

# Database Principles: Fundamentals of Design, Implementation, and Management

Tenth Edition

## *Chapter 7*

### *Data Modeling with Entity Relationship Diagrams*

## Objectives

- In this chapter, students will learn:
  - The main characteristics of entity relationship components
  - How relationships between entities are defined, refined, and incorporated into the database design process
  - How ERD components affect database design and implementation
  - That real-world database design often requires the reconciliation of conflicting goals

# The Entity Relationship Model (ERM)

- ER model forms the basis of an ER diagram
- ERD represents conceptual database as viewed by end user
- ERDs depict database's main components:
  - Entities
  - Attributes
  - Relationships

## Entities

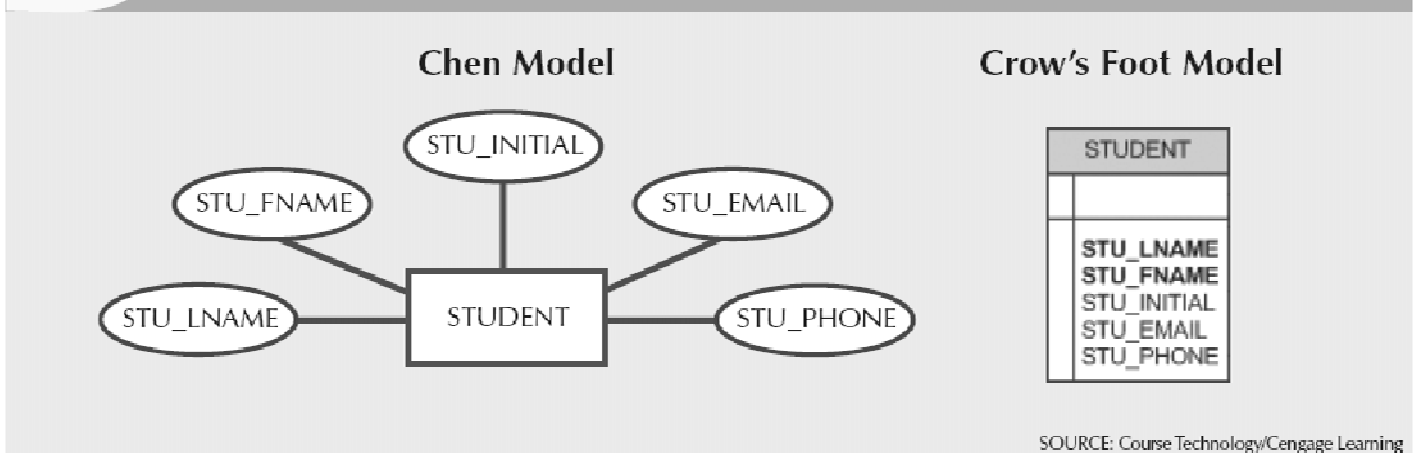
- Refers to entity set and not to single entity occurrence
- Corresponds to table and not to row in relational environment
- In Chen and Crow's Foot models, entity is represented by rectangle with entity's name
- The entity name, a noun, is written in capital letters

# Attributes

- Characteristics of entities
- Chen notation: attributes represented by ovals connected to entity rectangle with a line
  - Each oval contains the name of attribute it represents
- Crow's Foot notation: attributes written in attribute box below entity rectangle

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**FIGURE 7.1** The attributes of the STUDENT entity: Chen and Crow's Foot



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# Attributes (cont'd.)

- Required attribute: must have a value
- Optional attribute: may be left empty
- Domain: set of possible values for an attribute
  - Attributes may share a domain
- Identifiers: one or more attributes that uniquely identify each entity instance
- Composite identifier: primary key composed of more than one attribute

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**FIGURE 7.2** The CLASS table (entity) components and contents

Database name: Ch07\_TinyCollege

CLASS_CODE	CRS_CODE	CLASS_SECTION	CLASS_TIME	ROOM_CODE	PROF_NUM
10012	ACCT-211	1	MWF 8:00-8:50 a.m.	BUS311	105
10013	ACCT-211	2	MWF 9:00-9:50 a.m.	BUS200	105
10014	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10015	ACCT-212	1	MWF 10:00-10:50 a.m.	BUS311	301
10016	ACCT-212	2	Th 6:00-8:40 p.m.	BUS252	301
10017	CIS-220	1	MWF 9:00-9:50 a.m.	KLR209	228
10018	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10019	CIS-220	3	MWF 10:00-10:50 a.m.	KLR209	228
10020	CIS-420	1	W 6:00-8:40 p.m.	KLR209	162
10021	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114
10022	QM-261	2	TTh 1:00-2:15 p.m.	KLR200	114
10023	QM-362	1	MWF 11:00-11:50 a.m.	KLR200	162
10024	QM-362	2	TTh 2:30-3:45 p.m.	KLR200	162
10025	MATH-243	1	Th 6:00-8:40 p.m.	DRE155	325

SOURCE: Course Technology/Cengage Learning

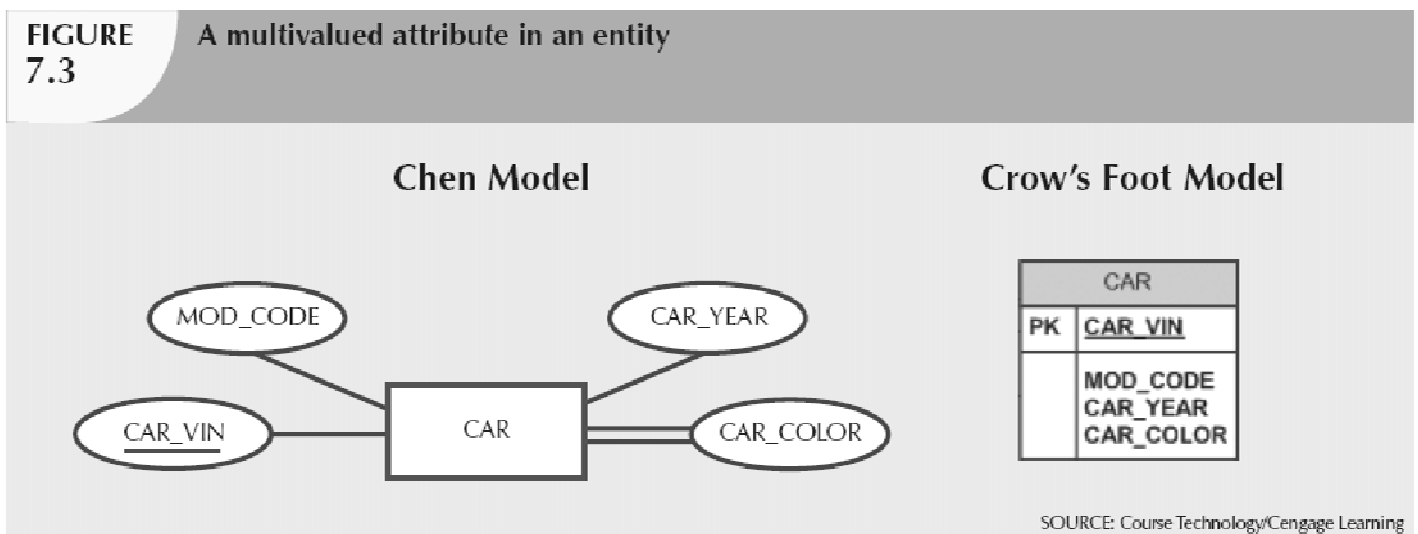
# Attributes (cont'd.)

- Composite attribute can be subdivided
- Simple attribute cannot be subdivided
- Single-value attribute can have only a single value
- Multivalued attributes can have many values

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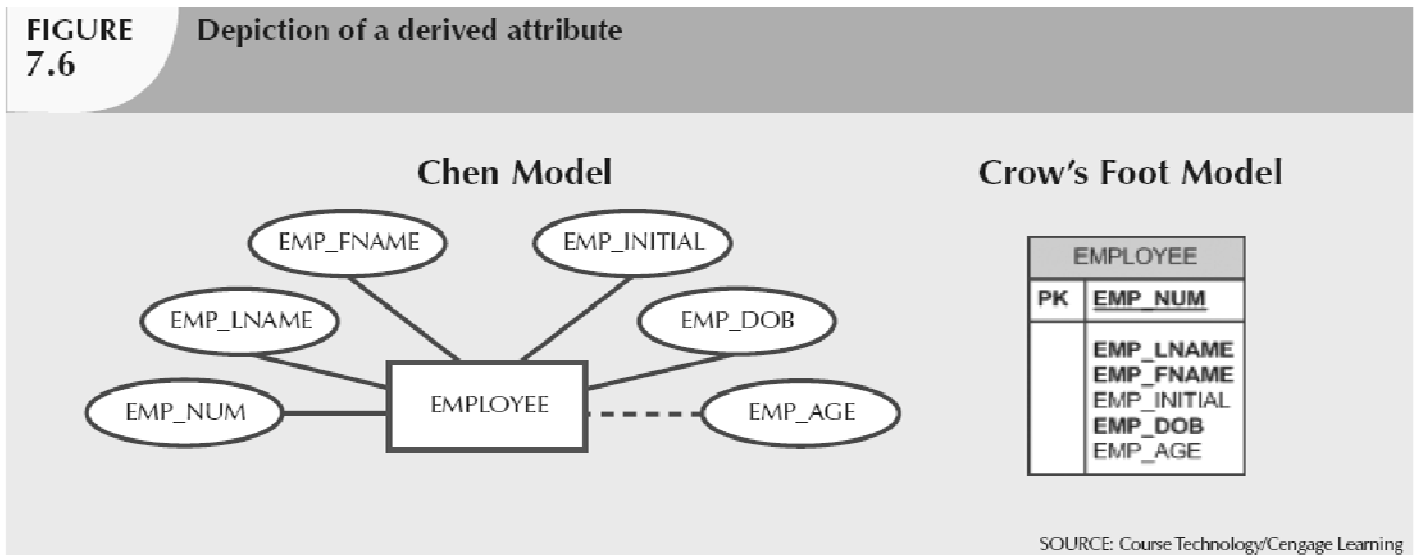
**FIGURE 7.3** A multivalued attribute in an entity



SOURCE: Course Technology/Cengage Learning

# Attributes (cont'd.)

- M:N relationships and multivalued attributes should not be implemented
  - Create several new attributes for each of the original multivalued attributes' components
  - Create new entity composed of original multivalued attributes' components
- Derived attribute: value may be calculated from other attributes
  - Need not be physically stored within database



**TABLE 7.2** Advantages and Disadvantages of Storing Derived Attributes

	DERIVED ATTRIBUTE	
	STORED	NOT STORED
<b>Advantage</b>	Saves CPU processing cycles Saves data access time Data value is readily available Can be used to keep track of historical data	Saves storage space Computation always yields current value
<b>Disadvantage</b>	Requires constant maintenance to ensure derived value is current, especially if any values used in the calculation change	Uses CPU processing cycles Increases data access time Adds coding complexity to queries

# Relationships

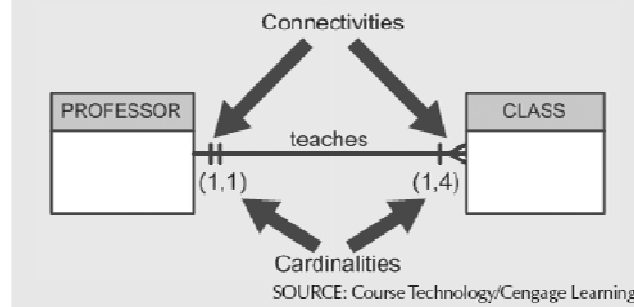
- Association between entities
- Participants are entities that participate in a relationship
- Relationships between entities always operate in both directions
- Relationship can be classified as 1:M
- Relationship classification is difficult to establish if only one side of the relationship is known

## Connectivity and Cardinality

- Connectivity
  - Describes the relationship classification
- Cardinality
  - Expresses minimum and maximum number of entity occurrences associated with one occurrence of related entity
- Established by very concise statements known as business rules

FIGURE  
7.7

Connectivity and cardinality in  
an ERD



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## Existence Dependence

- Existence dependence
  - Entity exists in database only when it is associated with another related entity occurrence
- Existence independence
  - Entity can exist apart from one or more related entities
  - Sometimes such an entity is referred to as a strong or regular entity

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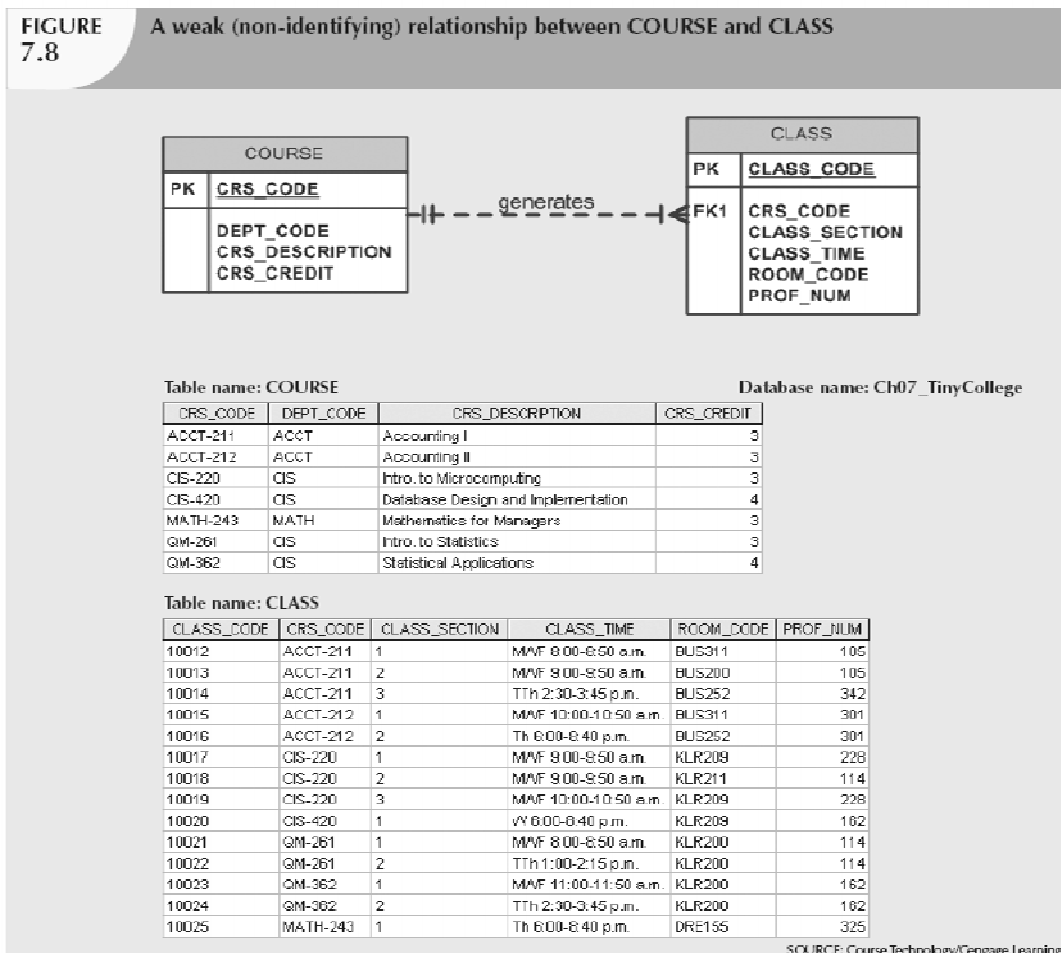
16



# Relationship Strength

- Weak (non-identifying) relationships
  - Exists if PK of related entity does not contain PK component of parent entity
- Strong (identifying) relationships
  - Exists when PK of related entity contains PK component of parent entity

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**FIGURE 7.9**

**A strong (identifying) relationship between COURSE and CLASS**

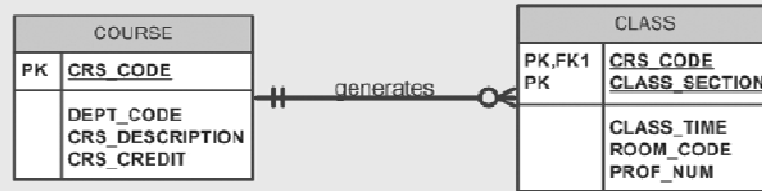


Table name: COURSE

CRS_CODE	DEPT_CODE	CRS_DESCRIPTION	CRS_CREDIT
ACCT-211	ACCT	Accounting I	3
ACCT-212	ACCT	Accounting II	3
CIS-220	CIS	Intro. to Microcomputing	3
CIS-420	CIS	Database Design and Implementation	4
MATH-243	MATH	Mathematics for Managers	3
QM-261	CIS	Intro. to Statistics	3
QM-362	CIS	Statistical Applications	4

Database name: Ch07\_TinyCollege\_All

Table name: CLASS

CRS_CODE	CLASS_SECTION	CLASS_TIME	ROOM_CODE	PROF_NUM
ACCT-211	1	MMWF 8:00-9:50 a.m.	BUS311	105
ACCT-211	2	MMWF 9:00-9:50 a.m.	BUS200	105
ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
ACCT-212	1	MMWF 10:00-10:50 a.m.	BUS311	301
ACCT-212	2	Th 6:00-8:40 p.m.	BUS252	301
CIS-220	1	MMWF 9:00-9:50 a.m.	KLR209	228
CIS-220	2	MMWF 9:00-9:50 a.m.	KLR211	114
CIS-220	3	MMWF 10:00-10:50 a.m.	KLR209	228
CIS-420	1	W 6:00-8:40 p.m.	KLR209	162
MATH-243	1	Th 6:00-8:40 p.m.	DRE155	325
QM-261	1	MMWF 8:00-9:50 a.m.	KLR200	114
QM-261	2	TTh 1:00-2:15 p.m.	KLR200	114
QM-362	1	MMWF 11:00-11:50 a.m.	KLR200	162
QM-362	2	TTh 2:30-3:45 p.m.	KLR200	162

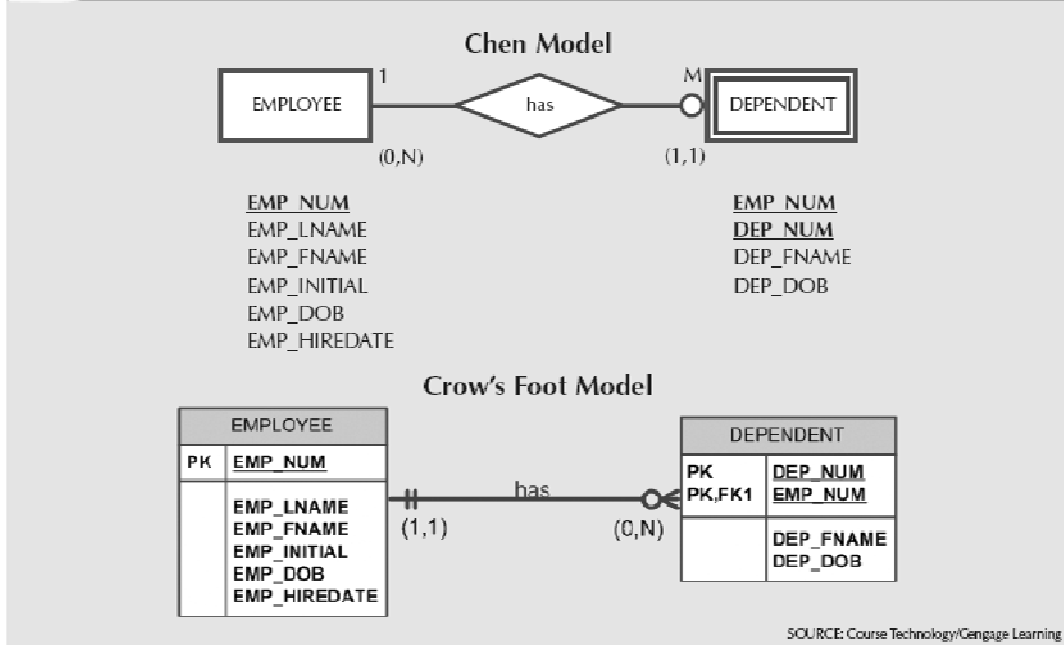
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## Weak Entities

- Weak entity meets two conditions
  - Existence-dependent
  - Primary key partially or totally derived from parent entity in relationship
- Database designer determines whether an entity is weak based on business rules

**FIGURE 7.10** A weak entity in an ERD



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**FIGURE 7.11** A weak entity in a strong relationship

**Table name: EMPLOYEE** Database name: Ch07\_ShortCo

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_DOB	EMP_HIREDATE
1001	Callitants	Jeanine	J	12-Mar-64	25-May-97
1002	Smithson	William	K	23-Nov-70	28-May-97
1003	Washington	Herman	H	15-Aug-68	28-May-97
1004	Chen	Lydia	B	23-Mar-74	15-Oct-98
1005	Johnson	Melanie		28-Sep-66	20-Dec-98
1006	Ortega	Jorge	G	12-Jul-79	05-Jan-02
1007	O'Donnell	Peter	D	10-Jun-71	23-Jun-02
1008	Brzenski	Barbara	A	12-Feb-70	01-Nov-03

**Table name: DEPENDENT**

EMP_NUM	DEP_NUM	DEP_FNAME	DEP_DOB
1001	1	Anniccio	05-Dec-97
1001	2	Jorge	30-Sep-02
1003	1	Suzanne	25-Jan-04
1006	1	Carlos	25-May-01
1008	1	Michael	19-Feb-95
1008	2	George	27-Jun-98
1008	3	Katherine	18-Aug-03

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# Relationship Participation

- Optional participation
  - One entity occurrence does not require corresponding entity occurrence in particular relationship
- Mandatory participation
  - One entity occurrence requires corresponding entity occurrence in particular relationship

TABLE 7.3 Crow's Foot Symbols

CROW'S FOOT SYMBOLS	CARDINALITY	COMMENT
⊙	(0,N)	Zero or many; the "many" side is optional.
⊙	(1,N)	One or many; the "many" side is mandatory.
	(1,1)	One and only one; the "1" side is mandatory.
⊙	(0,1)	Zero or one; the "1" side is optional.

FIGURE 7.13

CLASS is optional to COURSE



SOURCE: Course Technology/Cengage Learning

FIGURE 7.14

COURSE and CLASS in a mandatory relationship



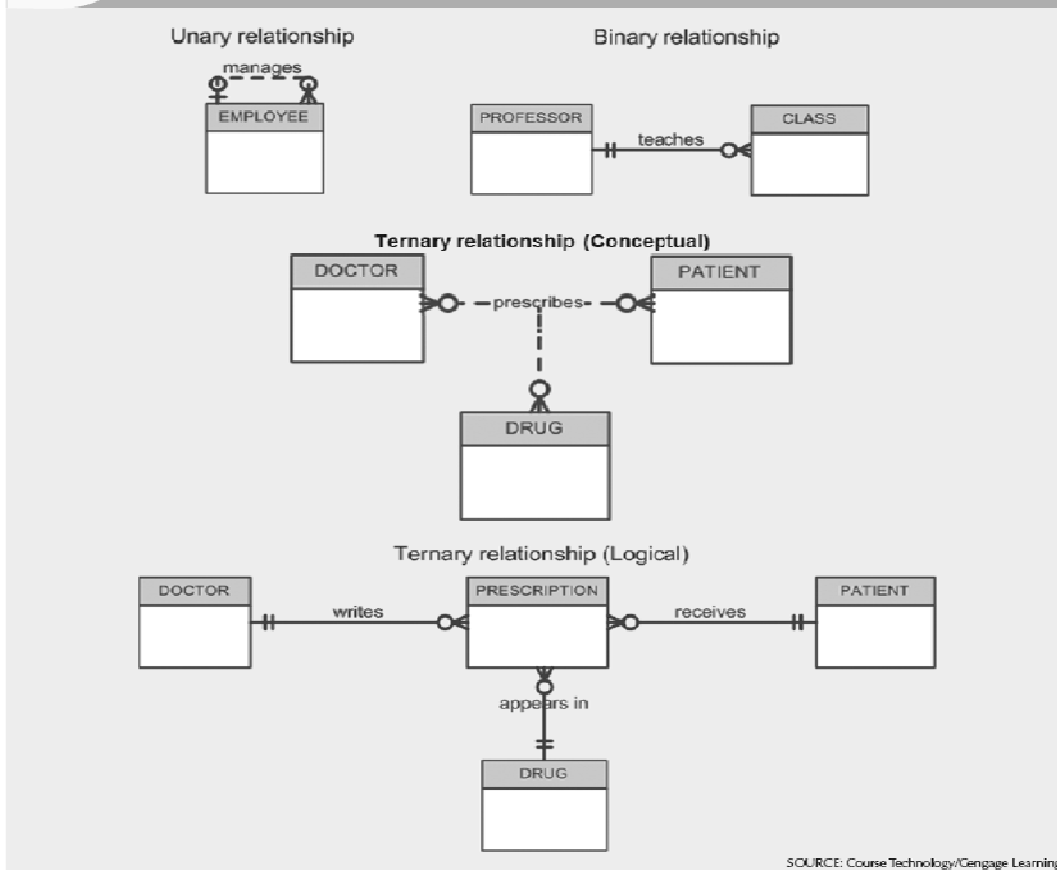
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## Relationship Degree

- Indicates number of entities or participants associated with a relationship
- Unary relationship
  - Association is maintained within single entity
- Binary relationship
  - Two entities are associated
- Ternary relationship
  - Three entities are associated

**FIGURE 7.15** Three types of relationship degree



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**FIGURE 7.16** The implementation of a ternary relationship

Database name: Ch07\_Clinic

**Table name: DRUG**

DRUG_CODE	DRUG_NAME	DRUG_PRICE
AF15	Atgopen-15	25.00
AF25	Atgopen-25	35.00
DR0	Diazepam-Chloride	111.88
DRZ	Diazepam-Crystalline	18.88
KO15	Kolobor-Oxycodone	85.75
OLE	Oleander-Orizapan	123.65
TRYP	Tryptotec-HepatitisB	79.45

**Table name: PATIENT**

PAT_NUM	PAT_TITLE	PAT_LNAME	PAT_FNAME	PAT_INITIAL	PAT_DOB	PAT_AREACODE	PAT_PHONE
100	Mr.	Kelmycz	George	D	15-Jun-1962	615	324-5496
101	Ms.	Lovins	Rhonda	G	15-Mar-2005	615	324-4472
102	Mr.	Varcan	Rhett		14-Nov-1955	501	675-6553
103	Ms.	Jones	Anne	M	15-Oct-1974	615	888-3498
104	Mr.	Lange	John	P	08-Nov-1971	501	504-4430
105	Mr.	Williams	Robert	D	14-Mar-1975	615	800-8220
106	Mrs.	Smith	Jeanine	K	12-Feb-2000	615	524-7883
107	Mr.	Claris	Jorge	D	21-Aug-1974	615	880-4587
108	Mr.	Wessentech	Paul	R	14-Feb-1988	615	887-4388
109	Mr.	Smith	George	K	15-Jun-1981	501	504-3330
110	Mrs.	Garkazi	Lolita	M	18-May-1970	501	669-6095
111	Mr.	Washington	Rusard	E	03-Jan-1985	615	880-4025
112	Mr.	Johnson	Edward	E	14-May-1961	615	698-4387
113	Ms.	Smythe	Melanie	P	15-Sep-1970	615	324-9006
114	Ms.	Brandon	Marie	G	02-Nov-1992	501	682-6045
115	Mrs.	Saranda	Hermine	R	25-Jul-1972	615	324-5505
116	Mr.	Smith	George	A	08-Nov-1985	615	880-2894

**Table name: DOCTOR**

DOC_ID	DOC_LNAME	DOC_FNAME	DOC_INITIAL	DOC_SPECIALTY
29927	Sanchez	Julie	J	Dermatology
32145	Jorgensen	Annalisa	G	Neurology
33455	Korenski	Anatoly	A	Urology
33985	LaGrande	George		Pediatrics
34410	Washington	Dennis	F	Orthopedics
38221	McPherson	Ralph	H	Dermatology
38712	Orteling	Herman	G	Psychiatry
38995	Ninh	Tien		Neurology
40014	Chin	Mina	D	Orthopedics
40028	Feinstein	Denise	L	Gynecology

**Table name: PRESCRIPTION**

DOC_ID	PAT_NUM	DRUG_CODE	PRES_DOSEAGE	PRES_DATE
32445	102	DRZ	2 tablets every four hours -- 50 tablets total	12-Nov-12
32445	113	OLE	1 tea spoon with each meal -- 250 ml total	14-Nov-12
34409	101	KO15	1 tablet every six hours -- 30 tablets total	14-Nov-12
38221	109	DR0	2 tablets with every meal -- 60 tablets total	14-Nov-12
38985	107	KO15	1 tablet every six hours -- 30 tablets total	14-Nov-12

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# Recursive Relationships

- Relationship can exist between occurrences of the same entity set
  - Naturally found within unary relationship

**FIGURE 7.19** Another unary relationship: "PART contains PART"

Table name: PART\_V1 Database name: CH07\_PartCo

PART_CODE	PART_DESCRIPTION	PART_IN_STOCK	PART_UNITS_NEEDED	PART_OF_PART
AA21-6	2.5 cm. washer, 1.0 mm. rim	432		4 C-130
AB-121	Cotter pin, copper	1034		2 C-130
C-130	Rotor assembly	36		
E129	2.5 cm. steel shank	128		1 C-130
X10	10.25 cm. rotor blade	345		4 C-130
X34AW	2.5 cm. hex nut	879		2 C-130

SOURCE: Course Technology/Cengage Learning

**FIGURE 7.20** Implementation of the M:N recursive relationship "PART contains PART"

Table name: COMPONENT Database name: Ch07\_PartCo

COMP_CODE	PART_CODE	COMP_PARTS_NEEDED
C-130	AA21-6	4
C-130	AB-121	2
C-130	E129	1
C-131A2	E129	1
C-130	X10	4
C-131A2	X10	1
C-130	X34AW	2
C-131A2	X34AW	2

Table name: PART

PART_CODE	PART_DESCRIPTION	PART_IN_STOCK
AA21-6	2.5 cm. washer, 1.0 mm. rim	432
AB-121	Cotter pin, copper	1034
C-130	Rotor assembly	36
E129	2.5 cm. steel shank	128
X10	10.25 cm. rotor blade	345
X34AW	2.5 cm. hex nut	879

SOURCE: Course Technology/Cengage Learning

**FIGURE  
7.22**

**Implementation of the 1:M recursive relationship "EMPLOYEE manages EMPLOYEE"**

Table name: EMPLOYEE\_V2

EMP_CODE	EMP_NAME	EMP_MANAGER
101	Waddell	102
102	Orincona	
103	Jones	102
104	Rebailoh	102
105	Robertson	102
106	Deltona	102

Database name: Ch07\_PartCo

SOURCE: Course Technology/Cengage Learning

## Associative (Composite) Entities

- Also known as bridge entities
- Used to implement M:N relationships
- Composed of primary keys of each of the entities to be connected
- May also contain additional attributes that play no role in connective process



**FIGURE 7.23**

**Converting the M:N relationship into two 1:M relationships**

Database name: Ch07\_CollegeTry

Table name: STUDENT

STU_NUM	STU_LNAME
321452	Bowser
324257	Smithson

Table name: ENROLL

CLASS_CODE	STU_NUM	ENROLL_GRADE
10014	321452	C
10014	324257	B
10018	321452	A
10018	324257	B
10021	321452	C
10021	324257	C

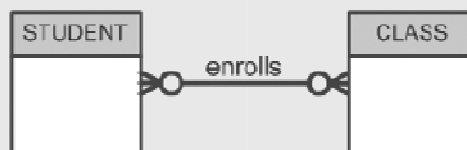
Table name: CLASS

CLASS_CODE	CRS_CODE	CLASS_SECTION	CLASS_TIME	ROOM_CODE	PROF_NUM
10014	ACCT-211	3	TTh 2:30-3:45 p.m.	BUS252	342
10018	CIS-220	2	MWF 9:00-9:50 a.m.	KLR211	114
10021	QM-261	1	MWF 8:00-8:50 a.m.	KLR200	114

SOURCE: Course Technology/Cengage Learning

**FIGURE 7.24**

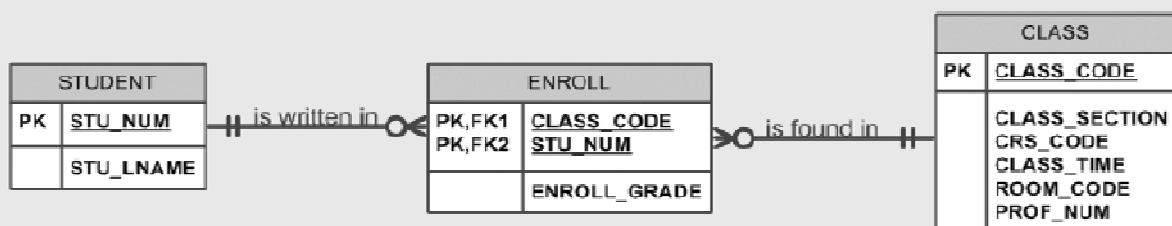
**The M:N relationship between STUDENT and CLASS**



SOURCE: Course Technology/Cengage Learning

**FIGURE 7.25**

**A composite entity in an ERD**



SOURCE: Course Technology/Cengage Learning

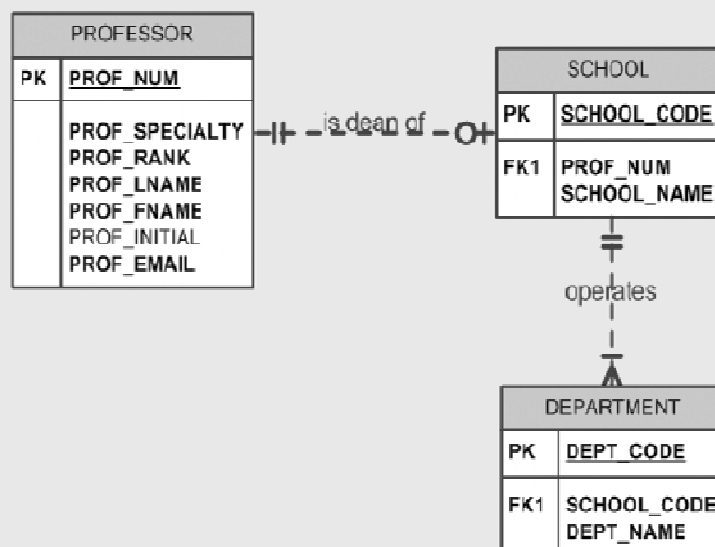
# Developing an ER Diagram

- Database design is an iterative process
  - Create detailed narrative of organization's description of operations
  - Identify business rules based on description of operations
  - Identify main entities and relationships from business rules
  - Develop initial ERD
  - Identify attributes and primary keys that adequately describe entities
  - Revise and review ERD

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FIGURE 7.26 The first Tiny College ERD segment



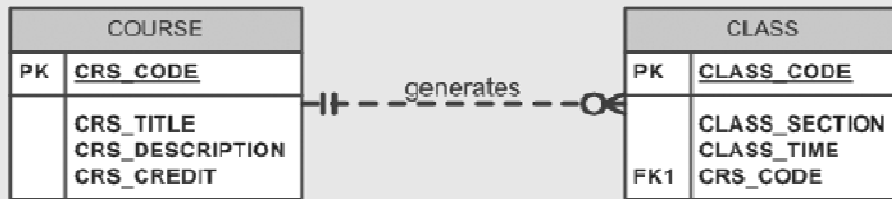
SOURCE: Course Technology/Cengage Learning

**FIGURE 7.27** The second Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

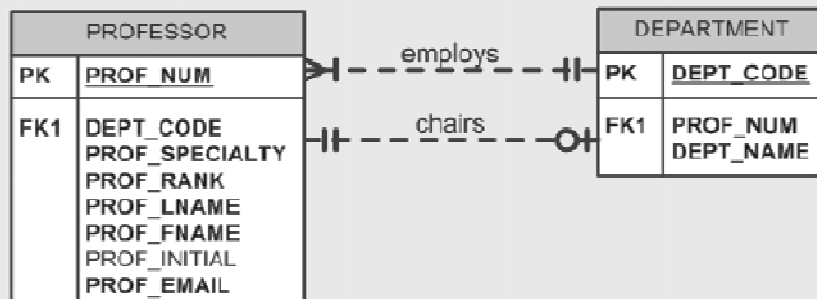
**FIGURE 7.28** The third Tiny College ERD segment



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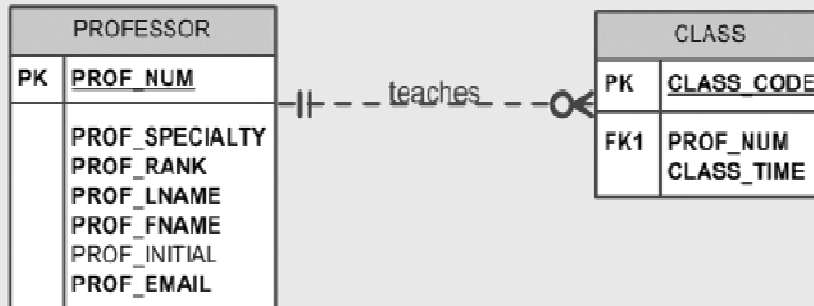
**FIGURE 7.29** The fourth Tiny College ERD segment



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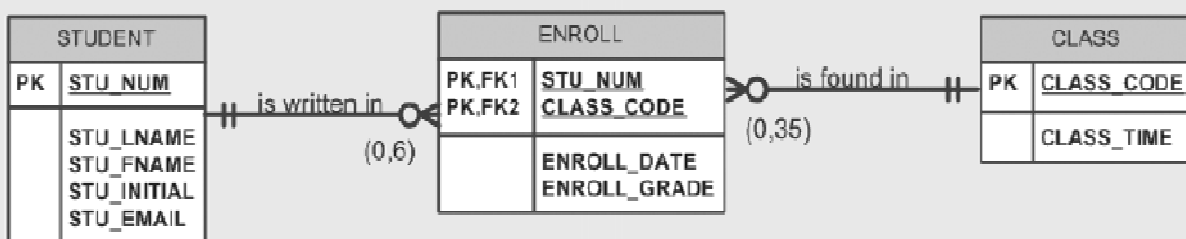
**FIGURE 7.30** The fifth Tiny College ERD segment



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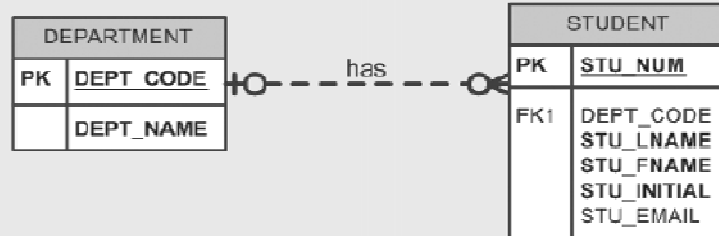
**FIGURE 7.31** The sixth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

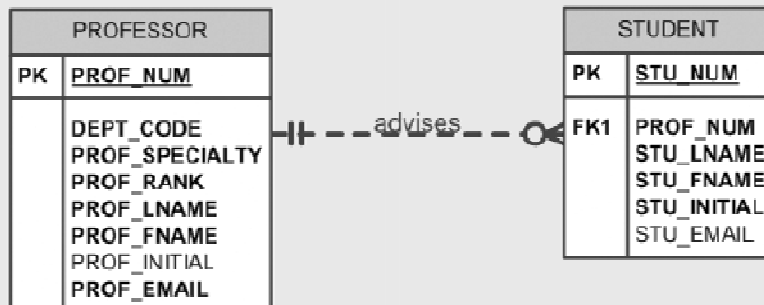
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**FIGURE 7.32** The seventh Tiny College ERD segment



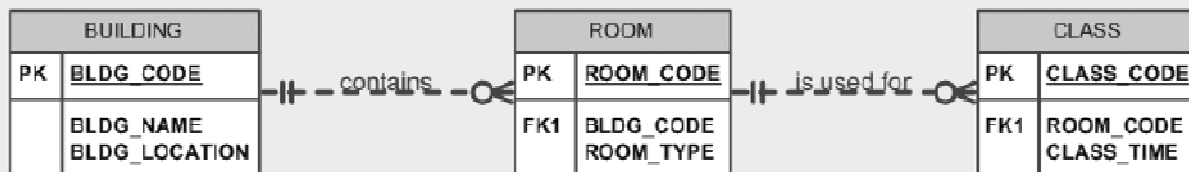
SOURCE: Course Technology/Cengage Learning

**FIGURE 7.33** The eighth Tiny College ERD segment



SOURCE: Course Technology/Cengage Learning

**FIGURE 7.34** The ninth Tiny College ERD segment



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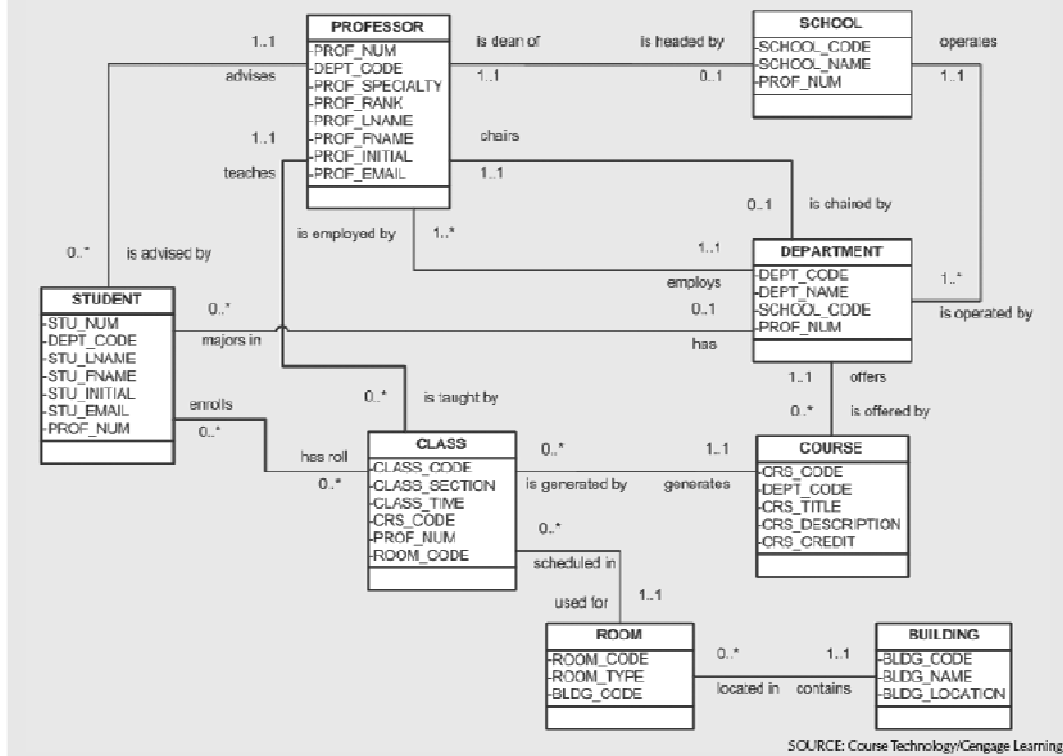
**TABLE 7.4** Components of the ERM

ENTITY	RELATIONSHIP	CONNECTIVITY	ENTITY
SCHOOL	operates	1:M	DEPARTMENT
DEPARTMENT	has	1:M	STUDENT
DEPARTMENT	employs	1:M	PROFESSOR
DEPARTMENT	offers	1:M	COURSE
COURSE	generates	1:M	CLASS
PROFESSOR	is dean of	1:1	SCHOOL
PROFESSOR	chairs	1:1	DEPARTMENT
PROFESSOR	teaches	1:M	CLASS
PROFESSOR	advises	1:M	STUDENT
STUDENT	enrolls in	M:N	CLASS
BUILDING	contains	1:M	ROOM
ROOM	is used for	1:M	CLASS

Note: ENROLL is the composite entity that implements the M:N relationship "STUDENT enrolls in CLASS."

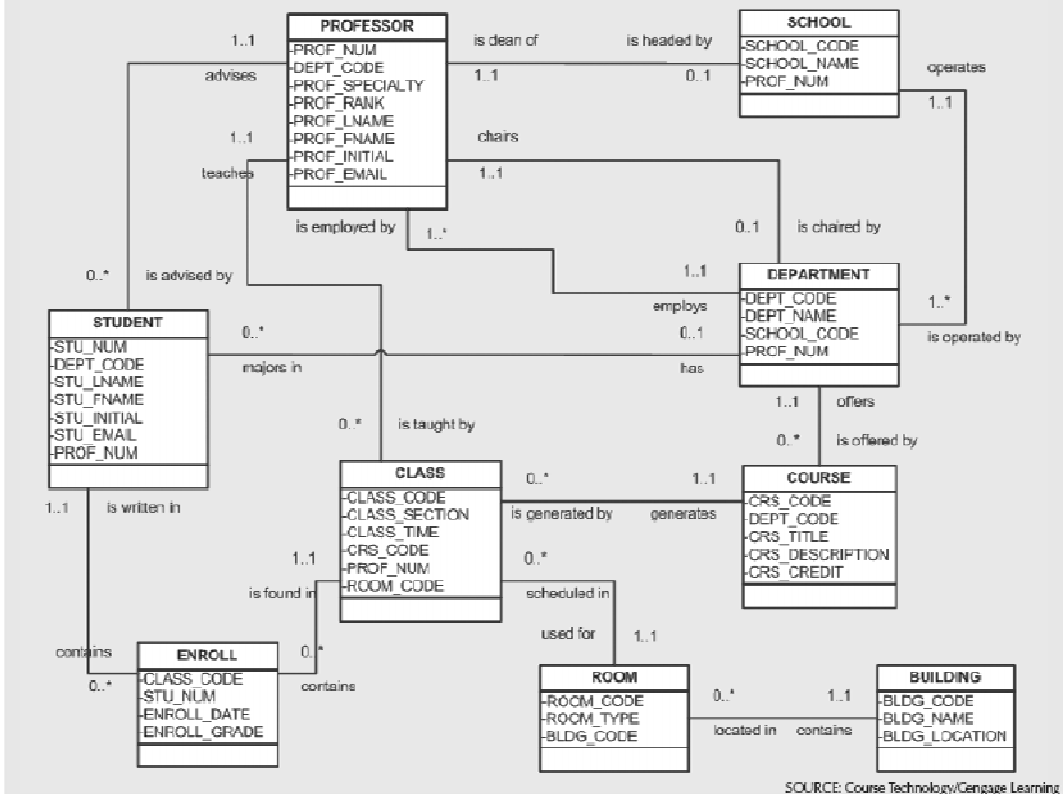
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**FIGURE 7.36** The conceptual UML class diagram for Tiny College



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**FIGURE 7.37** The implementation-ready UML class diagram for Tiny College

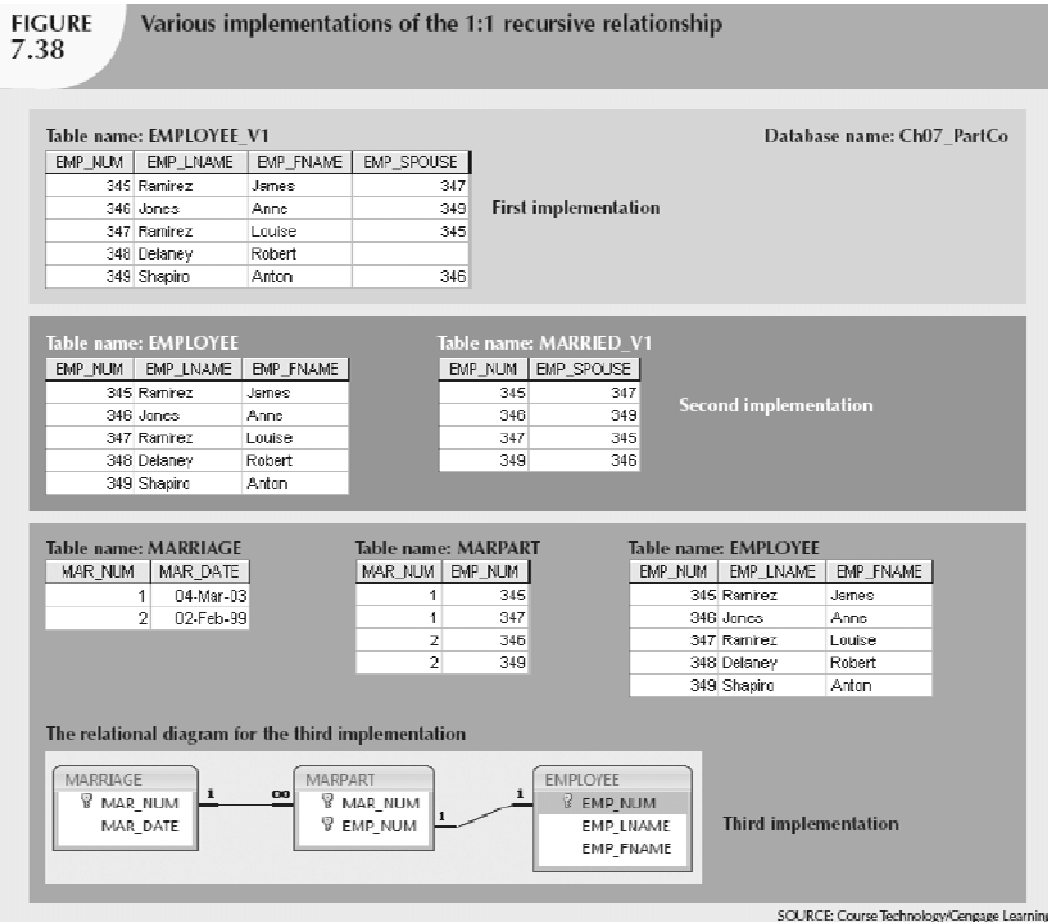


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# Database Design Challenges: Conflicting Goals

- Database designers must make design compromises
  - Conflicting goals: design standards, processing speed, information requirements
- Important to meet logical requirements and design conventions
- Design is of little value unless it delivers all specified query and reporting requirements
- Some design and implementation problems do not yield “clean” solutions

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# Summary

- Entity relationship (ER) model
  - Uses ERD to represent conceptual database as viewed by end user
  - ERM's main components:
    - Entities
    - Relationships
    - Attributes
  - Includes connectivity and cardinality notations

## Summary (cont'd.)

- Connectivities and cardinalities are based on business rules
- M:N relationship is valid at conceptual level
  - Must be mapped to a set of 1:M relationships
- ERDs may be based on many different ERMs
- UML class diagrams are used to represent the static data structures in a data model
- Database designers are often forced to make design compromises