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THE PROSPECT OF PERSONALIZED EDUCATION GUIDED BY STUDENT GENETIC INFORMATION

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Genetics-related research is rapidly developing increased understanding of the genes that underlie most human traits as well as the molecular processes in which these genes take part. It is reasonable for educators to assume that many learning-related traits will be found to have a genetic basis and that genetic testing will someday allow educators to access this learning-related information for each student. Knowledge of learning preferences would enable advisors, instructors and the students themselves to more closely match student needs with the appropriate educational environments and teaching methods. At the extreme, this information could make possible truly personalized education.

Introduction

Scientists and physicians have made great strides in the last decade in their efforts to understand the various gene-driven molecular processes that occur within the human body. While most genes are similar from person to person, it is the genes that are different that go a long way toward making each person unique, and researchers are rapidly gaining knowledge about how each of these genetic differences can alter the molecular processes that impact a person's health, behaviors and thought processes. As this knowledge accrues, the use of genetic information to develop truly personalized services will become more and more common. For example, personalized medicine will use a patient's genetic information to develop customized medical treatments for a particular malady rather than applying the standard treatment for that malady to virtually every patient afflicted with it.

Nobel Prize winner James Watson, co-discoverer with Francis Crick of the structure of DNA, suggests that personalized education should also prove to be a fruitful use of genetic information (2003, pp. 398-399). While noting that not enough is yet known about the specific ways in which genetics impacts learning, he suggests that the necessary knowledge will become available and proposes that educators will be able to use student genetic information to develop customized educational programs designed around the learning-related characteristics of each individual student. It may even become possible to treat various learning-related genetic defects, allowing a student to overcome a mental disability or enabling a slower learner to keep up with a rapidly moving class.

This paper expands on Watson's idea. It provides the necessary background information on both genes and learning styles to allow business faculty to develop a greater appreciation for the potential impact of genes on student learning preferences. It also provides some examples from recent biological research into the molecular processes behind learning and memory formation, demonstrating the kind of work being done and the rapid progress being made, with the goal of convincing business faculty that personalized education may become feasible within a relatively short time period. The paper concludes with some recommendations on how to implement personalized education when the necessary information becomes available, including a brief discussion of the resistance that has been shown to various uses of genetic information in the past. Spurred on by the sequencing of the human genome, researchers are progressing at a phenomenal pace, suggesting that the knowledge required to allow personalized education may not take that much longer to achieve. Thus the time is now for educators to begin considering these possibilities and to begin discussing some of the issues that might arise. It would be irresponsible of us to not utilize this information about individual learning preferences to improve our educational delivery processes and our students' achievement and satisfaction.

Although this paper's focus is on personalized education, it makes sense to begin with a discussion of personalized medicine, a gene-driven paradigm shift that is already underway (Neilson, 2005).

Personalized Medicine

Quite understandably, much of the genetics-related research done so far has focused on developing a better understanding of the underlying molecular causes of disease. The overriding long-term objective of this body of work is to develop the ability to provide personalized medicine - medical care in which a patient's genetic makeup would be used not only to diagnose the presence of disease but also to develop a customized treatment regimen. Ridley (1999, pg. 258-270) provides an

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example of the need for personalized medicine using the apolipoprotein gene APOE, a gene that is commonly found in three versions. Although the underlying molecular causes are not yet fully understood, the likelihood of contracting both heart disease and Alzheimer's disease are known to be significantly impacted by which version(s) of APOE a patient possesses (note that inheriting one gene from each parent results in a patient possessing either two copies of one particular version of APOE or one copy each of two different versions). Furthermore, and more importantly when considering personalized medicine, the potential success of at least one Alzheimer's drug is impacted by the patient's version(s) of APOE. The key idea here is that a person's genetic makeup can impact not only the likelihood of contracting certain diseases but also the appropriate choice of treatment. Ridley goes on to suggest that "the day will come when a doctor will not prescribe you many kinds of medicine until he has checked which version of a gene or genes you have" (p. 267). This emerging capability to evaluate the differing ways in which various treatments will affect different patients with different genetic makeups has led to the development of a new medical specialty called pharmacogenetics.

Although a tremendous amount of work remains to be done, personalized medicine's day is coming closer, as evidenced by the recently announced pilot study to be conducted by the National Human Genome Research Institute (Pennisi, 2005). This study will involve 400 apparently healthy volunteers and will not only sequence a portion of each participant's DNA looking for genetic hints of disease, but will also carefully observe participant reaction to the disease-related genetic information that they might receive. Although critics suggest that the study will result in little biomedical knowledge because there is simply too little known at this point about the functions of most genes and the parts that those genes might play in various diseases, supporters point out that the true benefit of the study will be the knowledge gained about patient reaction. The medical community simply doesn't know whether or not symptom-free people will truly want to have disease-related genetic information and, if so, how they might react to and utilize that information when they get it.

Human Traits as a Function of Both Heredity and Environment

Genetics has caught the public's attention, with reports of genetic discoveries appearing on almost a daily basis in the popular press. Unfortunately, these reports have contributed to a common misconception by using headlines taking the generic form "Gene that causes trait X discovered." This is misleading in two ways. The first error is the implication that the trait in question is caused entirely by one gene acting alone. The second error is the implication that the trait in question is caused entirely by the person's genetic makeup and hence not at all by the person's environment and experiences.

Concerning the first error, it is rarely the case that one gene alone would cause a particular trait. Although some traits, such as the traditional high school biology class example concerning blue eyes versus brown eyes, are indeed determined by differences in only one gene, most traits are the result of a multitude of genes acting in concert.

Concerning the second error, there has been an ongoing debate for literally centuries between those who argue that a person's characteristics and behaviors are determined almost entirely at birth (or, more accurately, at conception) and those who argue that characteristics and behaviors are determined almost entirely by environment and experience. This argument, termed *nature versus nurture*, is not a productive one because it turns out that both sides are wrong. Although some traits are indeed entirely genetically based and some are entirely the result of environment and experience, the vast majority of traits are due to a mixture of nature and nurture. Marcus provides an example (Marcus, 2004, pg. 8) using fingerprints, calluses and bicep size. Fingerprints are almost entirely due to DNA. Calluses, in contrast, are generally the result of life experiences. Bicep size is a result of both, determined partially by the innate genetic propensity to build large muscles and partially by the person's lifestyle - diet, exercise, occupation, and so forth. Marcus also points out that most mental traits - the main concern here in an article focusing on learning - are similar to biceps in that they are influenced by both nature and nurture.

Note that it can be dangerous to make intuitive assumptions concerning the relative impact of nature and nurture on a particular trait. For example, DNA has been shown to significantly impact such things as degree of religious fervor and certain aspects of personality (Ridley, 2003, pp. 79-83), traits that would intuitively seem to be almost entirely a function of upbringing and experience.

This ability of nature and nurture to both have an impact on most human traits is made possible by the fact that genes serve two primary roles - protein template and genetic switch. Genes act as protein templates, with the DNA in each gene providing the code that specifies the

sequence of amino acids that must be constructed to produce a particular protein. Most of what happens in the human body, including the development and growth of the body itself, is controlled by proteins and is thus impacted by genes. The protein insulin, for example, helps to control blood sugar and the protein hemoglobin carries oxygen through the bloodstream. Note that most body processes involve the participation of many proteins and also that many proteins take part in more than one process. Production of a particular gene's protein, which is referred to as gene *expression*, is generally controlled by a molecular signal, often a signal sent via a protein produced by another gene. In essence, the task of many genes is to turn other genes on and off. Because these controlling or *regulatory* genes send most of their signals in response to environmental stimuli, the body's processes are able to react to their environment. Note that the term "environment" here would in many cases be more correctly interpreted as the environment within which a particular cell resides rather the environment within which the body as a whole resides.

A simple example of this ability to react to the environment can be seen in the work of Monod and Jacob in the 1960's that first demonstrated the existence of genetic switches (Watson, 2003, pp. 80-82). These studies showed that the bacterium E. coli wouldn't produce the protein beta-galactosidase, an enzyme involved in digesting the sugar lactose, unless lactose was present. When no lactose was present a particular molecule, termed a *repressor*, would bond to a portion of the gene that provided the template for beta-galactosidase, preventing the beta-galactosidase from being produced. When lactose was present, however, the repressor molecule would bond with a portion of the lactose, freeing up the gene's information to be used in production of the beta-galactosidase needed to help digest the lactose. Hence, the bacterium has a gene that is literally able to react to its environment.

Similarly, gene-guided reactive protein production plays a role in virtually every process in the human body, including the changes to the brain that occur with learning and memory. A person's collection of traits, therefore, is influenced not only by genetics - which versions of various genes he inherited from his parents - but also by experience and environment - which of those genes were switched on and when and for how long. The importance of the genetic switches should not be underestimated, either in terms of their impact on an individual life or their impact on an entire species. Scientists have discovered that species that would seem to be drastically different, such as humans and mice, actually share many of the same protein templates. It is suspected, therefore, that it is the switches that cause much of difference between species. We are so different from mice not because our genes are all that different, but rather because we have different sets of genes switched on, at different times during development, and for different amounts of time (Ridley, 1999, p. 32).

Heredity's Role in Memory and Learning

Gene-related knowledge can be somewhat arbitrarily broken down into four levels of understanding, listed below starting with the lowest level:

- knowing that a trait is at least partially determined by a person's genetic makeup (but not knowing the particular gene or genes involved)
- knowing that a particular gene is correlated with a particular trait (but not necessarily a cause of the trait)
- knowing that a particular gene is a cause of the trait (but not knowing the precise role played by the gene's protein and the other genes and proteins with which it interacts)
- knowing the underlying molecular process or processes behind the trait in question

Research to develop the first level of understanding has been going on for decades - even before scientists were able to identify individual genes. Such research generally involves studying whether closely related people are more similar in terms of the trait of interest than less closely related people. Research to develop the second level of understanding is more recent and generally involves studying whether or not people with the same version of the gene of interest are more similar than people with different versions. Research to develop the third level of understanding is even more recent as it generally requires the manipulation of the subjects' DNA and thus requires the use of advanced skills and technology. This type of research generally disables the gene of interest or adds the gene of interest (possibly even a gene from another species) to see if those changes impact the trait being considered. The genetic manipulation utilized in this type of research generally mandates the use of nonhuman subjects. The final level, the development of a detailed understanding of the various molecular processes underlying human characteristics and behavior, is the ultimate goal that has so far been only minimally realized. However, the completion of the Human Genome Project has enabled the discovery of many previously unknown genes, spurring a concerted search to discover not only

additional genes but also the functions of the proteins connected with those genes. The body is astonishingly complex, with thousands and thousands of different proteins performing an unimaginable number of molecular tasks, but the scientists who study such things are making remarkable progress and are expected to continue to do so.

While a large portion of the genetic research done so far has been focused on disease, many studies have also been done on brain development and functioning. Pang and Lu (2004), for example, included fully 174 references in their survey of a body of research focusing on the impact of only two proteins, tPA and BDNF, which have been shown to have an impact on long-term memory. Lichtneckert and Reichert (2005) included 107 references in their survey of research on brain development similarities between the mouse and the fruit fly Drosophila melanogaster. A sampling of the research being done on memory, brain function and brain illness will help to demonstrate the general nature of the work and some of the progress being made.

Demonstrating the intense effort currently occurring to discover candidate genes - genes that are likely involved in some way in the processes of interest and that therefore deserve further study - Igaz, Bekinschtein, Izquierdo and Medina (2004) tested 1176 genes in rats, looking for altered protein levels following a training exercise. They found that 33 proteins showed an increase and six showed a decrease, suggesting that those genes are potentially involved in the formation of memory.

Koponen, Lakso and Castren (2004) studied the role played by the protein BDNF, a protein already known to play an important role in memory formation but for which the precise molecular processes aren't yet clear. This study manipulated the DNA of mice to intentionally overexpress the protein trkB that is believed to play a role in converting the BDNF signal into memory-related changes seen in the synapses of the brain. The overproduction of trkB led to altered expressions for various other genes in various portions of the brain, giving the researchers a better understanding of the role of BDNF.

Reynolds, Jansson, Gatz and Pedersen (2005) expanded on previous work done on gene 5-HT2A by testing for a correlation between a particular version of the gene and memory performance, finding that long-term memory is less effective for persons carrying that version of the gene, but only for one of the three memory tasks used. Jang et al (2003) disabled the mouse gene that expresses a protein called μ-opioid receptor and found that the lack of this receptor led to diminished spatial memory (in particular, a reduced ability find a submerged platform in a water maze). In another mouse study, Gass et al (2004) disabled the memory-related gene c-fos and replaced it with another gene from the same family. They found that performance on certain memory tasks was unaffected but that spatial memory (again involving a water maze) was hindered, suggesting that different versions of the c-fos family are involved in different learning and memory tasks.

As mentioned earlier, much genetic work has focused on disease. Raber, Huang and Ashford (2004) demonstrated the major impact of the apolipoprotein apoE on Alzheimer's disease. Because both the likelihood of contracting the disease and the age at which the disease appears are highly dependent on a patient's version(s) of apoE, the authors suggest further study of this protein to develop tests allowing for earlier detection, prevention and treatment of the disease. Lopes, Chettouh, Delabar and Rachidi (2003) studied the gene C21orf5 and determined it to be a candidate gene possibly playing a role in the mental retardation seen as one of the many possible symptoms of Down syndrome. Down syndrome is an especially difficult malady to analyze because it isn't caused by a person having a different version of a gene but is rather caused by a person having an extra 21st chromosome (or a portion of the chromosome), meaning that the person has extra copies of certain genes. This can lead to an overproduction of certain proteins, meaning that the disease isn't caused entirely by the lack of a certain needed protein or the presence of a harmful protein, but rather by simply having too much of what would generally be considered a necessary protein.

Overall, many of the papers are either correlational or causal in nature, relating a gene to a trait but admitting a lack of complete knowledge concerning the underlying molecular processes in which the protein of interest participates. However, the authors generally include some informed conjecture as to the nature of those processes as well as some suggestions for how those conjectures should be further investigated. For a nonscientist reading these articles there is a tremendous sense of science moving incrementally but steadily forward and a sense that it won't be too much longer before knowledge will have advanced sufficiently to make personalized medicine relatively commonplace and personalized education feasible.

Student Learning Preferences

The concept of learning style is recognition of the fact that students differ in the ways in which they can most successfully acquire, store and retrieve information. Some students, for example, would thrive

in a traditional lecture setting while others would learn more effectively in a group discussion or a hands-on experiential exercise. Similarly, a large semester-long open-ended student-run project would inspire the creativity of some students. Others, who would be overwhelmed by both the size of the project and its lack of structure, would much prefer a series of smaller assignments, each performed under the close supervision of the instructor. A student's learning style represents a set of learning-related preferences that define the environment in which the student prefers to learn, the learning methods that the student prefers to utilize and, by implication, the teaching methods that the student would most like the instructor to utilize.

Most students don't fully recognize their preferences, even though they repeatedly apply the same learning strategies in many classes. Similarly, and possibly more importantly, many students don't consciously recognize that their lack of success in certain courses is often due to a mismatch between the course and their learning style more than it is due to a lack of effort, lack of intelligence or lack of interest in the subject area. Learning styles represent a general approach to learning that is applied over and over again in multiple classes, although there is evidence that some students alter their behaviors somewhat depending on the subject being taught (Jones, Reichard and Mokhtari, 2003).

There is no one best learning style. The philosophy behind learning styles suggests that the educational community should move away from viewing some students as good learners and others as poor learners and should instead recognize that virtually any student can learn more successfully if provided with the learning environment and teaching methods that best fit that student. Gregorc (1979) suggests that the most successful students in any given class will often be those whose learning style most closely matches the instructor's teaching style and the classroom environment rather than the students who have the most ability or those who put forth the greatest effort. Similarly, Bloom (1976) suggests that the use of teaching methods that don't match every student's needs contributes significantly to the high level of variability in learning seen in most classes and notes that the use of a variety of methods will generally lead to increased success.

Dunn and Dunn (1979) provide one of the more complete learning style models. Their model classifies the relevant preferences into four categories of elements. Environmental elements include the sound level, lighting, temperature and overall design of the classroom. Emotional elements include the student's degree of motivation to learn, persistence to continue despite difficulties, degree of responsibility taken for his own learning success, and need for structure, specificity and guidance from the instructor. Sociological elements include the student's preference for working alone versus in groups and for working with peers versus with the instructor. Finally, physical elements include the student's preference for learning by hearing, seeing or doing, as well as the student's time-of-day rhythms, need to eat, drink or smoke while studying, and need for frequent breaks.

The authors suggest that experienced educators generally recognize that there are multiple ways to learn effectively and that many students can only make use of a few of those ways. Nevertheless, many of these same educators continue to utilize only one or a limited number of environments and teaching methods, often emphasizing those under which they had been most successful as students. Note, by the way, that the frequently condemned traditional lecture is actually a successful teaching method for the auditory learners who make up approximately twenty percent of the population. The dominance of lecture as a teaching method of choice in most schools means that these auditory learners are likely to enjoy school and achieve academic success. An inordinately large proportion of them end up as educators - educators who teach using the lecture method (Tileston, 2000, p. 14).

A wide variety of other style-related factors have been proposed in addition to those included in the Dunn and Dunn model. Some of these are:

- Whether a student tends to focus on the details and needs extra assistance to see the big picture, or vice versa (Gardner and Long, 1962, as cited in Keefe, 1987)
- The degree to which the student can tolerate encountering new ideas that conflict with his preconceptions (Gardner et al., 1959, as cited in Keefe, 1987)
- The student's susceptibility to distraction (Gardner et al., 1959, as cited in Keefe, 1987)
- The student's ability to recognize subtle differences as opposed to over-generalizing (Gardner et al., 1959, as cited in Keefe, 1987)
- The student's level of curiosity (Berlyne, 1954, as cited in Keefe, 1987)
- The student's reaction to a reward or punishment provided by the instructor (Skinner, 1953, as cited in Keefe, 1987)
- The extent to which the student is trying to satisfy

the instructor versus satisfying an internal standard of excellence (McClelland et al., 1955, as cited in Keefe, 1987)

An effective instructor must consider not only student learning preferences but also the learning objectives set for the class as a whole. Bloom's Taxonomy (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956; Krathwohl, Bloom & Masia, 1964) provides a classification hierarchy of learning objectives. At the lowest level, Knowledge, a student should be able to recall various facts and ideas. At higher levels, all of which build upon the levels below, students should be able to perform more complex learning tasks such as interpretation, extrapolation, application and synthesis. While many teaching methods have been shown to enable students to successfully achieve the Knowledge level, higher levels generally require methods that call for more active participation from the students and an increased focus on the part of the student on his or her own learning processes.

The literature on learning styles, although extensive, is somewhat disjointed and sometimes contradictory. Sternberg and Grigorenko (2001) note that many studies involve an instrument designed to measure one particular construct, with each study measuring a different construct using a different instrument. Although many studies find the construct of interest to be significant, there has been little replication and little effort to measure the same construct with a different instrument. In addition, many of the constructs receive only mixed empirical support with some receiving little or none. As a result, the generalizability of a substantial portion of the work must be called into question. There is also a sense of each study going off in its own separate theoretical direction with insufficient attention being given to the task of developing an overall theory to tie the individual ideas together. Dunn and Dunn (1979) suggest that there have been so many separate theories put forth because most studies focus on such a small part of the overall picture. Nevertheless, enough of the models have received empirical support that most psychologists and educators accept the value of the learning styles concept in general and the value of many of the individual constructs. The intuitive appeal of learning styles, coupled with the fact that the educational community receives a substantial amount of anecdotal evidence in support, has led many instructors to implement these ideas in their classrooms.

The earlier discussion suggesting that most human traits are determined at least partially by heredity obviously implies that many learning style traits will be discovered to be genetically based, an idea that is supported by Watson (2003), Gardner (1995) and Gregorc (1979). In an example more specifically tied to learning-related traits, Hohnen (1999) demonstrated that literacy ability was determined to a significant extent by heredity. The genetics-related work focusing on brain development and function, in tandem with continuing studies on learning styles, should allow researchers to develop a greatly increased understanding of learning styles - which factors are important, the extent to which the important factors are genetically based, the gene(s) involved, and eventually even the underlying molecular processes in which the gene expression takes place. Genetic testing could then be used to determine the makeup of each student, using that information to highlight the student's various learning preferences, preferences which most incoming freshmen do not currently know.

Many learning style instruments exist, some of which are quite popular. An obvious question concerns the need for genetic testing given that so many of these instruments are already in use. Irvine and York (2001) discuss problems that can hinder the usefulness of some of these instruments, which include:

- No one instrument measures all of the potentially important learning style constructs, with most instruments measuring only a small portion
- The relevant research does not fully support the construct being measured
- Some instruments designed to measure style may actually measure ability as much as style
- Some instruments may measure cognitive impairment more than the construct of interest
- Multiple instruments designed to measure the same construct often demonstrate low correlation when used on the same subjects
- Some instruments demonstrate a lack of validity and reliability
- Many of the instruments require the students to report about their own preferences, preferences that are often not completely clear to the students themselves
- The authors suggest that the weaknesses of these instruments are particularly problematic now that the educational community is being so strongly encouraged to apply the results of these tests to the design of their classrooms and curriculum.

Accommodating Learning Preferences in Business Education

Business faculty has been encouraged for many years to use a variety of teaching methods in addition to

traditional lecture as a way of reaching more students. Garvin (1991) and Lundberg (1993), for example, discuss the benefits of case discussion as a way to promote greater student involvement with the material and hence a higher level of learning. Sternan (1992) and Parmenter (1999) discuss the benefits of hands-on experiential exercises. Thompson and Stappenbeck (2002) promote the use of computer simulation games.

Implicit in the use of this variety of teaching methods is an assumption that different methods will succeed at different levels of success with different students - a recognition that each student learns in slightly different ways. Multiple methods are utilized in the hope that every single student will be reached by at least one of these methods and will thus effectively learn the concepts that the instructor is attempting to impart. Although not guilty of a "one size fits all" mentality, this strategy is somewhat guilty of "many sizes fit all" thinking. Although faculty use multiple methods, with the hopes of satisfying all students at least partially, they don't generally go to the trouble to learn which student is best served by which method. Thus, although a variety of methods is applied to the class as a whole, there is little attempt to customize instruction to the needs of the individual student. The customization that might become possible through student genetic information would represent a significant improvement for many students in that they would then be taught in the ways most appropriate for them.

Resistance to Use of Genetic Information

As Watson notes (2003, pp. 398-399), the key question is not whether it will become possible to make use of genetic information but rather whether society will be willing to do so. Many people and governments have been resistant to the genetic engineering advances of the last several decades. And many people are, with some justification, fearful of the possible misuse of genetic information.

The fear of genetically engineered products is widespread although not entirely reasonable. For centuries farmers and animal breeders have been developing improved versions of various plants and animals by selecting parents with the desired characteristics and thus the vast majority of what most humans eat has been developed through the artificial selection process of controlled breeding. To put it bluntly, unless it's a wolf, a pet dog isn't really all that much more natural than Dolly the cloned sheep. Some of those who resist the developments in genetic engineering are unhappy with the idea of mankind, in essence, "playing God." Others are afraid of the unintended side effects that might occur when a particular plant or animal is genetically altered. Genetically altered foods, termed "Frankenfoods" by their detractors, are illegal in some nations.

Fear of the misuse of genetic information, however, may be quite reasonable. Possible misuses could include an insurance company's refusal to provide medical coverage to a person determined to have an increased likelihood of contracting a serious genetic disease. Similarly, the government could refuse to provide a marriage license to a prospective bride and groom because both carry the same dangerous version of a gene. Such fears should not be viewed as evidence of paranoia considering that in the first half of the 20th century the U.S. government used the genetically based pseudo-science of eugenics as a basis for restricting immigration and even mandated forced sterilization for those with particular mental problems (Ridley, 1999, pp. 286-300).

In the context of education, many will have similar fears concerning the potential misuse of data. These potential misuses could include students being tracked into slow-learner classes against their will or schools using genetic information concerning potential learning disabilities to deny admission to certain students. If student genetic information does indeed become obtainable there will have to be a tremendous amount of discussion on the part of the educational community to determine just how that information should be used. It would be irresponsible on the part of universities to ignore the availability of the information and thereby forego the potential benefits that might be gained by both the schools and the students, but it would be equally irresponsible to use that information in haphazard and possibly unethical ways.

Utilizing Learning Preference Information

There are many actions that will need to be taken in order to enable business schools to take full advantage of increased information concerning student learning preferences. Below are some recommendations designed to prompt the start of a serious discussion of this topic. Note that some of these recommended actions would be beneficial even without the genetic information being discussed in this paper.

Faculty should develop increased expertise concerning learning styles and the applicability of various teaching methods to those learning styles. Aspiring business faculty is generally fully trained in the research process during graduate school but is often given little formal training in the teaching process. It will become increasingly important for them to learn some of

the basic concepts and techniques that their faculty colleagues in colleges of education take for granted.

Faculty will need to provide each student with general information about the concept of learning styles as well as information concerning that student's specific learning preferences. Gaining increased knowledge about his own learning preferences can allow a student to take more control over the learning process (Jones et al. 2003). Students who perform metacognition - who consciously think about how they think and learn - are more likely to recognize their own learning problems and adjust their learning strategies accordingly (Forget and Morgan, 1997).

Faculty will need to broaden their portfolio of teaching skills in order to be able to effectively teach students with various learning styles. Faculty should also recognize that there is a natural tendency to assume that their teaching methods provide a better fit for students than is often the case.

Students should be encouraged to learn in their preferred ways but should also be encouraged to develop increased skill at using some of the learning methods in which they are currently weak (Silver and Strong, 1997). Certain assignments and exercises should be structured so as to encourage more focus on learning how to learn rather than on learning course content.

The advising process should receive increased support, whether performed by faculty or by a separate office dedicated to that function. Effective evaluation and presentation of the learning preference information will require increased expertise and time. Genetic information will make the advising process more complex but will also make it potentially more valuable and rewarding as the advice provided can have a bigger impact on student success.

The Admissions Department should be involved in implementation planning as it will likely be a gatekeeper for the learning preference information. There are many privacy-related issues that should be fully considered for the protection of both the students and the university. Note that genetic testing is likely to become commonplace in the future, meaning that learning-related information may have been made available to students long before they enter college. If so, the university may not have to take any action whatsoever to generate this information and, because of privacy-related issues, may choose to allow students to manage this information themselves rather than requiring them to provide the information to the school. If that is the case, it will become very important to provide the necessary education concerning learning styles (e.g. in freshmen orientation) so that students will be able to utilize their personal learning style information wisely.

Carefully evaluate course offerings to consider the possibility of offering more courses in nontraditional modes and/or allow certain students to take more nontraditional courses as part of their programs of study. Learning preference information should allow easier identification of those students who would thrive in the less closely supervised environment of an independent study, correspondence or online course. Faculty administering independent study work will be expected to increase their ability to determine the correct amount of structure and guidance that each student might need and how much freedom should be provided.

Carefully evaluate the assignments and exercises used in each course with an ultimate goal of providing customizing coursework to each student. Although it sounds somewhat unfair to think of assigning different tasks to two students taking the same class, assignments tailored to each student's preferred learning style may result in improved learning for all students. For example, students who are self-directed, highly motivated by challenging tasks and skilled at integrating related concepts could be given a large semester-long exercise, possibly as a group project, in which choices concerning things such as articles to read and websites to visit would be left almost entirely up to the students. Conversely, students who are likely to be overwhelmed by such a large and vaguely defined assignment would be given a series of small fully defined assignments, each accompanied by a detailed reading list and the questions that they would be expected to be able to answer once the reading has been completed. Utilizing customized assignments would obviously complicate the grading process. It might also be perceived as being unfair by some students and would thus call for a significant amount of explanation.

Carefully evaluate the possibility of developing a course schedule that includes information concerning the teaching methods to be employed and the nature of the assignments to be utilized in each course. This would allow students to select the section of a particular course that would most closely fit their own learning preferences. Many students currently make such choices based on their knowledge of the instructor. The learning style and teaching method information that future students will possess should allow them to make these choices in a more informed way.

CONCLUSION

While the specific nature of the coming genetically-

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based educational developments is not yet clear, it is not unreasonable to assume that many of the characteristics that impact student learning success will be determined to have a genetic basis. It is also not unreasonable to assume that genetic testing will become both readily available and affordable. The educational community would be remiss if it were to write off these potential developments as science fiction or as something to be dealt with by a future generation of faculty. The startlingly rapid progress being made by the scientific community suggests that the knowledge necessary to implement personalized education may become available rather soon. Thus universities should begin considering the various relevant issues in preparation for the potentially dramatic changes that may result.

This paper has discussed the possible use of genetic information to devise an educational program that most closely matches the learning-related characteristics of a given student. It has not, however, evolved what many might view as the logical next step - genetically altering the student himself in order to develop a better learner. It may become possible in the not too distant future to alleviate learning-related problems via genetic means. And, although it raises many ethical questions, it may also become possible to enhance the abilities of even the best students, i.e. to create "super students." Scientists have already managed to genetically improve the learning speed of a fly and the memory of a mouse. It may not be too long before the same can be done for a human.

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