immediate *corrections*.

2.3 Problem solving

Many outsiders (and unfortunately, some students, coaches and teachers) think of endless repetitive drills as the core of practices in sports and in mathematics classes, alike. While we cannot speak for other team sports (but doubt that it is correct for these). Indeed, a key design principle for soccer practices is to build these around activities that require continuous development of problem solving skills.

The obvious motivation is that there are no two game situations that are exactly alike. Moreover, without timeouts or electronic communication devices to obtain directions from the coaching staff (as prevalent in some other team sports) the game of soccer is distinguished by the requirement for continuous decision making by the eleven individuals on each team.

Due to evolutionary reasons humans may have a natural inclination to categorize and systematize all possible game situations and develop catalogues of automatic responses. However, the beauty of the game and the reason why it continues to attract hordes of spectators may well be attributed to its defiance and resistance to be confined in such ways. (Think ahead: what makes mathematics so beautiful and attractive?) Indeed, up to the very highest levels of international competition, the most common complaint is a widely deplored lack of *creativity* of, in particular, the US men's National team, compare e. g. the USSF guidelines [3], or the widely popular recent article [7]. This stands in stark contrast with the broadly acknowledged technical perfection and amazing athletic capabilities of the players.

Guided by this final objective, the recommendations call for developing creative problem solving skills right from the beginning. For obvious developmental reasons it is clear that at the younger ages (e.g. age eleven and younger) hardly any instruction is about tactics (and none about strategy), instead the primary focus is on developing basic ball skills. But this is to be done in an environment encouraging creativity and problem solving. The word *drill* is an anathema: *drills kill creativity*. Following the same principle for the aspiring coaches as for the players, coaches are not given a manual of sessions. Instead, the focus is on design principles, and coaches are asked to be creative themselves!

At its easiest, we want practices to not repeat activities. Instead, every week we have exercises with different rules. At the younger ages these almost always take the form of some game, with rules rigged in whatever way to make the players learn a new skill or technique. A fundamental design principle (heeding the rule of the *three Ls:" No laps, no lines, no lectures"*) is to start with incomplete instructions. We want the players to start exercising with the ball as quickly as possible, further instructions are added with time. While initially considered frustrating for the players, this simple principle does an amazing job at training players to come up with creative interpretations of the rules, make new rules, and create unscripted solutions. We invite the reader to pause for a second, and reflect whether this applies to mathematics instruction? Can we do it? Should we do it? Do we do it?

A more specific example in the same spirit was recently nicely reiterated by M. Beale who works at the Chelsea FC Academy (Chelsea FC in London is one of the premiere clubs in professional soccer in the world):

A crucial idea in coaching young players is to introduce an element of choice into drills and practices. For example, instead of telling a player simply to dribble up to a cone and shoot, put another player several meters to his right or left and offer the attacking player the choice of shot or lay-off. This approach encourages individuality and self-expression and helps fight against the cookie-cutter mentality. Ultimately, this will help develop a player's flare and confidence.

If we want to foster creativity, make innovative choices, we must accept that many of these choices are not the best ones, many may even quite bad choices. One cannot expect anyone to freely explore new avenues if there is any fear of punishment. On the soccer field, this means constant encouragement for bold choices and questioning about whether the player thinks this was a good choice. During competitive games, this primarily involves discounting numerical losses, making players and parents feel comfortable with loosing a game today, but having learnt a lot by making some bold choices. Especially at the youngest age, there is widespread agreement that one should deemphasize counting goals and wins as much as possible—as a focus on winning all too often only impedes creative player development.

In a nutshell, we never say “*never do this*", we do not prescribe scripted actions, but instead encourage making choices and trying unconventional solutions starting at the earliest stages. This approach is strongly motivated by designing the curriculum from the final objectives backwards.

2.4 Focus and corrections

As a 20 year veteran of teaching mathematics at the university level, one of the hardest items to learn for the author as a soccer coach was not to try to correct every mistake all the time. Indeed, learning from his soccer coaching courses, he has changed his approach to teaching mathematics!

A fundamental design principle of any class/practice is to clearly identify the topic that is to be learnt in any single session. In youth soccer these may be simple items as good balance (with slightly bent knees), *locking the ankle* when striking the ball, alignment of the shoulders when making a pass, protecting the ball from an encroaching opponent, letting the ball *come across the body* when receiving a pass. The typical session starts with some unrestricted activities that explore the concept to be learnt/practiced, then restricts the space and, in stages, adds pressure (opponents), continues with practicing the concept/skill in game like situations, and ends with small-sided games with rules rigged in a way to foster work on the concept.

As explained above, given limited time resources, the activities start as quickly as possible, and usually with incomplete instructions. The experienced coach looks for *coachable moments*, incidents where a player made a questionable choice, and will immediately interrupt play to question the decisions. Most typically the player is aware of a bad choice, and now is asked to come up with better choices. These are explored and reworked until a desirable performance is achieved. What really impressed this author, and what he found so hard to do, is the emphatic guideline to *only correct* missteps that involve this session's topic: If today's topic is *receiving passes*, then the coach is instructed to only correct mistakes involving receiving passes, and to (from the player's side) completely ignore whether e.g. a player strikes the ball inappropriately, say, with the tip of their toes.

Does it work? The guidelines by the professional organization say so. But just like the mathematics teacher who already *knows what works bes*t, many a coaching candidate ignores these guidelines. This author has seen many coaches discount the guidelines, and in their own clubs try to correct everything at the same time. Anecdotal evidence, players developing much better in some environments than in others, has convinced him that it pays to heed the advice from experts in developmental psychology. We will revisit this item from a mathematics perspective below—but the reader is encouraged to reflect on this now.

3. Teaching university mathematics

3.1. Learning on the job

The author has been teaching mathematics at the post-secondary level for over 20 years—yet he never received any formal training on how to teach until long after he started. Even then, it was purely voluntary participation in workshops which almost counted against him as they took time and effort away from the primary research mission of his institution. Basically, he was thrown into the water, to *swim or sink*.

Today's graduate students are usually a little better off as they are typically required to participate in teaching assistant training workshops. Yet the majority of college and university teachers have precious little formal training on pedagogy, and psychology of mathematics education. Moreover, in many countries, heated debates continue about the proper balance of teaching content knowledge and pedagogy to mathematics (and science) teachers at the secondary (and even the elementary) level.

This author acquired his fragmented understanding of how to teach mathematics in a long and painful trial-and-error process, augmented by voluntary participation in workshops, courses, and conferences which are in tight competition with efforts related to his primary research area. Very limited time is available to go beyond this, to e.g. familiarize himself with findings in the mathematics education literature—there are too few executive summaries! Curiously, some of the strongest impacts to consciously redesign the classroom teaching come from outside the discipline, e.g. from encountering *active learning* as in *Workshop Physics*, compare e.g. [8], and *cooperative learning* as e.g. [9].

This experience does not seem to be unusual, and we note that our discipline is lacking systematic mechanisms that ensure that findings from education research are implemented into teaching practice in a timely manner. While at the younger levels, recommendations such as [10] do have measurable effects, at the higher college levels, the time scale seems to be measured only in generations. Let us consider mathematics analogues of the items highlighted in the previous section.

3.2 Problem solving

It is hard to find someone who does not agree that mathematics is about problem solving. However, once we try to more precisely nail down what we mean by *problem solving*, the agreements quickly end. This author shakes his head at the designations given to the last part of each section in typical mathematics textbooks, usually *“Problems"*, and only rarely *“Exercises”*. It takes little reflection to note that the large majority of items in these parts of popular algebra or calculus books do not at all satisfy the following characterization [11]:

A problem is only a problem (as mathematicians use the word) if you don't know how to go about solving it. A problem that has no 'surprises' in store, and can be solved comfortably by routine or familiar procedures (no matter how difficult!) is an exercise.

Let us accept that the starting point for curriculum design should be its end: what we want the successful graduates to be able to do and to know. One may question the importance of problem solving skills in mathematics. This author takes the stance, that, in particular, with the virtually ubiquitous access to networked universal information systems, problem solving skills as in Schoenfeld's characterization above [11] are becoming ever more important in mathematics. On the other hand, drill of manually executing routine algorithms becomes ever less important—as the very straightforward nature of traditionally taught algorithms makes them predestined to be programmed on and executed by machines.

If we accept this view, the question arises how to most effectively design mathematics classes at all levels. There has been much controversy and discussion over the balance of drill of basic *manual manipulations* versus other contents such as conceptual understanding and problem solving skills. One of the most fervent opinions about abolishing traditional items was elaborated in [12], and it appears that this opinion is standing the test of time! Certainly, the large majority of the secondary and college entry-level mathematics courses taught around the world emphasize drill over problem solving, even while there are calls from all sides to devote more attention to problem solving. But how to do this?

This author took lessons learnt while coaching soccer into his classrooms (and into activities with his children when at the primary school level). The first guideline is so simple: start right away, typically with incomplete instructions! Initially the reaction is one of frustration, sometimes even anger—but it does not take long and students at all ages turn out to be a lot more resourceful than many a teacher may believe. No long lectures, long demonstrations, detailed worksheets—instead, start student centred activities with only rudimentary instructions. In the last few years, the author has been mostly teaching courses at the upper undergraduate level such as *Advanced Calculus / Intro to Analysis*, *Abstract Algebra*, *Intro to Topology*. At this level, the key is to reverse the traditional order of axiom - definition - lemma - theorem -proof - example. Instead, we start with a vaguely circumscribed setting, some intriguing observations and invite exploration and conjecture. Theorems are proposed, but they do not have precisely stated hypotheses—instead the hypotheses, and often even good definitions are outcomes of the process of trying to prove a theorem that captures the main idea. At this first sight this approach may appear to be opposite to the *Moore method*[13] but our teaching experiments, even in Moore's *home turf* of point set topology indicate otherwise: The common goal is to foster problem solving skills by providing suitably challenging activities. Over the last years we have experimented with various details of this approach—but the highly successful classes attest to the focus on *problem solving* being the key. A critical ingredient for making these successful is to establish an environment of *no fear*, of mutual respect for even the wildest ideas. In practical terms, this involves the whole class, or small groups engaging in prolonged brain-storming sessions during which no criticism is allowed. These are followed by periods in which all ideas are explored—and quite often we develop ideas and proofs on the board which turn out to be dead-ends. These are not at all futile efforts, in some sense they are so much more important than the polished proofs presented in the textbooks. Credit is always given for the creative ideas!

As a simple, easily accessible example from (advanced) calculus consider the inverse function theorem, which captures the intuitive picture of a function being locally invertible near a point where its graph has a nonzero slope. The mathematics problem (in the advanced calculus class) is to make this picture into a theorem, and prove it. The picture is quick, and provides incomplete information. Indeed, one of the main challenges is to decide what should be part of the hypothesis, what be part of the conclusion—the main issues are regularity assumptions on the function and the existence of the inverse. A sampling of a handful popular textbooks reveals almost any combination of such choices.

Let us end with one practical example from arithmetic: This father all too often was annoyed with the rigidity of his children's math worksheets. One extreme example involved long division. Rather than arguing its intrinsic merits and importance [12], our point here is its similarity to the above described repetitive soccer drills. Just like in a game situation, there should always be choices that have to be made. The easiest, and likely most natural one for any mathematician is to rewrite the division problem as a fraction, simplify it by cancelling common factors, or by multiplying numerator and denominator by powers of two or five, and then work a simpler division problem, if still necessary. Yet, the author's daughter insisted that this was not allowed—she had to exactly follow the prescription, no creative shortcuts were allowed.

In summary, starting from the ultimate objectives for the graduates, the author considers the development of creative problem solving skills one of the most important tasks in mathematics teaching. In order to achieve the goals, he consciously chooses activities that demand creative work, making choices, exploring without fear of punishment, and at the same time absolutely minimizing rote repetitive drill exercises.

3.3. Clear focus: one item at a time

It may sound so simple—focus on one item at a time. After all, don't our textbooks and syllabi typically specify one single topic for each class? This is comparatively easy for lectures. For student centred classes the first major challenge is to break the tasks into bite-size chunks—which can be attacked one at a time. See [14,15] for a masterful implementation in a modified Moore style of such break-up, and a detailed discussion and reflection on these challenges.

Yet, in his experiments with student centred classrooms, this author *did not get the message* until he consciously reflected on his correcting players as a soccer coach: Indeed, he found it exceedingly difficult to only correct mistakes (or rather interrupt for questionable choices) that were directly related to the particular session's topic. It is very hard to quell the urge to admonish any unrelated "*why did you not take the shot?*", "*did you not make that open pass?*", "*do not kick with your toes*", "*use the other foot,*" "*let the ball come across your body?*", ... Indeed, the routine way focuses on one topic only, and uses questioning as opposed to *telling* what to do: "*if you could do it over again, would you make the same choice?" what else could you have done?*"

Yet personal experience convinced this coach that the professional guidelines were right after all, and he eventually learnt to follow them.

The next step: Reflect how this relates to teaching (in this case, university level) mathematics. Clearly we focus on one topic at a time (do we?). In lecture-format classes one is to avoid distracting digressions. But what about teaching in the modern student centred classroom, where students work in teams, present work on the board, routinely interject ideas, some of which are really far off the wall? Once he realized the analogies, this author caught himself looking for all possible kinds of mistakes and less than perfect choices at the same time, wanting to correct all of these all the time. In USSF soccer coaching education, this is an absolute no-no, and a guarantor for failing the examination, not earning a coaching license.

It is a long way from recognizing a likely deficiency (trying to correct everything at all times), to mediating it. The author has consciously tried hard to not only clearly identify the technical mathematics topics that are the subject of each class' meeting, but also the items that shall be subject to discussion and correction upon student discussion and presentation. Typical items, again at the levels of *Advanced Calculus*, *Intro to Topology*, *Abstract Algebra*, and, most recently, a *Second Course in Differential Equations* include writing, arithmetic and basic algebra, logic (implications and their converses, alternating quantifiers), meticulous attention to all hypotheses (especially regularity assumptions), utilizing (building on) previously established results. While purely anecdotal, the author has become convinced that in the student centred mathematics classroom—just like in the youth soccer practice—learning success substantially increases if the instructor does not try to fix all problems at the same time. In his most recent topology class, he informally laid out a parallel time-table for correctible items as above. These include e.g. grammar and punctuation, slang versus formal language, proper use of prepositions for mathematical relationships, not using any symbols that have not been quantified before unless they have been assigned a value). This accompanied the official syllabus which focused on technical topological structures. Rather than being a linearly ordered sequence, it naturally had a semester-long, more circular structure with various items being revisited repeatedly. A typical example is the simple logical structure of most compactness proofs that use the open cover definition: While being addressed relatively late in the semester, this is a typical point where to again focus on the logical structure of the arguments, especially the innocent looking part "*every open cover of ...*" which all too often is incorrectly employed in various proofs. In practical terms, this simply means to develop a set of activities involving items that addresses both related logical issues and some compactness property. In presentations and discussion, we downplay, or even ignore, all sorts of other mistakes, misconceptions, misstatements, and focus on every student getting the key logical issue right 100 percent of the time.

At the author's institution, the second course in Differential Equations (the first course on their qualitative theory) is distinguished by having several different prerequisites: A first (calculation oriented) course in Differential Equations (DE), a first course in Linear Algebra (LA), and Advanced Calculus (AC). The large majority of students in this course have major deficiencies in more than one of these, often due to mismatches to courses taken at the institutions from which they transferred. While barely changing the core syllabus for this class, the author consciously aligned the learning objectives in such a way that students had a chance to make up any gaps in the prerequisites—one issue at a time. While having three such different prerequisites for one course first appeared to cause extra problems, it turned out that this forced the author to consciously reflect on and plan how to bring in each one of these. In daily practice this meant that mistakes in any areas other than the ones focused on were most casually downplayed, or sometimes even ignored. This required choosing the examples addressed in class activities in such a way that *desired* mistakes would likely appear repeatedly, whereas off-topic mistakes be less frequent.

In the end, it remains a major challenge when grading papers (homework, exams, ...) to focus on one designated item to be corrected, and not get side-tracked into marking every mistake at the same time. The ultimate goal is that all students master all topics, satisfy all criteria. It is possible to focus on clearly identified subsets on individual exams. A careful design of problems assigned or test items selected helps a long way, but it will take many rounds of experimentation to perfect this.

In summary, for traditional lecture-style classes it is comparatively easy to focus on one item, and in the wrap-up at the end summarize the one (or three) items to take home. In student centred classes, a critical component is learning from one's mistakes—and it is a real challenge for the teacher (coach) to focus on correcting only one kind of mistake at a time.

4. Summary

This article reflected on similarities between effective strategies for teaching mathematics at the postsecondary level and coaching youth sports. Rather than attempting deep explanations in terms of general learning theories, the focus was on practical, day-to-day activities. We focused on two specific topics: the desired focus on activities that enhance problem solving skills, and on the desirable habit of the teacher/coach restrict and focus her/his feedback on one item at a time.

Whereas neither of these two individual parallels may prove truly important, we hope that this note encourages all teachers to become ever more open-minded, and actively search for insights into what constitute best practices, and for innovative teaching strategies in even the most far-fetched and most remote places. In the end, teaching and learning of no matter which subject all involve the same human organ!

References

[1] King, A. (1993). *From Sage on the Stage to Guide on the Side*. College Teaching , **41**, no. 1, pp. 30–35.

[2] Title IX, Education Amendments of 1972,

http://www.dol.gov/oasam/regs/statutes/titleix.htm

[3] United State Soccer Federation, *Best Practices For Coaching Soccer In The United States: Player development guidelines*.

http://images.ussoccer.com/Documents/cms/ussf/Best_Practices.pdf

[4] Quinn, R. and Carr, D. (2006). *Developmentally Appropriate Soccer Activities for Elementary School Children* J. Physical Education, Recreation & Dance (JOPERD), **77** no. 5, pp. 13 –17.

[5] Kidman, L. (2001). *Developing decision makers. An Empowerment Approach to Coaching.* Univ. of Otago, College of Educ. Innovative Print Communication, pp. 118–130.

[6] Ma, L. (1999), *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the U.S.*, L. Eribaum Assoc., Mahwah, USA.

[7] Woitalla, M. (2006, October), *Do we want Robinhos or Robots?* Soccer America Magazine.

[8] Laws, P. (2006), *The Development of Workshop Physics – A Laboratory Centered Approach to Teaching Introductory Physics*, AAPT Announcer, **33** no. 2, pp. 134–138

[9] Johnson, D.W., Johnson, R.T., and Smith, K.A. (1998), *Cooperative Learning Returns to College: What Evidence Is There That It Works?* Change **30** no. 4, pp. 26–35.

[10] National Council of Teachers of Mathematics (1989), *Curriculum and Evaluation Standards for School Mathematics*, Reston, USA.

[11] Schoenfeld, A.H. (1983), *The wild, wild, wild, wild, wild world of problem solving:*

A review of sorts, For the learning of mathematics **3,**, pp. 40–47.

[12] Ralston, A. (1999), *Let's Abolish Pencil-and-Paper Arithmetic*, Journal of Computers in Mathematics and Science Teaching, **18** no. 2, pp. 173–194.

[13] *The Moore method*, references: http://www.discovery.utexas.edu/rlm/reference.html

[14] Schumacher, C. (2001), *Chapter Zero*, Addison Wesley.

[15] Schumacher, C. (2005), *Pointing the way to proof*, Proc. delta 05, 5th Southern Hemisphere Symp. Undergrad. Mathematics Teaching, pp. 265–270, Brisbane, Australia.