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The Dynamic Curriculum Planning for a Database Design Tutoring System

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***Abstract*—As an intelligent tutoring system that tutors learners in the domain of relational database schema normalizations. This virtual tutor is designed to be able to dynamically plan a sequence of problem solving sessions based on the run time interactions between a learner and the virtual tutor. This is an essential effort to make a virtual tutor more humanized so that instead of reiterating the knowledge that a learner has already conceived the virtual tutor can more appropriately challenge the learner at a suitable level of difficulty.**

***Index Terms*—virtual tutor, intelligent tutoring system, dynamic curriculum planning.**

I. Introduction

WITHIN the shifting of paradigms from the traditional *Computer Aided Instruction (CAI)* to the newer *Intelligent Tutoring System (ITS)*, a remarkable advancement is that ITS can mimic real life tutoring behavior better than the traditional CAI. In real life, most of the human tutors will continuously evaluate the knowledge levels that their learners have conceived and prevent to reiterate what they have already learned. While the traditional CAI was not taking this essential human tutoring factor into consideration but tutoring all learners in the same manner to go through the entire set of predefined lessons, the newer ITS is more humanized in a manner of preparing dynamic curricula for learners based on their actually knowledge levels. This paper describes the dynamic curriculum planning within an intelligent tutoring system for relational database schema normalizations.

II. Background

ANT (A Normalization Tutor) is an intelligent tutoring system motivated by the necessity of tutoring students in the domain of relational database schema normalization. The normalization of relational schema is the most important trade-off between database performance and data redundancy. This is also one of the major hurdles that database beginners will struggle to leap over. With this concern in mind, I implemented an intelligent tutoring system to assist the learning of this domain. Cognitive studies showed that students being tutored privately can learn approximately four times faster than students attending traditional classroom lectures [5]. Considering the very limited availability and affordability of hiring private tutors, the most cost effective alternative is working with intelligent tutoring systems. Furthermore, learning from intelligent tutoring systems is authentic and risk free. The system is available 7 days a week and 24 hours a day. A student can sit comfortably and work with the system whenever possible.

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A. The Emulation of Real Life Tutoring

In this application domain, the life tutoring is emulated by the collaboration of five modules, namely the *student modeling*, the *instruction modeling*, the *domain knowledge*, the *curriculum planning* and the *user interface*. While tutoring, these five modules work together as follows [7], [8]:

1) The *student modeling* module is used to reflect a student's *cognitive status* of learning normalization. Based on the student's interaction with the system, it continuously evaluates the student's progress of knowledge acquisition, and diagnoses the misconceptions that a student has revealed. The overall learning status is then become the basis to plan an adaptive *curriculum* for the current student.

2) By consulting student modeling and domain knowledge, the adaptive *curriculum planning* module customizes a sequence of problem solving sessions to be conducted to the current student.

3) In accordance with the adaptive curriculum begin planned, the *instruction modeling* module mimics a human tutor to conduct the curriculum. In this system, I adopt the *Socratic style* of tutoring to control the discourse and avoid open-end discussions [2], [4], [6].

4) The *domain knowledge* is a typical module in intelligent systems. In this system, a *backward chaining* inference engine using rule-based normalization knowledge from *First Normal Form (1NF)* to *Third Normal Form (3NF)* is implemented to support the problem solving.

5) As an auxiliary module to facilitate learning, the *user interface* is a vital design to push through *learn-by-doing* and make a student feel comfortable and confident while working with the virtual tutor.

B. A Sample Tutoring Session

In the tutoring domain of ANT, the *Socratic style* of tutoring is implemented as a dynamic protocol driven by the interactions between a student and the virtual tutor. A sample tutoring session taken from the system is illustrated in the following steps [8]:

1) Presenting a 1NF schema to the student in which the *Primary Key (PK)* is *underlined* and the *Functional Dependencies (FDs)* are visualized by *arrows* going from the determinant attributes to dependent attributes as shown in Figure 1. This schema reads as *A and B* together are the compound *PK*, *A and B functionally determine C*, and *B functionally determines D*. The student is then asked to click the problematic *FD* that prevents R1 from being in 2NF or click the $\downarrow$ if R1 is in 2NF inherently.

2) Diagnosing the student's misconceptions based on what is being clicked. The user interface is designed to allow clicks on the given FDs and the $\downarrow$ only. In R1 the $B \rightarrow D$ is the only problematic FD that prevents R1 to be in 2NF. All

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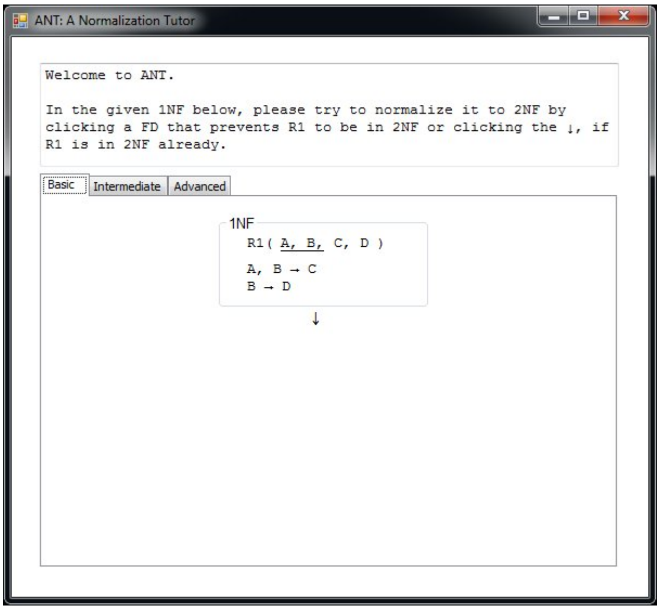

Fig. 1. A Given Schema in 1NF

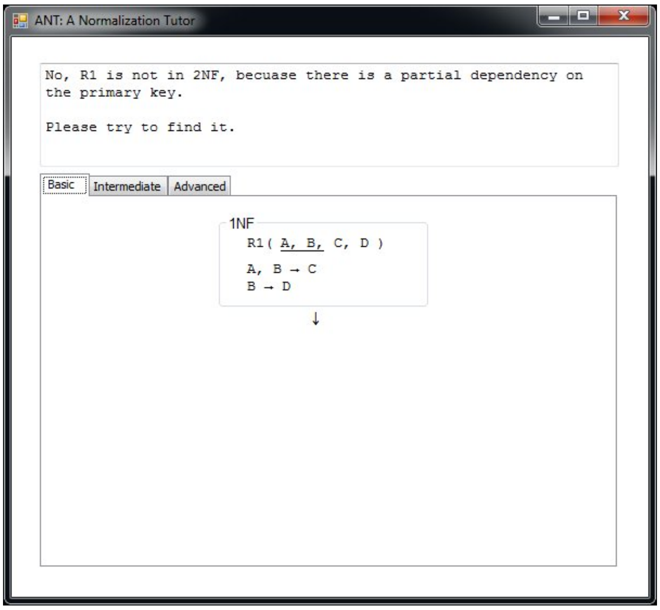

Fig. 2. Diagnosing the Student's Misconception about 2NF

other clicks are diagnosed as the student's misconceptions and the virtual tutor will take remediate actions accordingly to further guide the student towards finding the problematic FD as shown in Figure 2.

3) After the $B \to D$ is clicked, the system will decompose R1 into R2 and R3. Both R2 and R3 are now in 2NF. The student is then asked to click the *FD* that prevents R2 from being in 3NF or click the ↓ if R2 is in 3NF inherently as shown in Figure 3.

4) Diagnosing the students misconceptions based on what is being clicked. Since R2 is in 3NF already, the ↓ should be clicked. Other clicks are diagnosed as the student's misconceptions and the virtual tutor will take remediate actions accordingly as shown in Figure 4.

5) After the ↓ is clicked, the system will bring R3 down to the level of 3NF. The student is then asked to click the *FD* that prevents R3 from being in 3NF or click the ↓ if R3 is in 3NF inherently as shown in Figure 5.

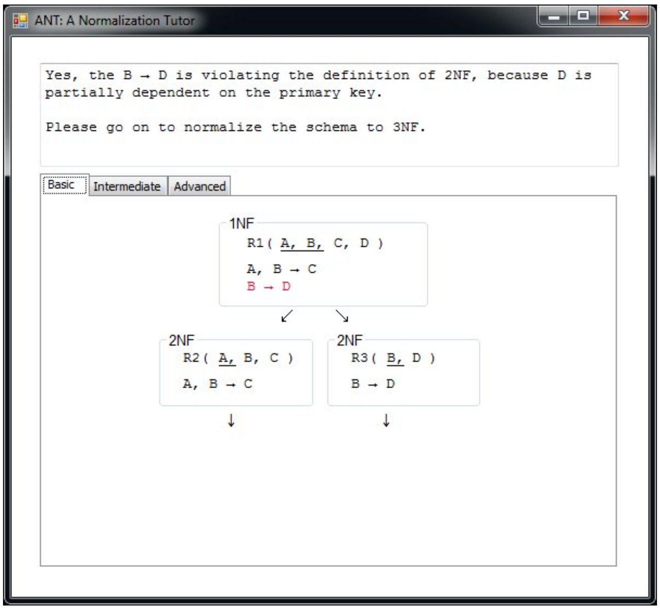

Fig. 3. The Schema Is Normalized into 2NF

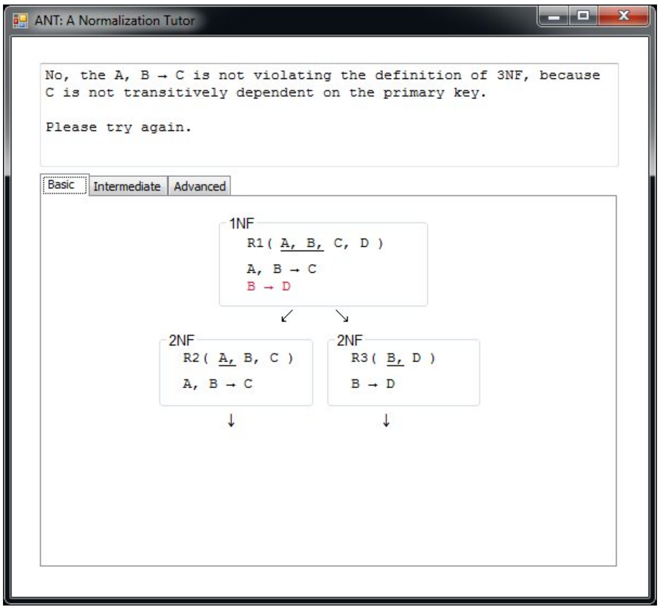

Fig. 4. Diagnosing the Student's Misconception about 3NF

6) Diagnosing the student's misconceptions based on what is being clicked. Since R3 is in 3NF already, the ↓ should be clicked. Other clicks are diagnosed as the student's misconceptions and the virtual tutor will take remediate actions accordingly as shown in Figure 6.

7) After the ↓ is clicked, the system will bring R3 down to the level of 3NF as shown in Figure 7.

Along with a tutoring session, the student is able to *visualize* the sequential processing of normalizations from 1NF to 3NF and *perceive* all of the misconceptions that have been made. At the end of a session the student's performance is evaluated and used as an indication to place the student at an appropriate level in the next tutoring session.

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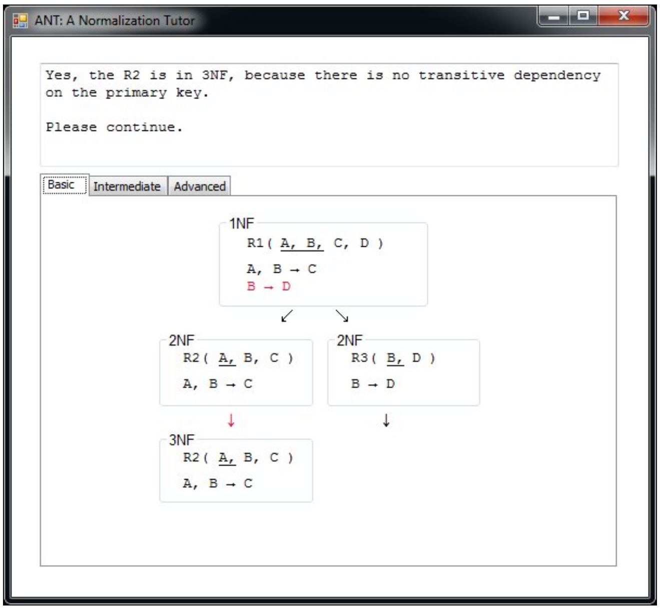

Fig. 5. The Schema Is Partly Normalized into 3NF

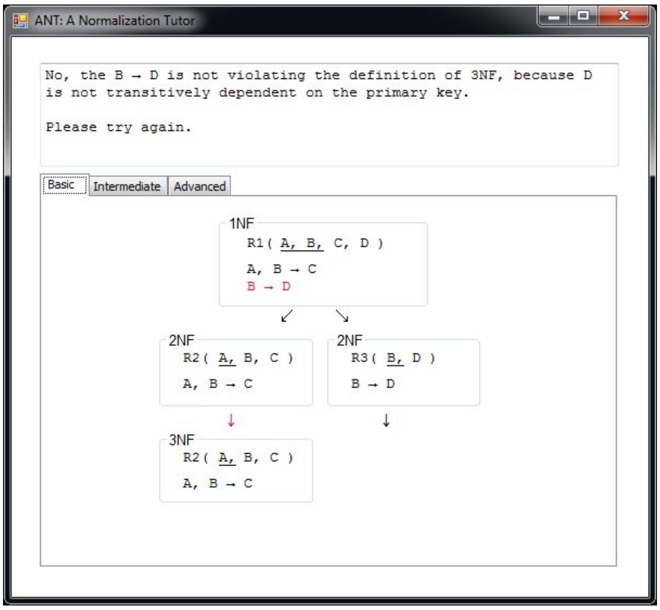

Fig. 6. Diagnosing the Student's Misconception about 3NF Again

III. THE DYNAMIC CURRICULUM PLANNING

The current version of ANT consists of three difficulty levels, namely the *basic level*, the *intermediate level* and the *advanced level*. Each difficulty level in turn consists of three problem solving sessions. Although the learner is allowed to choose any level to start a tutoring session, at the end of a session, the curriculum planning module will consult the student modeling module to know the learner's performance. Based on the learner's actual performance the curriculum planning module can dynamically determine a level for the next tutoring session. The learner may be *retained* at the same level, *promoted* to a higher level, or *demoted* to a lower level. So that different learners may go through different sequence of problem solving sessions until the domain knowledge is really comprehended.

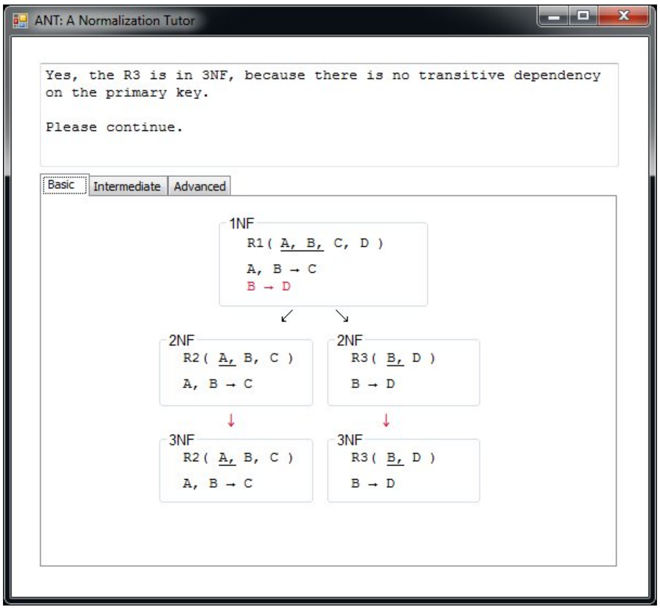

Fig. 7. The Schema Is Completely Normalized into 3NF

TABLE I
THE PROGRESSIONS AND MISCONCEPTIONS

Progression		Misconception	
1	From 1NF to 2NF	1	Misconceiving FFD
		2	Mis-defining 2NF
2	From 2NF to 3NF	1	Misconceiving TD
		2	Mis-defining 3NF

A. The Learning Status of a Student

To support the aforementioned dynamic curriculum planning, a student's misconceptions are continuously evaluated by the student modeling module during a tutoring session. In the current implementation the possible misconceptions in each progression are listed in Table 1, where the *FFD* stands for *Fully Functional Dependency*, and *TD* stands for *Transitive Dependency*. In this table, each progression is also numbered according to its difficulty level and each misconception is numbered according to its severe level within its related progression.

The learning status of a student is evaluated by the *Weighted Total of Misconceptions (WTM)* that a student has revealed during a tutoring session. Based on the misconceptions that a student has revealed, a *WTM* is calculated by accumulating the multiplication of each misconception number and its progression number. As an illustration of this weighted calculation, assume that a student has mis-defined 2NF and misconceived TD, this student's WTM is calculated as:

$$WTM = 1 \times 2 + 2 \times 1 = 4$$

At the end of a tutoring session, this WTM will be considered by the curriculum planning module to dynamically determine the difficult level of next tutoring session. Based the WTM scale listed in Table 2, the curriculum planning module may decide to retain, demote, or promote a student.

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TABLE II
THE WTM SCALE AND NEXT TUTORING SESSION

WTM Scale	Next Tutoring Session
WTM=0	Promote to the next higher level
$1 \leq$ WTM ≤ 2	Retain at the same level
WTM > 2	Demote to the next lower level

```
BEGIN
    Choose a difficulty level to start
    SWITCH (level)
        CASE basic:
             Go on to the planning of
             basic sessions
        CASE intermediate:
             Go on to the planning of
             intermediate sessions
        CASE advanced:
             Go on to the planning of
             advanced sessions
        CASE exit:
             Exit the system
    ENDSWITCH
END
```

Fig. 8. Choosing a Level to Start

B. The Start of Curriculum Planning

Whenever the system is executed, a curriculum is dynamically planned. At the beginning the virtual tutor allows students to choose any difficulty level to start based their self-estimation of knowledge levels. The algorithm to start a self-chosen session is shown in Figure 8. From then on, the virtual tutor may decide to promote, retain, or demote the student to a level that is considered to more appropriate for the current student.

C. The Planning of Basic Sessions

When the student has chosen to start from the basic level, or has been demoted to the basic level, the virtual tutor will sequentially conduct the three predefined problem solving sessions until the student is promoted to the intermediate level. If the student is still retained at this level after all of these threes sessions are conducted, the virtual tutor will repeat these sessions again until the the student is qualified for a promotion. The planning algorithm of basic sessions is shown in Figure 9.

D. The Planning of Intermediate Sessions

A student may choose to start from the intermediate level, may be promoted to the intermediate level, or may be demoted to the intermediate level. When the student enters this level, the virtual tutor will sequentially conduct the three predefined problem solving sessions until the student is either promoted to the advanced level or demoted to the basic level. If the student is still retained at this level after all of these threes sessions are conducted, the virtual tutor will repeat these sessions again until the the student is further promoted or demoted. The planning algorithm of intermediate sessions is shown in Figure 10.

```
BEGIN
    promoted = false
    WHILE (NOT promoted)
        Conduct basics session 1
        IF (WTM == 0)
            promoted = true
            BREAK
        ENDIF

        Conduct basics session 2
        IF (WTM == 0)
            promoted = true
            BREAK
        ENDIF

        Conduct basics session 3
        IF (WTM ==0)
            promoted = true
            BREAK
        ENDIF
    EDNWHILE
    Go on to the planning of intermediate
    sessions
END
```

Fig. 9. The Planning of Basic Sessions

E. The Planning of Advanced Sessions

A student may choose to start from the advanced level or may be promoted to the advanced level. When the student enters this level, the virtual tutor will sequentially conduct the three predefined problem solving sessions until the student is either qualified to leave the system or demoted to the intermediate level. If the student is still retained at this level after all of these threes sessions are conducted, the virtual tutor will repeat these sessions again until the the student is allowed to leave or demoted. The planning algorithm of intermediate sessions is shown in Figure 11.

IV. CONCLUSION

There is a fine line between challenging a student and frustrating a student. This critical trade-off is an essential tutoring philosophy that confronts not only human tutors but also virtual tutors. In the context of virtual tutoring, a good curriculum planner must able to dynamically choose and sequence the sessions to be tutored based on the run time interactions between a student and the virtual tutor [1], [3]. In this paper, I addressed the dynamic and adaptive curriculum planning within the tutoring domain of ANT system. Although the current implementation is covering the normalizations from 1NF to 3NF only, it will be continuously enhanced to have a full coverage of the normalizations from 1NF to 5NF. Some more related pedagogical theories will also be incorporated to further abound the tutoring strategies of this system.

V. ACKNOWLEDGEMENT

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```
BEGIN
    demoted = false
    retained = true
    promoted = false
    WHILE (retained)
        Conduct intermediate session 1
        IF (WTM > 2)
            demoted = true
            BREAK
        ELSE
            IF (WTM == 0)
                promoted = true
                BREAK
            ENDIF
        EKDIF

        Conduct intermediate session 2
        IF (WTM > 2)
            demoted = true
            BREAK
        ELSE
            IF (WTM == 0)
                promoted = true
                BREAK
            ENDIF
        EKDIF

        Conduct intermediate session 3
        IF (WTM > 2)
            demoted = true
            BREAK
        ELSE
            IF (WTM == 0)
                promoted = true
                BREAK
            ENDIF
        EKDIF
    EDNWHILE

    IF (demoted == true)
        Go on to the planning of
        basic sessions
    ELSE
        IF (promoted == true)
            Go on to the planning of
            advanced sessions
        ENDIF
    ENDIF
END
```

Fig. 10. The Planning of Intermediate Sessions

```
BEGIN
    demoted = false
    retained = true
    WHILE (retained)
        Conduct advanced session 1
        IF (WTM > 2)
            demoted = true
            BREAK
        ELSE
            IF (WTM == 0)
                BREAK
            ENDIF
        EKDIF

        Conduct advanced session 2
        IF (WTM > 2)
            demoted = true
            BREAK
        ELSE
            IF (WTM == 0)
                BREAK
            ENDIF
        EKDIF

        Conduct advanced session 3
        IF (WTM > 2)
            demoted = true
            BREAK
        ELSE
            IF (WTM == 0)
                BREAK
            ENDIF
        EKDIF
    EDNWHILE

    IF (demoted == true)
        Go on to the planning of
        intermediate sessions
    ENDIF
END
```

Fig. 11. The Planning of Advanced Sessions

REFERENCES

[1] B. Cho, J. Michael, A. Rovick and M. Evens, ”A Curriculum Plannig Model for an INtelligent Tutoring System,” in *Proceedings of the Twelfth International Florida AI Research Society Conference (FLAIRS-99)*, Orlando, FL, USA, pp. 197-201, 1999.

[2] M. Evens and J. Michael, ”One-on-One Tutoring by Humans and Computers,” *Mahwah, NJ, USA: Lawrence Erlbaum Associates Incorporation*, 2006.

[3] S. Katz, A. Lesgold, G. Eggan, M. Girdin and L. Greenberg, ”Self-adjusting Curriculum Planning in Sherlock II,” in *Lecture Notes in Computer Science: Proceedings of the Forth International Conference on Computers in Learning (ICCAL'92)*, Berlin: Springer Verlag, pp.343-355, 1992.

[4] G. Kearsley, ”Artificial Intelligence and Instruction: Applications and Methods,” *Reading, MA, USA: Addison Wesley Longman Publishing Corporation*, 1987.

[5] B. J. Reiser, J. R. Anderson and R. G. Farrell, ”Dynamic Student Modeling in an Intelligent Tutoring System for LISP Programming,” in *Proceedings of the Eighth International Joint Conference on Artificial Intelligence*, Los Angeles, CA, USA, pp. 8-14, 1985.

[6] E. Wenger, ”Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge,” in *Los Altos, CA, USA: Morgan Kaufmann Publishers Incorporation*, 1987.

[7] F. Yang, ”The Ideology of Intelligent Tutoring Systems,” *ACM Inroads*,Vol. 1, No 4, pp. 63-65, 2010.

[8] F. Yang, ”A Virtual Tutor for Relational Schema Normalization,” *ACM Inroads*,Vol. 2, No 3, pp. 38-42, 2011.