



## USING BAYESIAN NETWORKS TO UNDERSTAND RELATIONSHIPS AMONG MATH ANXIETY, GENDERS, PERSONALITY TYPES, AND STUDY HABITS AT A UNIVERSITY IN JORDAN

Linda Smail

Mathematics and Statistics Department, Zayed University, Academic City, Dubai, United Arab Emirates  
Email: linda.smail@zu.ac.ae

### *Abstract*

Mathematics is the foundation of all sciences, but most students have problems learning math. Although students' success in life related to their success in learning, many would not take a math course unless it is their university's core requirements. Multiple reasons exist for students' poor performance in mathematics, but one prevalent variable worth consideration is the personality type. This work seeks to uncover relationships, if any, between students' math anxiety and the students' learning type in learning math and preparing for exams and tests. We use Bayesian networks to link those different variables and detect possible relationships among these variables. The data was obtained from population of 468 students during spring in 2009 at a U.S. institution in Jordan. Not many researches have been performed in the area of math study and personality types so we undertook this study to add to this area of knowledge. The study reveals that math anxiety related to gender, personality type, and study habits among this group of university students.

**Keywords:** Mathematics Anxiety, MBTI, Personality Types, Bayesian Networks

### *Abstrak*

Matematika adalah dasar dari semua ilmu pengetahuan, tetapi kebanyakan siswa memiliki masalah dalam belajar matematika. Meskipun keberhasilan siswa dalam kehidupan berkaitan dengan keberhasilan mereka dalam belajar, kebanyakan menganggap matematika bukan bagian dari sesuatu yang harus dipelajari dan sebagai syarat utama di universitas mereka. Meskipun beberapa alasan berasal dari siswa yang memiliki kemampuan yang belum baik dalam bidang matematika, satu variabel lain yang layak dipertimbangkan adalah tipe kepribadian. Karya ini bertujuan untuk mengungkap hubungan, jika ada, antara kecemasan matematika siswa dan gaya belajar siswa dalam mempelajari matematika, dan mempersiapkan diri mereka untuk mengikuti ujian dan tes. Kami menggunakan jaringan Bayesian untuk menghubungkan variabel-variabel yang berbeda dan mendeteksi kemungkinan hubungan antara variabel-variabel tersebut. Data yang digunakan dalam tulisan ini berasal dari populasi yang tersedia dari 468 siswa selama musim semi tahun 2009 di institusi AS di Yordania. Karena sedikit atau tidak ada penelitian yang telah dilakukan terkait hubungan kegiatan belajar matematika dan tipe-tipe kepribadian siswa, kami melakukan penelitian ini untuk menambah pengetahuan pada topik penelitian ini. Penelitian ini mengungkapkan bahwa kecemasan matematika yang berhubungan dengan jenis kelamin, tipe kepribadian, dan kebiasaan belajar antara kelompok mahasiswa.

Kata Kunci: kecemasan matematika, MBTI, tipe-tipe kepribadian, jaringan Bayesian

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Based on conversations with hundreds of students over many years, I have observed that many students enrolled in math courses across a variety of levels expressed concern about the courses due to what they felt were their inadequate backgrounds in math. These students found math difficult and disagreeable, and they feared math because they saw it as a complex and abstract subject that involves many formulas and complicated arithmetic operations. Many factors affected these students' abilities to learn math, but

one factor worth considering is personality type. Students who do well in math typically have a positive attitude toward the subject and toward all math-related courses. Thus, these students will most likely take further math-related courses and perform better in them; these students may even pursue careers in science, math, or engineering. In contrast, students with math anxiety will be attracted to careers that require less math or no math at all. Thus, students' attitudes are clearly important, but we do not know all the factors that affect attitudes toward math. (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013; Preston, 1986; Scarpello, 2005)

During the past decade, math anxiety has become a critical research topic for educators. Numerous studies have been conducted on math anxiety to address the following issues: what is math anxiety, where does it stem from, and how do students' genders and attitudes contribute to it. (See for example: Philipp, 2007; Golden, 2014; Preston, 1986; Perry, 2004). However, research addressing the relationships between personality types and math study has been lacking. Therefore, this study was undertaken to contribute to this area of knowledge.

Math anxiety is a common phenomenon among today's college and university students; according to Scarpello (2005), students with math anxiety are limited in their college majors and career choices, and furthermore, many adults are unable to pursue a large number of professional job opportunities because they perform poorly in mathematics.

The purpose of this study was to investigate possible relationships among university students' personality types, their math anxiety, genders, and study habits. The purpose was accomplished using data gathered on university students enrolled in various math classes at different levels in a U.S. institution in Jordan. In this country, mathematics is viewed as a male field, and only a few mathematics Ph.D holders are female. In the U.S. institution where the study was conducted, only 10% of the mathematics faculty was female.

In this work, we propose the use of Bayesian networks (BNs) to determine possible relationships among the variables involved in this study—primarily students' personality types, math anxiety, students' majors, students' ranks, study habits, and genders. The main advantage of BNs is that they are very simple tools to use and interpret by users without a background in Statistics. They provide a visual way that is easy to read and interpret, and therefore they can be used as a framework for inference and relevance analysis.

The paper is organized as follows: math anxiety, personality types, and Bayesian networks are described in the Theoretical Background Section. The purpose of the study, method, instruments, and data analysis are presented in the Study Section. The Findings Section summarizes answers to the research questions; these are followed by the Bayesian Network approach. Finally, we present our conclusion and recommendations.

***Math Anxiety***

Math anxiety has been defined as a state of discomfort that occurs in response to situations involving mathematical tasks that are perceived as threatening to one's self-esteem (Cemen, 1987). This anxiety can lead to panic, tension, helplessness, fear, distress, shame, the inability to cope, sweaty palms, a nervous stomach, difficulty breathing, and the loss of the ability to concentrate (Cemen, 1987; Posamentier & Stepelman, 1990; Tok, 2013).

Tobias (1993) defined math anxiety as feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematics problems in a wide array of situations in ordinary and academic life. Math anxiety can cause one to forget important facts and lose one's self-confidence.

Similarly, Spicer (2004) stated that mathematics anxiety is "an emotion that blocks a person's reasoning ability when confronted with a mathematical situation".

A review of current and past research suggests that math anxiety does not appear to have a single cause. In fact, one of the early math anxiety researchers, Tobias (1993), stated that math anxiety might be the result of many factors that can be summarized into the following three causes. Imposed authority: students think that the teacher is the only source of knowledge. Public exposure: students are afraid to participate or give answers in front of the class for fear of being wrong and shamed. Time deadlines: exam deadlines cause substantial anxiety and stress. Similarly, Hadfield and McNeil (1994) noted that math anxiety is caused by many factors that can be divided into environmental, intellectual, and personality categories. Similarly, most researchers agree that environmental factors might include negative experiences in classrooms, pressure from parents or family members, ineffective teachers, and/or a bad teaching style (Dossel, 1993; Tobias, 1990). Whereas intellectual factors may include teaching styles that are incompatible with students' learning styles, self-doubt, and lack of confidence (Cemen, 1987; Miller & Mitchell, 1994), personality factors may include reluctance to ask questions and low self-esteem. Furthermore, the most important personality factor is viewing math as a male domain (Cemen, 1987; Devine, 2012; Fawcett, Szűcs, and Dowker, 2012; Gutbezahl, 1995; Levine, 1995; Miller & Mitchell, 1994; Krantz, 1999). In addition, researchers agreed that these three factors should encourage an examination of teaching methods and that less emphasis should be placed on lecturing and more on student-directed classes and discussion.

***Personality Types***

A personality type classifies students according to the way they receive information and how they process it to reach a conclusion. Personality types, as determined by the Myers-Briggs Type Indicator (MBTI) (Myers, McCaulley, & Alto, 1985), consist of four indices; each index illustrates one of four preferred choices for describing how students perceive and react in a given situation. We summarize the indices below; for further details, see (Smail & Jafar, 2007; Fagan & Squitiera, 2002; Wingenbach, 2000).

***Brief description of the MBTI factors***

1. Extraversion-introversion (EI) describes whether a person is oriented toward the outer world (Extravert) (E), by focusing on people and objects, or toward the inner world (Introvert) (I), by focusing on concepts and ideas.
2. Sensing-intuition (SN) describes a person's choice in perceiving new information, by observing facts or experiences through one of the five senses (S) or by gathering information through meanings, relationships, and/or possibilities, and intuition (N).
3. Thinking-feeling (TF) describes how a person draws conclusions or makes decisions by relying on logic, in other words, thinking (T) or relying on a feeling (F) preference.
4. Judgment-perception (JP) describes the process one uses to confront the outer world, with judgment (J) using either thinking or feeling or with perception (P) using sensing or intuition in addressing the outer world.

These four items stem from combining eight possible personality factors. When combined, these eight factors result in 16 distinct personality types: ISTJ, ESTJ, ISFJ, ESFJ, ISTP, ESTP, ESFP, ISFP, ENTJ, INTJ, ENTP, INTP, ENFJ, INFJ, ENFP, and INFP.

The MBTI test is a popular instrument used for assessment by companies, organizations and industries (Costa & McCrae, 1992; Wicklein & Rojewski, 1995). Despite its popularity, it has limitations; for example, people with serious shortcomings will respond with only the positive type description provided by the MBTI to cover their difficulties. Additionally, the simplicity of the questions causes people to assume that the theory behind the instrument is simple as well. Despite its limitations, the MBTI test has strengths, it is easy to implement and use, and does not describe the respondent's personality, but simply purports to explain it. Tieger and Barron-Tieger (1993) described how the MBTI can be used by career counselors to help individuals find jobs that satisfy and best suit them. Personality type is an important matter in career decisions.

Because students have different personality types, they often learn and study differently (McKenzie, 1989; Marquart, Broomley, & Dalley, 1997). A deeper understanding of their personality types may tell us more about their feelings regarding studying math and their study habits.

***Bayesian Networks***

Bayesian networks are graphical models represented by directed acyclic graphs in which the nodes are the variables of the domain and the links show the dependencies among the variables. For more details about Bayesian networks, see (Smail, 2011; Cowell, Dawid, Philip, Steffen, & Spiegelhalter, 1999; Jensen, 1996).

The parameters of a Bayesian network, in addition to the graph structure, are conditional probability distributions (CPD) at each node. In our case of discrete probability distributions, each node

will have a conditional probability table (CPT) that lists the probabilities that each node assumes for each of its different values for each combination of values of its parents in the graph.

That is, given a set  $I$  of random variables and a directed acyclic graph (DAG)  $G$  on  $I$ , a Bayesian network (BN) (see Smail, 2011) is a family of random variables  $X_I = (X_i)_{i \in I}$ , such that for all  $i$ , the conditional probability of  $X_i$  conditional on the set of all random variables other than itself and its descendants (denoted by  $d(i)$ ), depends only on the value of  $x_{p(i)}$  taken by the set of its parents:

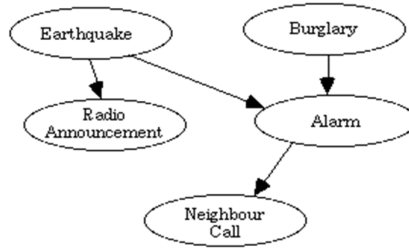
$$\forall i \in I P_{i|I - ((i) \cup d(i))} (x_i | x_{I - ((i) \cup d(i))}) = P_{i|p(i)} (x_i | x_{p(i)}) \quad (1)$$

with the convention that  $i$  is a root of the graph  $G$ ; that is,  $p(i) = \phi$  and  $P_{i|p(i)}$  is the probability of  $X_i$ . The result is that the expression of the joint probability distribution of the family  $X_I$  is as follows:

$$P_I (x_I) = \prod_{i \in I} P_{i|p(i)} (x_i | x_{p(i)}) \quad (2)$$

One of the major advantages of BNs is that the associated DAG reveals all dependence and independence relationships among the variables, which is important in determining, when computing probabilities, which of the variables of interest are important and which are not.

Consider the following example in Figure 1 from Friedman, Goldszmidt, and Wyner (1999).



**Figure 1.** Example of a Bayesian network called “Alarm”.

The Bayesian network in Figure 1 has five random variables: burglary, earthquake, alarm, neighbor call, and radio announcement. Each node has a set of parents and set of descendants that can be read directly from the graph. Alarm, as an example, has two parents, burglary and earthquake, and has as descendants (the only children in this case) neighbor call. In addition, Burglary has no parent and two descendants, alarm and neighbor call. In this Bayesian network, burglary and earthquake are independent, and burglary and radio announcement are independent given earthquake. In other words, no event affects both burglaries and earthquakes. In addition, burglary and radio announcements are independent given earthquake, meaning that whereas a radio announcement might result from an earthquake, a radio announcement will not result as a repercussion of a burglary.

Associated with each node is a conditional probability table. For example, the “Alarm” node has the following probability distribution as portrayed in Table 1.

**Table 1.** Probability distribution for the alarm node given the events of "earthquakes" and "burglaries"

E	B	P(A=On   E, B)	P(A=Off   E, B)
E	B	0.90	0.10
E	B'	0.20	0.80
E'	B	0.90	0.10
E'	B'	0.01	0.99

*Note:* A' indicates complement of A

For example, should there be both an earthquake and a burglary, the alarm has a 90% chance of sounding. With only an earthquake and no burglary, the alarm would sound in only 20% of earthquakes. A burglary unaccompanied by an earthquake would set off the alarm in 90% of burglaries, and the chance of a false alarm given no antecedent event should have a probability of only 0.1%.

Because of the independence among these variables, the probability distribution of the Bayesian network  $P(A, R, E, B)$ , i.e., the joint probability of the joint events alarm, radio announcement, earthquake, and burglary can be written by the chain rule as:

$$P(A, R, E, B) = P(A|R, E, B) * P(R|E, B) * P(E|B) * P(B). \quad (3)$$

Using conditional independence relationships, we can rewrite this as:

$$P(A, R, E, B) = P(A|E, B) * P(R|E) * P(E) * P(B). \quad (4)$$

This significantly reduces the number of joint probabilities involved in the computations and stored in memory.

As in the above example, one of the most important advantages of BNs is the associated structure that determines the dependence and independence relationships among the variables; therefore, it is possible to determine, without extra computation, what variables are relevant or irrelevant for some other variables of interest. Several algorithms allow the construction of Bayesian networks from data, i.e., determining the links among the variables and the associated conditional probabilities. In this work we used the PC algorithm described by Spirtes, Glymour, and Scheines (1993a). The PC algorithm belongs to the class of constraint-based learning algorithms. The basic idea of these algorithms is to derive a set of conditional independence and dependence statements by conducting statistical tests. For more details, see Spirtes, Glymour, and Scheines (1993a). Software packages exist that allow the construction of BNs from data. In this work, we have used the BayesiaLab software, available without

charge at <http://www.bayesia.com>.

## **METHOD**

In past work (Smail & Jafar, 2007), researchers related students' successes to their personality types, applied the results in the classroom, and thereby improved students' results and interactions in classes. Our goal is to use increased knowledge of the students' personality types to find ways to help students improve their learning skills and study habits and to increase students' interest in learning math both inside and outside the classroom. We proposed concentrating our efforts on understanding the various factors related to students' math anxiety by conducting a study to address this problem. This study was designed to find relationships among personality types (Myers & McCaulley, 1985), math anxiety, gender, grade point average (GPA), and math study habits. The primary objective of this study was to characterize whether students have math anxiety correlates with their gender, personality types, and study habits.

### ***Sample***

This study comprised 468 undergraduate volunteer students enrolled in different classes at a U.S. institution in Jordan. The students were from numerous disciplines at the university, such as business management, accounting, marketing, computer graphics, and computer science, and enrolled in different math courses at different levels. They were randomly selected from different math classes overseen by many instructors. Volunteers were from different year levels freshmen, sophomores, juniors, and seniors. Students were briefed about the study and given the opportunity to ask questions before deciding whether to take part. Those who accepted signed a consent form to participate. There was no incentive for participating and no consequences for not taking part in the survey.

### ***Instruments***

The instrument used to gather data was a three-part questionnaire: the first part included the MBTI test, which contained 32 questions designed to determine the personality types of the participant. (More information about the personality types and the MBTI can be found in Berens and Nardi (1999), Myers and McCaulley (1985), Smail and Jafar (2007), and Eysenck (1967).) The second part included the Abbreviated Math Anxiety Scale (AMAS) (Hopko, Mahadevan, Bare, & Hunt, 2003; Tapia & Marsh, 2004) to measure levels of math anxiety. This measure is the shortest valid math anxiety scale, with only 9 items using a 5-point scale, and has been shown to be as effective as the longer MARS Hopko, Mahadevan, Bare, & Hunt (2003) (internal consistency:  $\alpha = .90$ ; two-week test-retest reliability:  $r = .85$ ; convergent validity of AMAS and MARS-R  $r = .85$ ). The 5-point scale was shortened to 2-point scale (Yes for a score of three or more and No otherwise). The third part included a closed-form question section designed to yield information about the participant. (See Table 2 below for more details).

### Procedures

This study was conducted during the spring semester of the 2009–2010 academic year. The students were administered the MBTI and the Math anxiety instruments during a testing session. At the end of the two measurements, the students were asked to complete the third-part questionnaire.

The data on students' identities were coded through an assigned number to maintain confidentiality, and students' names were deleted as soon as the data were coded. A description of the considered variables can be found in Table 2.

**Table 2.** Descriptive of the different variables considered in the study

Variable	Description
Personality type	indicates the personality type for each student using the MBTI. It has 16 possible values: ENFJ, ENFP, ENTJ, ENTP, ESFJ, ESFP, ESTJ, ESTP, INFJ, INFP, INTJ, INTP, ISFJ, ISFP, ISTJ, or ISTP
Math Anxiety	indicates whether students have math anxiety.
Gender	indicates student's gender: male or female
Rank	indicates the student's year of study: Freshman, Sophomore, Junior, or Senior
Major	Indicates student's major: Accounting, Computer Graphics (CG), Computer Sciences (CS), Information Technology (IT), management Information system, (MIS), Management, or Marketing
GPA	indicates student's grade point average: a continuous numerical variable that was divided into [1.2, 1.9), [1.9, 2.6), [2.6, 3.3), and [3.3, 4]
Success	indicates whether students were more successful in sciences courses or social courses
Difficult	indicates what students thought was difficult: being a mathematician, a philosopher, or both.
More difficult	indicates whether students thought was more difficult: writing an essay or solving a math problem.
Challenging	indicates whether students enjoy challenging courses.
Enjoy Math	indicates whether students enjoy math courses more than other courses or not.
First step	indicates the first step students take when solving a math problem: Ask for help, do nothing, read again, or begin to solve.
Hard subject	indicates whether students think that math is a hard subject



First impression	indicates students' first impression when they face a math problem: Happy, Challenged, Confused, Stressed, Afraid, or Panicked
Trouble	indicates whether students experience problems before math exams.
Stress	indicates whether students feel stressed before and/or during a math exam.
Forget	indicates whether students forget what was learned before a math exam.
Study Habits	indicates whether students study regularly during the semester or just before exams.
Homework	indicates whether students study at least two hours a day
University experience	indicates how students ranked their university experience: Great, Good, So-So, Bad , or Terrible
Talking to teachers	indicates how students felt about talking to their teachers: Interesting, Never done, Useless, Scary
Advice	indicates what students advise others to study: science or other.

The study attempts to answer the following three critical questions:

1. Is there a relationship between math anxiety and: a) personality type and b) students' gender.
2. Is there a relationship between math study habits and personality type or students' gender.
3. Is there a significant difference between male and female students in their math anxiety, attitude toward social and/or science courses, study habits, and their university major.

## **RESULTS AND DISCUSSION**

### ***Descriptive Statistics***

Descriptive statistics were used to describe the data. The data demonstrated that the typical university student was sensing, thinking, and judging (STJ): 71.37% of the students were sensing (S), 34.19% of the sensing students were thinking and judging (TJ), and 49.57% of the students were sensing and thinking (ST).

In addition, 80.77% of the students declared that they enjoy challenging courses, but 62.82% of them were more successful in social science courses. Indeed, 69.66% of the students confirmed that they did not experience math anxiety, but 81.62% of the students forgot some of what they had learned whenever they take an exam. One explanation for this phenomenon may be their study habits: whereas 56.41% study hard only right before an exam, only 28.63% study and do their homework regularly.

## BAYSIAN NETWORK APPROACH

In this approach, we use Bayesian networks as a tool to analyze qualitative aspects of the problem, such as direct relationships among the problem variables that are worth considering.

We proceeded in steps, considering a different set of variables of interest each time. We first looked closely at the two variables math anxiety and personality types and used the Bayesian networks tool to find a possible relationship between them. We obtained a link between the two variables as shown in Figure 2.



**Figure 2.** Bayesian Network relating math anxiety and personality type

The conditional probability distribution associated to the variable math anxiety conditioned on the variable personality type is given in Table 3.

**Table 3.** Conditional probability table of math anxiety given personality type

Personality type	$P(\text{Math anxiety} = \text{Yes} \mid \text{Personality type})$
ESFJ	0.368421
ESTJ	0.265306
ISTP	0.06667
ISTJ	0.16129
INTJ	0.545455
ENTP	0.5
INFP	0.3
ESTP	0.285714
INTP	0.428571
ISFJ	0.66667
ENTJ	0.307692
ESFP	0.285714
ENFJ	0.25
INFJ	0.25
ISFP	0.444444

ISFJ and INTJ students were the main personality types among students who have a high probability of math anxiety.

As can be observed in Table 3, the IJ type was common in this case, as the definition of the I type implies that students with high math anxiety are oriented toward an inner world. This orientation makes it difficult for them to ask questions to learn from people. The J personality type indicates students with a preference for using their feelings to address the outer world. Thus, the fact that IJ students have a greater fear of math makes sense.

In contrast, ISTJ and ISTP were the primary personality types that did not experience math anxiety (see Table 4).

**Table 4.** The personality types with the lowest amount of math anxiety

Personality type	$P(\text{Math anxiety} = \text{No} \mid \text{Personality type})$
ISTJ	0.83870968
ISTP	0.93333333

The IST type was common in this case. Indeed, even students with less math anxiety were introverts, but they were sensing and thinking, meaning that they prefer using their five senses to address the outer world when observing facts or experiences. They also rely on logic to make decisions, which causes them to have a more positive attitude toward math than do other personality types.

In our second step, we tried to find a possible relationship between math anxiety and gender, to obtain the graph in Figure 3.



**Figure 3.** Bayesian Network relating math anxiety and gender.

The conditional probability distribution of the variable math anxiety conditioned on the variable gender is given in Table 5.

**Table 5.** The probability of having math anxiety conditioned on gender.

Gender	$P(\text{Math anxiety} = \text{Yes} \mid \text{Gender})$
Female	0.37097
Male	0.27907

Given the information that a student is female, her probability of having math anxiety is approximately 37%, which is higher than for a male (only 28%).

Third, we examined the relationship between the two variables — major and math anxiety. We found a relationship represented by the conditional probability table in Table 6.

**Table 6.** Conditional probability table of math anxiety given major

Major	P(Math anxiety = Yes   Major)
Marketing	0.246377
Accounting	0.2
Management	0.333333
Computer Graphics	0.5
Computer Sciences	0.428571
I.T	0.055556
M.I.S	0.342857

Fifty percent of all computer graphics (CG) students have math anxiety, which was the highest percentage of all the majors. In contrast, 6% of IT and CS students have math anxiety, which was the lowest percentage.

Third, we looked at the relationship between the two variables — rank and math anxiety—to obtain the conditional probability distribution in Table 7.

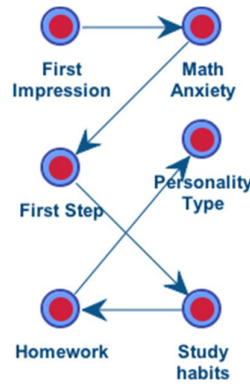
**Table 7.** Conditional probability table of math anxiety given rank

Rank	P(Math anxiety = Yes   Rank)
Sophomore	0.184615
Senior	0.372881
Junior	0.368421
Freshman	0.301887

Thirty-seven percent of seniors and juniors had math anxiety, but only 30% of freshmen so indicated. This difference is can be explained by the fact that students delayed taking math courses until no courses were left except those having math as a prerequisite.

Fourth, we looked at the relationship between math anxiety and the variables related to attitude toward math, which include First Impression, Hard Subject, and First Step.

The Bayesian network obtained in this case is given in Figure 4.



**Figure 4.** Bayesian Network relating math anxiety, personality type, study habits, homework, first step, and first impression.

All variables were connected in this network, which makes perfect sense, as they all represent attitude toward math and should be related rather than independent.

We also noticed that Math anxiety and First Impression are correlated. Additionally, the Math anxiety and study habits variables are independent, conditional on first step variable.

The conditional probability table of Math Anxiety, given First Impression, is given in Table 8.

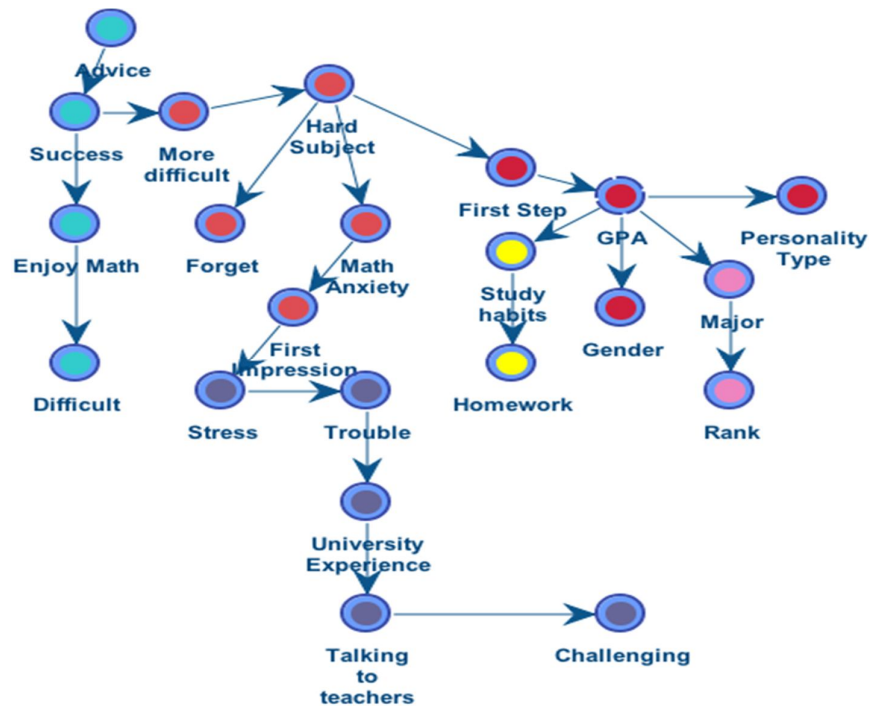
**Table 8.** Conditional probability table of math anxiety given first impression

First Impression	Panic	Challenged	Stressed	Confused	Happy	Afraid
Math Anxiety = No	0.46	0.9	0.33	0.56	0.88	0.125
Math Anxiety = Yes	0.54	0.1	0.67	0.44	0.12	0.875

If prior information in the BN states that when a student who feels confused when reading math problems has the ISFJ personality type and studies hard before exams, the next step is computing the probability of whether the student has math anxiety conditional to this new information; that is, the computation of  $P(\text{Math anxiety} \mid \text{Study habits} = \text{hard before}, \text{Personality type} = \text{ISFJ}, \text{First impression} = \text{confused})$ . By applying Bayes theorem, with this new information, called evidence, we get:

$P(\text{Math anxiety} = \text{Yes} \mid \text{Study habits} = \text{hard before}, \text{Personality type} = \text{ISFJ}, \text{First impression} = \text{confused}) = 45.22\%$ . Indeed, with this new evidence the probability of math anxiety increased from 30.34% to 45.22%

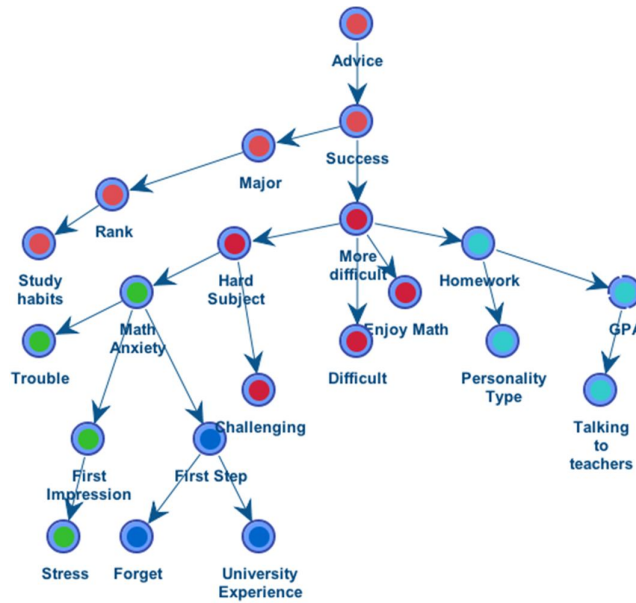
As a final step, we looked at the relationships among all variables included in the study for the entire data set and we obtained the Bayesian network in Figure 5.



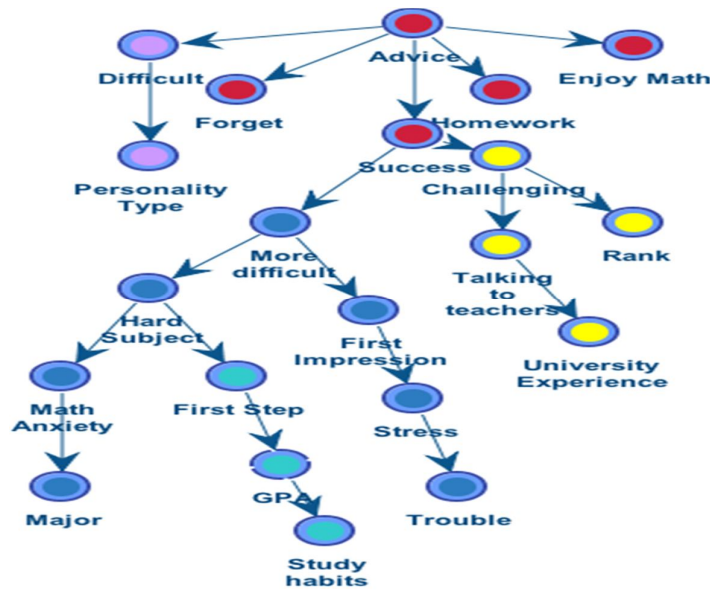
**Figure 5.** Bayesian Network including all variables in the study for all students.

All relationships can be read from the BN structure. Some of these relationships are first impression and hard subject are independent, conditioned on Math anxiety. First step and Math anxiety are independent, conditioned on hard subject, etc. If we begin with the above computation and add the information that the student is a male, we obtain the following result:  $P(\text{Math anxiety} = \text{Yes} \mid \text{Gender} = \text{male}, \text{Study habits} = \text{hard before}, \text{Personality type} = \text{ISFJ}, \text{First impression} = \text{confused}) = 40.66\%$ . In fact, the probability increases from 30.34% to 44.60%.

We also looked for relationships among all variables for only male students (Figure 6), and then for only female students (Figure 7).



**Figure 6.** Bayesian Network for female students including all variables in the study.



**Figure 7.** Bayesian Network for male students including all variables in the study

The BNs for male and female students have a set of links in common and differ in other links. They also differ in values of the involved variables. By comparing the two obtained BNs, we obtained that there was no female student with the ENFJ personality type, and also no female student in the computer science major. We also noticed that only male students do nothing as first step when they are asked to solve a math problem. Only male students in this study thought that their university experience was terrible.

## CONCLUSION

Our work is novel because it proposes the use of BNs to model relationships among Math Anxiety, personality type, gender, study habits, major, rank, and other variables involved in the study. We have described an approach (the BN approach) to detect and model the relationships mentioned above. We have additionally evaluated the model by comparing its results with those obtained with the SPSS regression analysis and results were similar with the exception that we have probabilities with Bayesian networks and we can update probabilities whenever we have a new evidence.

According to the analysis, students with personality type ISFJ have the highest probability of math anxiety. Students with personality type ISTP are most likely to study regularly. Female students more likely to have math anxiety, enjoy math more, and study math regularly than male students. Female students are more likely to be in all majors except in computer science, where male students are more likely to dominate.

The analysis demonstrated that math anxiety correlates with gender, personality type, and study habits among this group of university students. When separate analyses were conducted for males and females, different factors were significant for each gender; although students of both genders had the same opinions about math, the genders dealt with exams differently. This discrepancy may be explained by the fact that mathematics is often considered a male field. This possible explanation should be investigated more closely in future work.

Students with different personality types learn differently, and all teachers should be aware of this point and should learn about their students' personality types to better understand students' needs, adapt to each student's learning style, and provide adequate help to students with math anxiety. Therefore, we note the factor of teaching style and the role of math teachers in influencing their students' math learning; that is, a teacher's personality type is another factor that affects students' interest in math, and this issue should be studied further.

Discussing math, guessing answers to questions without fear of making mistakes, asking questions, actually doing the math and not simply repeating the processes, and having a positive attitude toward math might help students eliminate their math anxiety. It is always important to remind students that the key to success in mathematics is to practice regularly and that their practice with their homework and other assignments is very important when taking tests. Indeed, as with any mental or physical activity, practice sharpens skills and fosters success. We propose to look at the relationship between the two variables, personality type and homework, to learn more about ways to help students study more effectively.

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