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Viewpoint: Education and Football: a Multiphase Flow Approach*

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The influence of sports on the US academic environment is causing athletic achievement to distract from the need for educational excellence. This situation is exacerbated by university administrators who devote considerable energy to revenue generation through sports programs at the expense of the quality of academic programs. To overcome this problem and facilitate better integration of athletics with the educational mission of a university, faculty must move beyond membership on boards nominally in control of athletics and become the coaches of the athletic teams. Such a bold shift will ensure that athletic teams are representative of their schools and not units that function as mercenary revenue sources. A movement of faculty into coaching would be consistent with the shift of the educational paradigm to co-operative learning and peer instruction. In fact, academic disciplines actually have many facets in common with various athletic endeavors. As an example of this, the striking similarities between multiphase fluid flow in the subsurface and American football are demonstrated. Exploitation of these similarities can be a valuable tool in educating both those primarily interested in football and those primarily interested in subjects such as multiphase flow physics.

INTRODUCTION

FOR MANY years, teen-age students have encountered high school employees who take on the dual roles of athletic coach and classroom teacher. This tradition likely had its origin in the idea that the participants in extra-curricular athletics should be representative of their schools with teachers serving as coaches and students taking part as team members. Unfortunately, this concept has been distorted such that now extra-athletic curricula often seem to take a support role to athletics at many schools; and individuals who are primarily coaches are only rarely assigned classroom responsibilities. Young people who enroll in high school only to participate in sports are still designated as 'students', yet they are awarded scholarships to continue their 'education' at the college level because of their ability to run fast, jump high, or throw a ball accurately. Reading ability, mathematics skills, and appreciation of the arts can be of decidedly limited importance in such decisions.

I can recall that in my own high school days the football coach was our English teacher. He was under the impression that every noun that ends in 'ing' is a gerund and thus proclaimed that a wedding 'ring' is a gerund. He would not be dissuaded from his understanding; and because he was in charge, bigger than we were, and the football coach, his opinion was the law. Our chemistry instructor was a talented and dedicated teacher who performed numerous experiments designed to catch students' attention, such as igniting large balloons filled with hydrogen. Great explosions would reverberate through the hallways every hour about 40 minutes into each class period on the day the composition of water was being studied. However, those explosions were mute in comparison to the expressions of awe the day the football coach became so enraged over some student's mis-identification of a part of speech that he kicked a hole in the wall of the classroom. All day long students detoured on the way to their classes to take a reverential peek at the mammoth hole the coach had created. What a powerful teacher he was! Certainly someone who could destroy a thick plaster wall with one swipe of his leg while enforcing his proper rules of grammar was a memorable, if ineffectual, presence in the classroom.

In days gone by, colleges and universities have had athletic coaches who were assigned classroom duties, some who performed them with distinction. At the University of Notre Dame, Knute Rockne is well-remembered as having been a chemistry instructor before rising to national, and even international, prominence for his exploits as a football coach. However, as athletics have developed from sport to big business, it has become increasingly rare for a coach also to be involved in academic life, other than to ensure that his or her players have grade point averages that allow them to compete in sports. In fact, athletic and academic pursuits of this country's NCAA Division I institutions of

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higher learning that support high profile athletic programs have become sundered activities.

Today, college coaches with any classroom duties are nearing extinction. They are promoters, recruiters, motivational speakers, organizers, ring masters, and symbols of their universities. Scholarship players are, to a large degree, mercenaries hired to overcome the distractions of the classroom while succumbing to the demands of a rigorous and exhausting physical training regimen. The financial aid they receive is referred to as 'scholarship' but truth in advertising would demand that it be renamed an 'athleteship'. The young athletes tend to obtain their classroom experience in areas of study such as business, physical education, or criminal justice, where academic survival is more probable. Special sections of courses exist that are populated primarily by athletes who receive priority in scheduling, priority access to classes with less rigorous grading standards. The sciences and engineering have been virtually abandoned by scholarship athletes. These majors have been left to their shorter and weaker classmates who can only sit in the stands and imagine the days when teams were populated by athletic students who came to a particular school primarily to learn but also to participate in extra-curricular activities as time allowed. These trends cause one to wonder if the day is approaching when athletes, like their coaches, will have no academic responsibilities. Such 'students' would hone their abilities to shoot a ball through a hoop full time; or they would tackle inanimate dummies during a week of practice in anticipation of taking on what would be animate ones on Saturdays.

The evolution of many US institutions of higher education into pseudo-health clubs where athletics control the rhythms of the school year is being hastened by top-level administrators lacking in courage, character, and leadership skills who value accounting far more than accountability. Those administrators measure success primarily in terms of the blackness of the bottom line. Some who can't lead but would rather set up barriers to academic progress are continued in their positions by self-serving superiors who seek primarily to bask in the halcyon prestige of their own jobs until retirement time, too busy collecting accolades to perform their duties. If athletic teams can be marshalled that are able to vanquish the opposition, inept administration and weak academic programs can be overlooked. It is a similar mentality to that of despotic world leaders who, when faced with internal challenges, send their armies out against their neighbors to distract from fundamental failures. As long as mercenary athletes armed with the most fashionable shoes and a logo on their jerseys are able to battle competitively and profitably the mercenaries from other colleges and universities, just how important can the failures to educate and to build quality academic programs be? If the alumni remain willing to contribute, no NCAA sanctions are looming, and the team is regularly on national television, what else is necessary? Bowl games and basketball tournaments have become the substance and measure of excellence. One engineering dean has stated his position clearly in declaring unashamedly that educational programs don't matter to him, as long as he gets resources.

A PROPOSAL TO INTEGRATE ACADEMICS AND ATHLETICS

What can be done to reverse this trend, to restore the primary role of universities and colleges as educational institutions rather than establishments organized to promote team sports? The administrators seem disinclined to do what is needed. Conceivably, the original model of athletics at educational institutions was right and provides the route back to academic achievement being the measure of a university. The cornerstone of any plan to restore integrity to the relationship between academics and athletics should be that faculty must coach. If the leaders in the locker rooms were those same people who taught about physics, anthropology, psychology, art, and engineering, the situation at colleges would be different. Of course, if faculty were involved in such activities, they would be unable to fill positions on the make-work committees that provide the administrators a claim that they seek faculty input for their decisions. Someone else would have to serve in their stead. Perhaps such committees could be composed of displaced ex-coaches who, with their motivational skills and single-mindedness, could work together to occupy the administrators with inconsequential but seemingly importunate activities while assisting the development office in obtaining corporate sponsorship for campus educational programs and facilities.

Most faculty are not qualified to coach athletics in the manner employed today. They would have to serve as facilitators and moderators. However, rather than being a problem, this can be considered an asset totally consistent with today's classroom approaches of team and co-operative learning [1, 2] where the students accept responsibility for accomplishing course goals while the faculty teacher serves as a resource or facilitator. Furthermore, faculty in the locker rooms would be able to facilitate within the context of their academic disciplines. This would bring a cerebral aspect to sports and ensure that athletics were complementary to the classroom experiences. For example, studies of the game of baseball have already appeared in scientific journals dealing with such topics as the physics of the path taken by a thrown curve ball and the mechanics of hitting such a pitch. Among recent articles that make use of science and sports are those involving the mathematics of golf [3], probability theory and the professional basketball draft [4], paired-comparison rankings of football teams

[5], optimal race strategies [6] and mathematical models of running [7]. Why not integrate ballet and basketball, psychology and soccer, physics and fencing, history and hockey, engineering and everything?

A school's baseball or softball team could thus become part of a laboratory demonstration in Physics 1. Disciplines as diverse as sociology, philosophy, thermodynamics, and political science could develop their perspectives to form a truly culturally-diverse coaching staff capable of encouraging their athletic students to work together effectively, think through meaningful options, use their energy optimally, and become skillful leaders. Furthermore, since the athletic exploits of the students would build on, and not be separated from, their academic endeavors, the full educational experience at a university would be more effectively integrated. Athletic students would become seamlessly knowledgeable in both their academic disciplines and their sports.

If universities were to adopt this proposal, some faculty might be concerned that their disciplines would not be able to participate in such a renewal. It would be important for humanists, scientists, engineers, architects, and those in business to review their areas of expertise and discern where they might be able to make contributions in each sport. This may seem far-fetched with athletics really being quite different from academics. However, in the pursuit of academic excellence, athletics must be viewed once again as an extracurricular activity or additional complementary interest of those who have come to a university to form a community of learners and scholars. In fact, athletics that cannot be viewed in this light should be downplayed on the campuses. The key is to ensure an educationally sound balanced perspective.

As an example of the natural links that exist between academics and sports, a demonstration that American football may be viewed as a branch of the mechanics of subsurface, multiphase flow is presented here. The point of this discussion is not to capture football as the sport of groundwater hydrologists or petroleum engineers but to demonstrate the synergy between academic and athletic pursuits that could be exploited to enhance the college educational experience.

MULTIPHASE FOOTBALL: THE GAME

A football game begins when the ball is placed on the tee, and one team kicks the ball to the other. From this point on, the primary activity takes place on the field as the teams run back and forth with each team trying to break through the other team's defense for a score. The primary location for multiphase, subsurface flow is in a solid, porous matrix. In some instances, the flow occurs in a natural field environment where inhomogeneities in the matrix must be accounted for. At other times, ideal media developed in a laboratory to minimize uncertainty and provide well-defined conditions are used. These are the astroturfed and domed stadiums of multiphase flow. The porous flow matrix is essentially fixed in place and provides boundaries for the flow that develops. Typically, the football field matrix is anisotropic with teams finding it easier to move the ball from sideline to sideline than up and down field. On this matrix, out-of-bounds and yardage markers are aligned with the principal directions of the anisotropy.

Following a flow initiation event (i.e. a 'kickoff' of the multiphase flow event), such as an oil spill incident or the onset of organic leakage from a landfill into the underlying water, the two-phase flow of a water-based and an organic-based fluid in the medium begins. Let the phases be immiscible so that parts of one phase do not cross over and become a part of the other phase, much the same as the segregation between offensive and defensive teams on the football gridiron at the same time. The water, or wetting phase w, tends to attach itself to the solid grains and not be dislodged by the organic, or non-wetting phase o, from its location in the medium. Thus the w phase acts similarly to a football defense trying to prevent invasion into its territory by the offense, while the o phase is offensive from both water quality and football perspectives.

When contamination events occur, the organic is spilled into a system where the water phase occupies the void space. If, instead, the medium were already filled with organic, the additional o phase spilled would meet less resistance in moving through the matrix than when a wetting phase is present which serves to impede the flow. This is similar to the situation where a football offense would have little difficulty moving down the field in the absence of a defense. However, the presence of the defense reduces the permeability of the field to the advance. For the flow case, the reduction factor for the organic movement is called the relative permeability and takes on values between zero and one. A spilled o phase advances into the medium, as long as the relative permeability is greater than zero, such that a sharp front can be identified that locates the degree of success in invading the occupied territory. Because of the affinity of the w phase for the medium, the o phase must have an excess potential in order to advance. If insufficient potential is applied, the wetting phase will be dominant and not be displaced.

In football, a strong defense can also seriously impede the effectiveness of the offense in moving the ball upfield. The location of the ball at the beginning of play is called the line of scrimmage. As the offense moves the ball along the field (i.e. in the direction of greatest resistance) and into the territory being defended, the line of scrimmage also is advanced and serves as a sharp line of demarcation between the phases as well as a

measure of the success of the offensive assault. Because of the desire of the defense to defend its territory, the offense must exert a force on the defense that has the potential of allowing for a successful invasion. If the offense is inept or does not apply its potential effectively, the defense will be dominant and will be able to resist displacement and forward movement of the line of scrimmage.

In football, as in multiphase flow, having the most potential does not guarantee successful progress. For victory to be achieved, the offense must have good flow, must live up to its potential. Great insight to hydraulic potential can be gleaned from eighteenth century contributions [8] in fluid mechanics and from more recent work [9] for subsurface flow. Football potential, like hydraulic potential, has three main constituents: elevation above a datum, pressure, and kinetic energy. If an offense is to reach its potential it must elevate its play well above that of the reference level of the opposition. It must constantly apply as much pressure as possible. Finally, it must take advantage of superior size and speed as backs run through or around the defense in attempting to move the ball forward. If the saturation of the defensive players is low on one part of the field, the opportunity for the offense to run swiftly in that area will be high. If a ball carrier is driven to the turf by the defense, progress of his team down field will be retarded. Forward movement of a football offense occurs most effectively when the regions of greatest permeability are attacked so that an offense does not become tired and lose its potential to perform. If enough consistent pressure is applied by the offense, a defense will become unstable or even crack. Under these circumstances, the defense is vulnerable to a long pass, whereby the offense essentially short-circuits the defense massed at the line of scrimmage. This kind of pass reduces the residence time of the offense on the field and allows for faster breakthrough into the end zone such that the team scores.

Several mechanisms of movement, comparable to those in football, are operative in multiphase flow that allow an organic front to advance. The first is simple uniform movement of the *o* phase as it pushes against the *w* phase. This is similar to repeated plunges by a large fullback carrying the ball into the defense massed at the line of scrimmage. The organic phase has its greatest success in advancing if it can invade relatively permeable large pores or fractures where the water phase can be more easily displaced. Clearly, attempted movement into dead-end pores will be fruitless. The fullback is most effective in his efforts to advance the ball if he can find relatively permeable large holes between defensive players. If, instead, he insists on trying to run over or through large defensive linemen, he will find his efforts are fruitless.

Movement of an organic phase also will be influenced by heterogeneities in the medium and in the distribution of the resisting wetting phase. As in football, the offensive *o* phase will infiltrate most effectively if it exploits the weaknesses in the resistance. When heterogeneities exist, in addition to the uniform organic front movement, at times fingers of *o* fluid will streak into the *w* fluid causing the wetting fluid to be displaced at a non-uniform rate. This is analogous to the long pass in football that by-passes the defense. Although a defense may seal off most opportunities for an offense to advance the ball, if a seam in the defense can be found, it can be exploited to frustrate the defense and rapidly advance the offense. Similarly to the consequences of having a ball carrier tackled and driven into the turf, the movement of an organic phase will be retarded if it is adsorbed onto the solid matrix rather than moving swiftly through pores or fractures.

Surfactant enhanced transport of organics is a mechanism of front advancement that possesses qualities combining features of both the staid plunge and the exciting streak of a finger through a fracture. In this method, large surfactant molecules locate themselves at the interface between the *o* and *w* phases and break down the resistance of the wetting phase to the flow. This is similar to a football screen pass which gains its success from the ability of enormous lineman to insert themselves between the individual with the ball and the defensive team destroying their ability to stop the advancement. With both the screen pass and surfactant enhanced transport, the effectiveness of the mechanism is realized by overwhelming a defense with intermediaries rather than by simply having the ball carrier or organic take on the defense directly.

One final method of *o* fluid advancement is much like a football option play. In this play, fakes are used such that several different offensive players appear to have the primary potential to move with the ball. Thus, rather than concentrating its energies on one player, the defense must work to retard the advance of all the players who may be carrying the ball. This strains the defense in that offensive decoy ball carriers will try to attract tacklers in order to ease the way for their teammate who actually has the ball. Thus, although the defense may stop all the players with a small average gain such that superficial assessment of the situation would indicate success of the defense, the offense tries to ensure that the player who actually carries the ball will get the furthest advance. Indeed, when this happens, the dispersion of the offense is important to movement of the ball as the objective is to have the ball, rather than the center of mass of the team, cross the line of scrimmage and, eventually, the plane of the goal line. Similarly, movement of the leading edge of a contamination front can be more important in the monitoring of a two-phase flow problem than movement of the center of mass of the contaminant. Time of first arrival of the organic phase at a breakthrough point can be an important issue for assessment of contamination.

These simple parallels between two-phase flow and football can be extended easily to include some of the subtler aspects of each. For example, when a football offense moves the ball to the vicinity of the goal line such that a score seems imminent, the defense will attempt to increase its resistance. From the perspective of flow of a non-wetting phase, the goal line would be seen as a region of particularly high entrance pressure. Fumbles, interceptions, and punts—when the ball changes possession from one team to another—can be considered to be instances of variable, rather than preferential, wettability. Field goals, wherein the offensive team does not possess the ball as it crosses the goal line but rather kicks it through the uprights of the goal post, are particular analogues of fracture flow or short-circuiting the defense. Penalties, important parts of a football game, are instances of deviation from ideality. Besides being analogous to viscous fingering, long passes floating through the air also can be considered as surrogates for volatilization of an organic into a vapor phase. A prevent defense, often employed near the end of a game by a team that believes its lead is insurmountable, is designed to prevent a score while forcing the opposition to utilize much of the remaining game time. Some strategies for restricting the flow of an organic are similar in that the offensive contaminant is allowed to move but is contained such that it does not cause significant damage. Indeed. the best solution to pollution may not be dilution but rather a good prevent defense.

In hydrology and athletics the flow and the game are the respective focal points. However, much of the excitement of a game comes from its being a spectacle, from its ability to involve more than just the players in the spirit of the event. So too multiphase flow problems, particularly contamination events, are catalysts for strong emotions among many observers. Thus, football described from the vantage point of multiphase flow, must also take into consideration the importance of those who surround the sport.

MULTIPHASE FOOTBALL: THE FANS AND PROMOTERS

Football games inspire passion. Fans root for one team or the other. They do not just seek victory, they hope for the largest of margins in vanquishing the opposition. The general public is similarly passionate about a pollution event, or about allowable levels of contamination in their water supplies. Although a particular concentration limit may be designated to ensure that a toxic chemical does not create a threat to water supplies, arguments are raised, on one hand, for cutting costs by softening the standard or, on the other hand, for absolutely vanquishing the chemical from the water supply system. In the best of worlds, the scientist or engineer does not consider the emotion of the argument but studies multiphase flow for the purpose of understanding its behavior, not for the purpose of finding ways to circumvent scientific principles. Perhaps engineers and scientists should wear black and white striped shirts as they are the referees of contamination problems, not making either the physical laws or the administrative rules that govern the flow and distribution of organics but merely enforcing them.

Important contributors to the success of any college football team are the recruiters, the persons who scour the athletic talent available in the high schools and convince the biggest and speediest to attend their school. They are the analogues of the producers of organic chemicals, chemicals that can be a boon to society if managed properly. Unfortunately, some of these organics reach the hands of illegal dumpers who not only misuse them, but for financial gain release them untreated into the environment where they can do nothing but harm. Colleges that talk about educating young athletes but instead treat them badly—exploiting them for lucrative television sports contracts while failing to educate them—before releasing them unprepared for making positive contributions in a complex society are a far worse kind of illegal dumper. Indeed both defensive and offensive players are abused in this system, just as illegal dumping of chemicals is detrimental to both the *w* and *o* phases.

Sharing in the responsibility for fostering the atmosphere in which athletics are the reason for existence of a university are the sports journalists who speculate about whether players should stay in school or if they are sufficiently prepared to find fame and fortune as professional athletes [10]. Their discussions do not consider issues such as maturity, preparation for adult life, or even minimal mastery of an academic discipline. These journalists are like an environmental regulator who monitors an industrial site and allows a discharge of chemicals to take place before complete and proper treatment has been implemented that prepares it for the natural environment. Of course, one problem with proper regulation of chemical pollution is that government shutdowns can cause disruption of the monitoring process while the industrial process proceeds. Football games also are plagued by lengthy disruptive interludes. However, during these television timeouts, the action and the monitoring of the action, are both halted.

MULTIPHASE FOOTBALL: THE POST-SEASON

Post-regular-season college football games involving the most successful teams from the scheduled season are huge events. At the time they were instituted, these games were designated as 'bowls' after the shapes of the stadiums in which they were played. Now these games have grown so that they are spectacles extending far beyond the

slanting sides of the bowl to televisions around the world. Designating the games as 'bowls' in this era is not grandiose enough. The games are bigger than bowls and contain much more than can be contained in a mere bowl. A receptacle of similar shape that expresses both the enormity of the event and the ties between multiphase flow and football is the landfill. An excavated landfill is a large bowl. When it becomes filled, the action taking place seeps far beyond the boundaries of the landfill and draws, in some instances, worldwide attention. So post-season games could be symbolically designated as 'landfills', or simply 'fills', rather than 'bowls'. Games played in domed stadiums could be 'capped fills'. Then instead of naming the games after flowers, plants, and fruit, they could be named after a variety of pollutants. For example, a national championship game, the hottest game of the post-season, could be the High Level Nuclear Waste Fill.

The most prestigious all-star game at the end of the season would be the Priority Pollutant Fill where all the players who had the greatest impact on the football environment during the preceding year would appear. At this game, the players would certainly be pumped up in anticipation of being well-tested for their suitability to participate in theme sports at a professional level. Aspects of their game could be assessed and remediation approaches to overcome weaknesses would be proposed. Those with nagging injuries would be subjected to the latest bio-remediation technologies. Of course, some of the less-talented aspiring professionals would find this event degrading as they would be converted into spectators by their poor performances. Even in those cases, however, no footballers would run the risk of becoming mere waste because they would have become educated individuals while enjoying the opportunity of participating in college sports as an extra-curricular activity. They could be recycled into productive careers.

CONCLUSION

One of the greatest challenges facing higher education in the United States is the corruption of the mission of the colleges and universities to educate their students in favor of a strong athletic program. University administrators seem unable to deal effectively with this problem because financial considerations, rather than educational excellence, excessively influence their decision-making processes. Here a proposal has been made to steer affected universities back to their primary mission by ensuring that athletics are truly extra-curricular, rather than curricular, activities. This can only be accomplished if faculty are willing to demand that their schools do not succumb to the glamour of a successful sports program at the expense of the students who participate in them. Students who participate in athletics should be representative of their schools in terms of academic credentials, majors, and progress toward a degree. Special curricula and policies of providing athletes with priority enrollment in easy classes cannot be tolerated when they are simply accommodations for those most resistant to learning. Although such curricula ensure academic eligibility for participation in athletics, and often a diploma, they do not provide academic eligibility for functioning in society as an educated individual.

Athletics must not be separated from the academic pursuits of a university. The analogy between multiphase flow and football presented here is not frivolous if one views the college experience as learning to think, learning to relate all that one encounters to new challenges and circumstances that must be faced. Why shouldn't the lessons of the gridiron be applied to scientific and engineering studies? Why shouldn't the fundamental principles of multiphase flow, open channel hydraulics, history, or economics apply to athletic events? By teaching students to integrate all their experiences, to think about how the various aspects of their lives inter-relate, colleges and universities will provide a truly valuable educational experience.

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