CONTENT KNOWLEDGE TRANSFORMATION: AN EXAMINATION OF THE RELATIONSHIP BETWEEN CONTENT KNOWLEDGE AND CURRICULA

By: Ang Chen and Catherine D. Ennis

Abstract:

Theories associated with teacher knowledge suggest that teachers transform subject content knowledge into pedagogical content knowledge in teaching to enhance the content comprehensibility. It is assumed that the connection between teacher content knowledge and curriculum is characterized by the content knowledge transformation. This study, using an interpretive research method combined with cognitive knowledge elicitation and mapping approaches, examined the subject–pedagogical content knowledge transformation process that was associated with the teachers' curricular decision-making in secondary physical education. Findings indicated that the teachers shared a common subject content knowledge base but demonstrated a personalized pedagogical content knowledge repertoire, suggesting that the teachers' pedagogical content knowledge was personally constructed even though they shared a subject content knowledge base. The classroom curriculum was closely connected to the pedagogical content knowledge base. In addition, the teachers' curricular decisions regarding content inclusion/exclusion were primarily based on their perceptions of student learning abilities. The findings may imply that enhancement of prospective teachers' pedagogical content knowledge should be emphasized in teacher preparation programs because it serves as a bridge linking the subject content knowledge with the curriculum delivered in classrooms.

Article:

Teacher content knowledge is conceptualized in different yet related components that include subject content knowledge and pedagogical content knowledge (Shulman, 1986). In Shulman's (1986) content knowledge taxonomy, subject content knowledge refers to concepts, principles, and skills within a particular subject discipline. Key ideas, concepts, and skills in the subject content knowledge serve as "steel fibers" in the construction of the curriculum (Goodlad & Su, 1992). In different academic disciplines, those key ideas, concepts, and skills have been identified in academic areas of mathematics (Lampert, 1986), physics (Chi, Feltovich, & Glaser, 1981), and physical education (Jewett & Mullan, 1977). However, subject content knowledge usually is not taught in its original form as stored in the teacher's memory. A knowledge transformation is considered necessary. During the transformation, the teacher may elaborate on the subject content knowledge, identify various representations for the concepts, and reshape the knowledge into a teachable form to maximize its comprehensibility for student learning (Shulman, 1987). The teacher's knowledge of representations for presenting subject content knowledge is then detined as pedagogical content knowledge. This knowledge consists of useful forms of representations for the subject content knowledge such as analogies, illustrations, examples, explanations, demonstrations, learning cues, drills, "in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). The teacher is expected to be able to transform the subject content knowledge to pedagogical content knowledge for effective teaching.

Subject-to-pedagogical content knowledge transformation includes interpretation, representation, and adaptation stages. It is assumed that through these stages the teacher clarifies and interprets the subject content knowledge, identifies and determines representations for presentation of the subject content knowledge, and adapts and

tailors the transformed subject content knowledge to meet students' characteristics and needs (Wilson, Shulman, & Richert, 1987). Teachers' subject-to-pedagogical content knowledge transformation is considered directly relating to students' learning. Walkwitz and Lee (1992) examined how pedagogical content knowledge could facilitate effectiveness of teaching overhand throwing skill in physical education. In a teacher training program, a group of teachers was provided with pedagogical content knowledge information, while a control group received subject content knowledge information only. Their findings demonstrated that students taught by the teachers in the pedagogical content knowledge training group gained better performance and understanding about the throwing pattern. In science education, Smith and Neale (1989) studied science teachers' use of pedagogical content knowledge. Their findings suggest that not all teachers transform their subject content knowledge into pedagogical content knowledge during teaching. What was needed in the teachers' knowledge repertoire was a set of specific concept representations consisting of examples and metaphors such as strands of spaghetti to represent light rays (Smith & Neale, 1989, p. 16). These studies imply that an effective teacher is expected to be able to transform the subject content knowledge to pedagogical content knowledge so that he or she can make sound curriculum decisions in teaching. Wilson et al. (1987) suggest that because students are different in abilities, prior knowledge, and learning styles, teachers should be able to teach a concept in "150 different ways" (p. 104). In order for a teacher to be able to teach effectively, the teacher "should possess a *representational repertoire* that consists of the metaphors, analogies, illustrations, activities, assignments, and examples that teachers used to transform the content for instruction" (Wilson et al., 1987, pp. 119-120). In other words, the teacher should be able to transform the subject content knowledge into pedagogical content knowledge in order to make relevant curriculum decisions to meet the challenges in different teaching settings. Because the teacher is required to be able to prioritize the key ideas, concepts, and skills in the subject content knowledge and determine the representations for classroom presentation during the knowledge transformation, he or she should have an understanding of the importance and the structural organization of the subject content knowledge (Bruner, 1977).

From the cognitive science perspective, knowledge has to be organized into a structure to be useful (Howard, 1987). A knowledge structure refers to a cognitive schemata in which information can be cross-referenced and amended (Greeno, 1987). It is assumed that a knowledge structure serves as a mental model or road atlas that guides a person's decision-making process (Howard, 1987). A teacher is expected to possess such a knowledge structure in which the subject content knowledge (concepts, principles, and skills) and pedagogical content knowledge (representations) are organized in an integrated way for teaching. This integration of subject content knowledge and pedagogical content knowledge in the teacher's knowledge structure allows him or her to establish a repertoire consisting of ready-made curricular decisions that is critical to the instruction (Leinhardt, 1983). Leinhardt and Greeno (1986) found that three or four versions of 15 standard routine decisions about mathematics were structured in semantic forms for immediate retrieval in expert teachers' knowledge structures. Based on their findings, the researchers suggested that a teacher should have a well-developed content knowledge structure that allows him or her to teach with maximum flexibility and minimum effort.

Although it has been realized that transforming subject content knowledge into pedagogical content knowledge is a critical step toward effective teaching, teachers' underlying considerations that might influence content knowledge transformation still deserves a close examination. It is assumed that during the content knowledge transformation process, a teacher is required to address these questions,

> What are the core concepts, skills, and attitudes which this topic has the potential of conveying to students?... What analogies, metaphors, example, similes, demonstration, simulations, manipulations, or the like, are most effective in communicating the appropriate understandings or attitudes of *this topic* to students of particular backgrounds and prerequisites? (Shulman & Sykes, 1986, p. 9, cited in Wilson et al., 1987)

The purpose of this study was to examine the content knowledge transformation process associated with teachers' curricular decisions in the physical education domain. Specifically the study was intended to identify

and describe physical educators' underlying considerations that characterized the way the above questions were addressed.

Two perspectives appear dominant, in re-search on content knowledge and curriculum. From a holistic perspective, content knowledge and curriculum are studied within large social and cultural settings that include political, organizational, and personal and interpersonal influences (McNeil, 1986). On the other hand, a personal expertise perspective usually focuses on individual teachers' personal perspectives and examines the teachers' expertise in transforming knowledge and implementing the curriculum (Leinhardt & Smith, 1985). The personal expertise perspective was adopted to guide this study to provide in-depth information about the characteristics of the teachers' knowledge transformation in the process of curricular decision-making.

Method
Guided by the personal expertise perspective, an interpretative research design was used in conjunction with a cognitive knowledge elicitation and mapping approach. The combination of the two research approaches was well-suited for this study because the combination is regarded as a useful research tool that "can help in the analysis of both the context and the mechanisms which teachers use to perform specific functions" (Leinhardt, 1989, p. 19).

The Research Setting and Participants
The study was conducted in a suburban school district in a major metropolitan area. The student enrollment during the period of the study was 32,818 representing diverse student socio- economic and cultural backgrounds. The school district stated that its mission in schooling was to enhance students' abilities for high-level thinking. This was also incorporated as a major goal in the physical education program. Three middle school master physical education teachers, Jacob, Mary, and Allen, participated in the study. Their teaching experiences ranged from 14 to 32 years. All the teachers were recipients of state level teaching awards, had been involved in physical education curriculum development at the county and/or state level, and had exhibited effective classroom management skills in their teaching as evaluated by their supervisors. They were considered to be master physical educators in the school district. Informed consent was received from the teachers.

Data Collection
In this study the data were collected in a tour-stage iterative process: (a) participant observation, (b) formal interviews, (c) knowledge importance evaluation, and (d) the Pathfinder concept mapping. Participant observations and knowledge elicitation interviews were conducted to collect data on the teachers' content knowledge. In the importance evaluation, the teachers assessed the importance of content properties in the subject and pedagogical content knowledge. In the Pathfinder concept mapping, each teacher's personal knowledge structure was constructed and analyzed.

Observation and interview. An 8-week participant observation was conducted to identify a content unit and its knowledge and skills taught by the teachers. An effort was made to minimize the disturbance to their instructional plans and environments. Volleyball was chosen as the content knowledge base for the study because it was the unit taught by the three teachers. Field notes were written during the observation and transcribed daily for analysis. After the observation period, each teacher was interviewed twice. In the knowledge elicitation interview the teacher was asked to elaborate on volleyball subject and pedagogical content knowledge including the concepts and skills that were *not* presented during his or her teaching. A reflection interview was followed a week later in which the teacher was asked to review his or her data and reflect on the curricular decisions made in teaching. The interviews were conducted in the teachers' offices and lasted approximately 50 minutes each. The interviews were tape-recorded and transcribed for analysis.

Observation and interview data analysis. Data analysis began during the data collection period. Constant comparison (Goetz & LeCompte, 1984; Strauss, 1987) was used in the analyses. Field notes were retyped and reduced on a daily basis into emerging categories. New categories were created when a new data entry could not match the thematic descriptions of all existing data categories. The interview data were analyzed similarly.

The analysis procedure was repeated after the data collection was completed. The categorized observation and interview data were re-analyzed and re-categorized until all the data entries were theoretically exhausted. During the analyses, the relationship among the thematic categories were established. A word list containing the volleyball terms that the teacher used during teaching and the interview was organized for each teacher after the knowledge elicitation interview. Terms in the list were coded based on Shulman's (1986) subject and pedagogical content knowledge taxonomy. The word list was used for the importance evaluation.

Knowledge importance evaluation. The word list was presented to each teacher for the importance evaluation. He or she rated the importance of each term using a 5-point scale (1 = least 16 important, 5 = most important) based on his or her personal understanding of volleyball teaching. The importance evaluation resulted in a word list containing those terms rated most important (5 on the rating scale) by all the teachers. The word list was used in the Pathfinder concept mapping for construction of the teachers' individual and common knowledge structures.

Pathfinder networking. The computerized Pathfinder networking technique is a concept mapping approach used to assess cognitive knowledge structures based on perceived relatedness among selected terms. It is a highly personalized approach to elicit and analyze an individual's knowledge structure using a node-line network (Schvaneveldt, Durso, & Dearholt, 1989). The Pathfinder computer networking program (Interlink, 1992) was used in this study to generate the teachers' personal content knowledge structures.

The ratings were conducted on an individual basis using an IBM-compatible computer with the Pathfinder software version 4.0 (Interlink, 1992). During the rating, words were presented in pairs on the computer monitor and the teacher was instructed to rate the relatedness of the paired words on a 1-9 scale (1 = unrelated, 9 = highly related). Before rating the volleyball term list, the teacher practiced the task by reading specific instructions about the rating procedure and rating a 5-word list unrelated to volleyball.

The Pathfinder analysis. Data from the Path-finder ratings were analyzed using the Pathfinder computer program. Similarity among the teachers' knowledge structures was determined using the Pathfinder's similarity function. In addition, the teachers' knowledge structures were also analyzed using a visual inspection approach (Onorato, 1990) to determine the "highest-degree" nodes. Onorato (1990) defined highest-degree nodes as those with most links attached to other nodes and suggested that "highest-degree" nodes were higher order concepts used by a rater as anchors to connect other concepts.

Reliability and validity. During the participant observation, the teachers taught according to their year, semester, and daily plans. To maintain an authentic and natural research setting, the researchers made no effort to alter the teachers' teaching plans throughout the study. For the same reason, no pre-class interviews regarding lesson planning were conducted. However, after-class informal interviews occurred frequently to elicit the teachers' reflections on the content taught in the past class. The teachers were also asked to examine the field notes and interview transcripts to determine accuracy of the descriptions. Only data confirmed by a teacher as accurate were used to describe the teacher's perspective. Analysis consistency was periodically examined using researcher peer checking. Trustworthiness of the data was established by comparing and triangulating data from the observations, interviews, importance evaluations, and Pathfinder ratings to prevent irrelevant interpretations.

Results and Discussion
In the three middle schools, physical education was a required course. Although students could make content choices in the elective activity units, volleyball was a required course offered once a year to all students in grades 6-8. The content was similar in the three schools and consisted of "basic volleyball knowledge and skills." All three teachers covered volleyball skills of forearm pass (bump), set, and underhand serve. In addition, Mary and Jacob used direct instruction methods, while Jacob had his students "explore" the skills using questioning, problem-solving, and other indirect methods. Basic rules taught in the classes included the scoring system, side-out, and position alignment (zones). None of the teachers taught game strategies or patterned play.

The volleyball unit was taught in gymnasia with sufficient equipment in all three schools. In Mary and Allen's schools, however, the gymnasia were newer and larger than that in Jacob's school in which the gymnasium had previously been used as an auditorium. Jacob at times had some students practice on the stage of the old auditorium because of limited space. When teaching the spike Jacob borrowed the elementary school gymnasium housed in the same building. Jacob's unit lasted 5 weeks, while Allen and Mary offered a 2-week and 3-week unit, respectively. Mary and Jacob's students had a 40-minute class 5 days per week, while Allen taught during a 90-minute double-period in a 2-day and 3-day weekly rotation. In the three schools, students were given 5 minutes to change into school uniforms for physical education classes. During the observation period, students in the three schools were compliant with class rules and almost all the students participated in class activities.

The results presented below were derived from the settings briefly described above which were delimited within the gymnasia in the three schools. The data analyses and interpretations were conducted within a realm of these settings. Two emerging themes salient to the subject-to-pedagogical content knowledge transformation were identified: understanding of teachability and personalization of content knowledge and curricula. The themes were interpreted and presented based on the researchers' understanding of the teachers' perspectives on the knowledge transformation in teaching volleyball.

Table 1

Sources and Categories of Elicited Terms

	Total terms (121)			Terms rated important (16)		
	Observation	Interview	Sub-total	Observation	Interview	Sub-total
Categories						
Subject content	39	16	55	10	3	13
Pedgogical content	44	22	66	3	0	3
Sub-total	83	38	121	13	3	16

Understanding of Teachability

Teachers are not only expected to possess and understand the substantial knowledge base of the subject matter, they are also expected to identify the core ideas that are teachable. In this study, the teachers' understanding of teachability was reflected by their decisions to include and exclude particular concepts and skills. Data analysis suggests that the teachers had a shared core subject content knowledge base of volleyball. Table 1 shows that, in their teaching and interviews, the teachers mentioned a total of 121 volleyball terms. Among them, 83 (69%) were mentioned by the teachers while teaching. In addition, among the 16 terms rated most important, 13 (81%) were presented in their teaching. As an example, Figure 1 presents the categorized terms elicited from Jacob. All teachers had a tacit understanding of teachable concepts and skills within this knowledge base.

Subject Content Knowledge		Pedagogical Content Knowledge	
Concept	Skill	Learning cue	Practice drill
From observation			
accuracy	forearm pass	approaching	circle–bump drill
attacking	hitting	backswing	continuous pass
bump–set–spike bridge	jumping	body rotating	moving set drill
on-hand	overhand serve	clockwise-moving	standing set drill
positions	set	finger push	knee–down–bump
receiving	spike	hand form	set–spike drill
rotation	toss	hand heel	sit–set drill
setter	underhand serve	hand triangle	toss–spike drill
spiker		open hand	triangle drill
target area		take-off	
teamwork		window	
zones		wrist snap	
From interview			
anticipation	angle serve		call ball drill
cooperation	back set		call line drill
distance	block		continuous block drill
fun	high set		continuous spike
freeball	jump set		rotation drill
hitters 1, 2, 3	low set		bump–set–spike stations
team cohesion	top-spin serve		stationary spike

Figure 1. Jacob's categorized volleyball terms.

The teachers in this study agreed about the subject content knowledge teachability. Among the 55 subject content knowledge terms, 39 (71 %) were elicited from teaching. The terms rated by all teachers as most important were mostly (81 %) categorized as subject content knowledge terms (Table 1). In addition, the teachers' content knowledge was constructed in a similar way. As an example of the teachers' knowledge structures, Figure 2 presents the common knowledge structure that is an averaged representation for individual teachers' Pathfinder knowledge structures.

The Pathfinder similarity coefficient describes the extent to which two or more knowledge structures are analogous structurally based on common links shared in the different knowledge structures (Roske-Hofstrand & Paap, 1992). Table 2 reports the common links and similarity coefficients between individual teachers' and the common Pathfinder knowledge structure that represents an average knowledge structure for all the teachers. The average similarity coefficients .36 and .39 among the teachers' knowledge structures and between the teachers' and the common knowledge structures, respectively, represent moderate similarities among the knowledge structures (Roske-Hofstrand & Paap, 1992). Point probability value (Table 2) showed that, except for the value between Allen and Mary's knowledge structures, there was little chance for the teachers to obtain more exact identical links in their knowledge structures, suggesting that the knowledge structures among the teachers were relatively similar.

The curricula were centered on the subject content knowledge and skills that were perceived by the teachers as "basic," which meant teachable in their school setting. These volleyball "basics" included forearm pass, underhand serve, and set and the "basic" knowledge encompassed the scoring system and rules for playing volleyball. The teachers viewed the basic concepts and skills as both important for students to learn. They thought the physical skills, however, were more critical for students to learn. As Allen put it,

> These [bump, set, underhand serve, and basic rules] are basic concepts and skills. You have to know three hits, know a game is 15 points, know the game is won by two [points], know how to rotate, know how to serve....However, you can know all that but not enjoy the game because you don't know how to do the skills. So, you need not only *know* the concepts but also know how to *do* the skills.
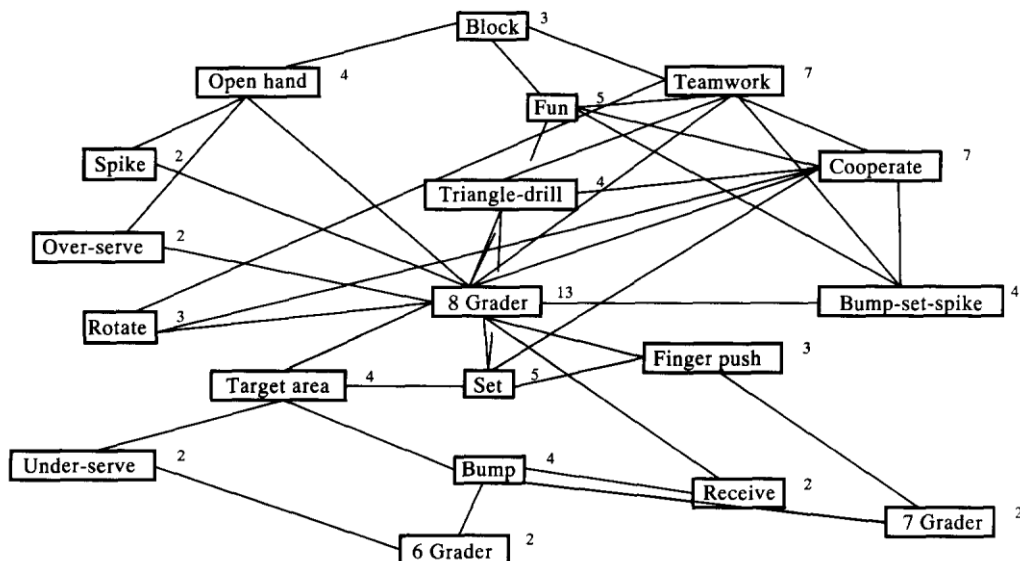

Figure 2. The teachers' common knowledge structures.

Other skills, such as block, overhand serve, and spike for example, were viewed as "advanced." These advanced skills were mentioned in the interviews but rarely taught to students in classes. In the importance evaluation the teachers rated advanced skills such as block, spike, and overhand serve as most important skills. They all agreed that in playing the games, these were indeed important skills, but all pointed out that these were also difficult skills to teach to their young students. In other words, they were considered not "teachable" to 6th, 7th, and 8th graders. However, two teachers, Mary and Jacob, did teach some of the advanced skills such as overhand serve

and spike. It seems that they taught them in an effort to either demonstrate students how a skill could be learned by themselves or enhance the excitement or enjoyment of the sport rather than for students' mastery of the "advanced" skills. For example, Jacob briefly taught the spike in his 8th grade class but his purpose was not to have the students master the skills. Jacob used the spike to teach students how to break down a skill in order to reduce the difficulty in learning. He asked the students to "explore" different stages of the spike so that the students could start with "approach," followed by "take-off" and "strike." He explained in the interview,

> I don't test them [students] on these, especially not on spiking though I teach it. I teach them in a discovery way, let them figure out the best way to learn spiking. I just want them to be able to understand the learning process.

Mary introduced the overhand serve in her class, because she wanted to "challenge them [students] so they can have more fun." Unlike teaching other "basic" skills, both Jacob and Mary did not use any learning cues (such as metaphors) and sequenced drills in teaching these advanced skills.

A gap between the teachers' expectations and their curricular decisions emerged during the triangulation analysis. In their knowledge structures, the term "8th grader" was linked to most of the concept and skill terms including the "advanced" concepts and skills. When the teachers reflected on the links connected to the "8th grader," they all reported that they expected 8th grade students to master these skills. However, the teachers also indicated, as data presented previously indicated, that they did not spend much time teaching those "advanced" concepts and skills or taught them for other purposes rather than for concept and skill mastery. They further indicated that these "advanced" concepts and skills were excluded from the curriculum not because they were unimportant, but because they were difficult to teach.

Table 2

Similarity and Coherence Data for the Common Word List

Teacher 1	Teacher 2	Links 1	Links 2	Com.Link	Similarity	Point p
Between Teachers' Knowledge Structures						
Mary	Jacob	77	47	31 (25%)	.33	.001
Allen	Jacob	43	47	17 (19%)	.23	.020
Allen	Mary	43	77	24 (20%)	.25	.040
Mean				24	.36	
Between Common and Teacher Knowledge Structures						
Jacob	Common	47	31	23 (30%)	.42	.001
Mary	Common	47	31	28 (26%)	.35	.001
Allen	Common	43	31	21 (28%)	.40	.001
Mean				24	.38	

Leinhardt and Smith (1985) suggest that teachers need a systematic way to assess students' competency or ability to learn so that they could better determine what to teach and how to teach it. In this study, the inconsistency between the teachers' expectations and curricular decisions indicated that the teachers' understanding of teachability were primarily based on their personal perceptions of students' learning competency and ability. They felt that students' physical development and abilities were rather limited at the middle school ages. The teachers perceived that students were not physically ready to learn the "advanced" volleyball skills. Consequently the teachers taught only those "basic" knowledge and skills and excluded those "advanced" ones.

> *Allen:* I don't think I can teach them these skills. We don't do the spike, dink, block, and overhand serve, because I don't think they are ready for those skills. Actually, I lower the net for the students because most of them can't jump that high. Some of them don't even have enough strength to bump the ball over the net. Teaching those [advanced] skills will go beyond their ability level, they would become frustrated soon.

Mary: Some kids have some difficulties in learning some skills, some of what I consider very easy skills. Some kids just don't think fast enough and act fast enough. Their mind and body just don't coordinate themselves quickly enough to react to certain skills such as spike or block.

Schmit, Porter, Floden, Freeman, and Schwille (1987) found that mathematics teachers may share the understanding of the importance of content on a common basis but may view students' abilities as individual entities with different learning potentials. They found that the mathematics teachers seemed to base their inclusion/exclusion decisions primarily on their understanding of the importance of the content and adjusted the content in the process of teaching to address individual differences in students' learning abilities. In other words, teachability has primarily been determined by the textbook in teaching mathematics. In physical education, students do not have textbooks. The teacher is responsible for identifying and teaching the most important concepts and skills. In this study, the teachers' perceptions of student physical development was a strong factor that dominated curricular decisions. Consequently, even though the teachers considered the "advanced" concepts and skills important in volleyball, they excluded those concepts and skills because they perceived that students were not able to learn them.

In summary, a major part of the teachers' subject content knowledge base consisted of concepts and skills that were perceived most teachable. It appears that the teachability of concepts and skills of volleyball was determined based on the teachers' classification of what was "basic" or "advanced." The teachers taught those "basic" concepts and skills and expected students to master them because they believed that students would not be able to play and enjoy the sport without learning them. They taught the "advanced" concepts and skills, however, for purposes other than students' mastery. Therefore, the teachers' decisions to include or exclude content were based on two factors, the teachers' perceptions of the importance of the content and of the student physical development.

Personalization of Curricula and Content Knowledge
Leinhardt and Smith (1985) revealed the differences among expertise of teaching mathematics. In their study, three expert mathematic teachers who had similar mathematics subject content knowledge base taught the same topic differently. Similarly, analyses in this study revealed that, although the three physical education teachers were teaching the same topic (volleyball) and shared a similar understanding of teachability, differentiation in their delivery of the curricula and pedagogical content knowledge were evident.

Differentiated curricula delivery. In the reflection interview, the teachers reported and articulated different curricular goals for student learning. Based on the goals, each teacher established learning objectives for the volleyball unit. Jacob emphasized "learning how to learn" and skill development in teaching physical education. He considered that development of students' analytical ability would directly improve their learning in physical education. He said that his main goal was to "teach students to learn how to learn while working on skill development." He described the program as "geared at giving the students one or two skills to master." He also reported, "I evaluate them at the end of the unit and see if they have mastered those skills. I grade them on their techniques not their success. If the student does show the correct technique, that is what I want [to see]."

Allen focused his program on teaching students social interaction skills through physical education. Concepts such as respect for other, recognition of other's rights, gender equity, cooperation, and teamwork were emphasized throughout his teaching. In his volleyball unit, Allen taught teamwork for the 6th graders and relationship between individuals and the team for the 7th and 8th grade students. In the interview he explained:

> Teamwork, teamwork, and teamwork. Get them out of that individualistic stage that they went through in the elementary school. And I start right at the 6th grade. They are in the middle school, they are a team now, and they should be functioning as a team. And all the skills and drills and course work here are done in a two to six people group which I implement with cooperative learning techniques.... For the 7th and 8th grade students I am trying to stress the individual roles in our teams. The team should take an individual student's strength to where the student can succeed.

Mary expected that her physical education program could help students get involved in a variety of activities that they could enjoy throughout their lives:

> The goals of our program are to get as many students involved as possible, make it [physical education] fun to them, but in the meantime make it a very worth-while learning experience for them.... We have units that will allow kids to, hopefully, have carry-over value later in life. Therefore, my main goal is that students learn the basic skills in order to have fun in the learning process as well as in the future.

Mary appeared to try to balance skill learning with fun. To Mary, students should learn the basic knowledge and skills to have fun and appreciate the value of the sport. Spike and block were not taught in her volleyball unit. After describing the block skill in the knowledge elicitation interview, Mary said, "To me, they can play volleyball at the middle school level without knowing how to block. They can still have fun. I am not really into advanced skills on the middle school level, I think high schools have a role to play." The observation data suggest that each teacher presented the volleyball concepts and skills in a unique way that was consistent with his or her curricular goals.

Jacob. The unit was team-taught with Jacob as the lead instructor responsible for organizing the content and giving instructions. Jacob started the unit with a video session as an advance organizer for students. Starting from the second day, Jacob directed the students to work in groups of two or three to practice the basic skills. A modified tournament was held during the last two class sessions during the last week of the unit. During the tournament Jacob conducted skill and written tests. In Jacob's class, skills were "explored" and "learned" by the student, not "taught" by the teacher. Volleyball skills were presented as movement problems for students to explore and solve. For example, in teaching the spike take-off, Jacob asked students to explore the skill and answer the question, "Which is a better take-off, one-foot or two-foot?" Students were instructed to try any take-off that they thought was appropriate during the practice. After their exploratory practice, the students concluded that a two-foot take-off was better than a one-foot take-off, because one-foot take-off caused one to "jump forward," while two-foot take-off could help one "jump vertically high."

Allen. Allen's class was a 90-minute double-period. He modified all the basic skills in his teaching to encourage students to learn "cooperation" and "teamwork." In forearm pass drills, for example, the ball was allowed to bounce once on the floor because "we have to help those people who cannot do it well." In a set drill, students were allowed to hold the ball so that other students could give help and feedback. Later, half of each class session was devoted to game play during which students played a modified game of volley-tennis in the first week and a regular volleyball game with lower net in the second week. The games were played under strict team organizations in which students were encouraged to discuss issues the team was facing, while only the captain could talk to student referees or Allen. Classroom order was maintained with the teacher as the ultimate team leader.

Mary. In Mary's unit, large group practices were the primary practice formation. She intentionally limited the number of balls available for practice because she thought she could better observe and supervise students' behavior with fewer balls in the gymnasium. Game play was a major part of Mary's class. Feedback was frequently given during the game when typical errors in performance were spotted. For example, Mary started a lesson, "We are going to start off with your games. I will leave some drills out for now. If we are not successful, we go back to these drills to practice." Related volleyball rules were introduced before the game began and were explained in detail during the game. Because Mary believed that she should base her instruction on the "teachable situations" derived from the games, she was concerned about keeping the entire class under her direct observation and supervision that at times she placed 10 students on each side of the court instead of 6. Rules were modified to encourage student involvement. For example, each side had five hits instead of three. During teaching Mary tried to reduce the level of difficulty to involve students in learning the skills by lowering the net, reducing the distance, allowing more trials (e.g., one could serve two times instead of one), and excluding some rules (e.g., carrying violation in setting).

Personalized pedagogical content knowledge. Having a solid subject content knowledge base is not enough for a teacher. He or she must possess a substantial pedagogical content knowledge repertoire consisting of representations such as analogies, metaphors, examples, pictorial and physical representations, and practices and drills to communicate effectively the subject content knowledge to the student (Wilson et al., 1987). Teachers are expected to use various representations to help students build mental models that facilitate understanding and learning (Gentner, 1981). Triangulation analysis revealed that the teachers in this study possessed such a pedagogical content knowledge repertoire. However, these representations were personally constructed. Although the teachers showed a shared subject content knowledge base of volleyball, the representations used to teach the subject content knowledge by an individual teacher were often different than those by other teachers. Within the 66 terms that were categorized into pedagogical content knowledge, only 11% of them (7 terms) were shared among the teachers. Among the terms commonly rated most important, only 18% (3 terms) were classified as pedagogical content knowledge. Analysis of the observation data suggested that this group of teachers rarely used similar learning cues and drills in teaching volleyball. It appears that each teacher had his or her own unique pedagogical content knowledge repertoire that contained representations different from those of the other teachers.

It was frequently observed that when teaching the same concept or skill, the teachers were likely to use different drill and learning cues to convey the concept or skill. For example, when teaching forearm pass skill, the teachers avoided using kinesiological and biomechanical descriptions about the arm movement. Instead, Mary used "forearm extension" as the cue word to emphasize the forearm position, while Jacob and Allen used "platform." For drills, Allen used a "bounce—hit" paired group drill, while Jacob and Mary used "wall hit" individual drill for students to practice the forearm pass. In the interview, Mary described how she transformed the set skill from subject content knowledge to a pedagogical content knowledge form.

> When teaching the set, I use a lot of drills and cues to help them understand the skill. I say "chicken wings" to remind them of the position of their elbows and "window" to have them lift their hands. The cues are helpful, because it is much easier to have students remember these cues than things like "eight inches above your shoulder."

Jacob explained that he used sequenced drills to help students better understand the process of learning the set skill.

> I had them sitting on the ground and setting the ball to their partners who were sitting very close. I did this because I wanted to reduce the complexity of body coordination.... What they did next was stand up facing each other very close and setting the ball. They had more experience for body coordination now.... From there, I moved the distance [farther] away. So they were setting farther and farther. They kept doing this until they could set the ball when moving on the court.

Allen, on the other hand, indicated that he focused on students' group work rather than individual skills to have students experience the concept of teamwork.

> Yes, I tell them [students] how to place their hands and use wall drills at the beginning to let them know the [set] skill well. But a more important thing for them to do is to work in a group. I stress how individual students' strengths can blend into and make a successful team. I want to get this basic concept [of teamwork] across. So my game may not relate to these [volleyball] skills very closely, but they [students] must show their understanding of the concept [of teamwork].... I told them that "point your ball to the net," "move the ball to the net,' because their teammates were in the net area. It really doesn't matter what skills [bump or set] they use, just by moving the ball to the net through teamwork I think I put a good concept into their heads.

It seems that the transformation of subject content knowledge to pedagogical content knowledge is a personalized process. The findings suggest that the teachers' curricula were characterized by individual teachers' differentiated pedagogical content knowledge and justified by the individual teacher's curriculum goals.

Summary and Implication

The study described the relationships between teachers' content knowledge and their curricula by revealing the process of content knowledge transformation associated with the teachers' curricular decisions. From the results obtained, the teachers' curricula seem to closely connect to the content knowledge transformation that was characterized by their understanding of teachability and personalization. Wilson et al. (1987) propose that knowledge transformation is a critical process in a teacher's pedagogical reasoning that determines teachers' curriculum decision-making. During the transformation process, the teacher critically interprets the subject content knowledge, identifies alternative knowledge representations, adapts the representations to his or her students' characteristics, and tailors the content to meet needs of a specific student group (such as a class) rather than those of the student population in general. The teachers in this study demonstrated that although they possessed an identical subject content knowledge base and organized the knowledge similarly in their knowledge structures, they interpreted the teachability of the knowledge primarily on the basis of their perceptions of students' learning abilities. Their perceptions of students' physical ability was used as a threshold to determine the "basic" and "advanced" concepts and skills in volleyball. It appeared to be pedagogically logical to the teachers that this student-ability-based subject content knowledge interpretation led them to the inclusion/exclusion curricular decisions in terms of what to teach. During this subject content knowledge interpretation process, the teachers demonstrated a similar understanding about the teachability of the subject content knowledge and the ways to determine it.

The differentiation occurred during the process of identifying knowledge representations. Each teacher's pedagogical content knowledge repertoire, the representations he or she might use in teaching, was different from those of other teachers. The subject content knowledge to be taught, even though similarly selected by the teachers, was described using different metaphors, terms, and demonstrations in classes and was experienced through different drills. These findings suggest that during the processes of identifying alternative knowledge representations and adapting the representations to student learning process, the teachers' pedagogical reasoning processes were characterized by personalization. Based on the analysis, it was likely that this personalized reasoning was mediated by the teachers' personalized pedagogical content knowledge repertoire and personalized understanding of educational goals in physical education. The findings imply that personalization is a salient factor that influences the subject—pedagogical content knowledge transformation and the connection between teachers' content knowledge and curricula. Teachers may have a similar subject content knowledge base and teach the same topics defined by the subject content knowledge. They are very likely, however, to use different representations that are perceived personally as relevant in terms of their curricular goals.

The findings may have two implications for physical education teacher education. As Bain (1990) noted, typically in physical education teacher preparation programs, the philosophical and sociocultural aspects of physical movement are deemphasized, while biological and behavioral perspectives dominate most of the programs. As a result, prospective teachers are likely to be instructed that applicability of movement content to teaching in elementary and secondary schools are determined by potential students' biological and behavioral factors. The teachers in this study clearly demonstrated that they based their content inclusion/exclusion curricular decisions primarily, if not solely, on the student biological development factors. Even Allen, who stated his curricular goals were focused on a more sociocultural related aspects, based his inclusion/exclusion curricular decisions on biological grounds. As Hellison (1991) argues that students' sociocultural factors should be taken into account when making curricular decisions because the student must be viewed as a whole-person that includes both biological and sociocultural characteristics. Therefore, curricular decisions need to be made on a broad understanding of students' characteristics rather than one aspect to offer the student a well-balanced learning experience.

The subject content knowledge in sport and exercise are usually acquired by prospective teachers through performance courses offered in most physical education teacher preparation programs. There has been an argument in terms of the purposes of the courses (Bain, 1990). Two perspectives have been presented. One perspective states that the courses should serve as content courses in which prospective teachers are expected to master specific physical movement skills, while the other claims that the courses should be taught as a particular type of teaching methods course in which the prospective teachers acquire general pedagogical knowledge and learn how to teach a particular physical movement (Bain, 1990). The findings of this study support the latter. Wilson et al. (1987) claim that subject content knowledge must be transformed for teaching and the teacher must have a substantial pedagogical content knowledge repertoire that can be used to identify useful representations for effective teaching. The findings of this study support the perspective (Wilson et al., 1987) and suggest that pedagogical content knowledge should be an integrated part of the teacher's knowledge. Further, despite the highly personalized nature of identifying, generating, alternating, selecting, and organizing procedures, concepts and skill representations should be incorporated in performance courses in physical education teacher preparation programs to enhance prospective teachers' content knowledge base for curricular decision-making.

References

Bain, L. L. (1990). Physical education teacher education. In W. R. Houston (Ed.), *Handbook of research on teacher education.* New York: Macmillan.

Bruner, J. (1977). *The process of education.* Harvard University Press.

Chi, M. T. H., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Sciences,* 5, 121-152.

Gentner, D. (1981). Generative analogies as mental models. In *Proceedings of the Third Annual Conference of the Cognitive Science Society* (pp. 97-100). Berkeley: University of California, Institute of Human Learning.

Goetz, J. P., & LeCompte, M D. (1984). *Ethnography and qualitative design in educational research.* San Diego, CA: Academic Press.

Goodlad, J. I., & Su, Z. (1992). Organization of the curriculum. In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 327-344). New York: Macmillan.

Greeno, J. G. (1987). Mathematical cognition: Accomplishments and challenges in research. In T. A. Romberg & D. M. Stewart (Eds.), *The monitoring of school mathematics. Background papers. Volume* 2. *Implications from psychology. Outcomes of instruction* (pp. 3-26). Madison: Wisconsin Center for Education Research.

Hellison, D. (1991). The whole person in physical education scholarship: Toward integration. *Quest,* 43,307-318.

Howard, R. W. (1987). *Concepts and schemata.* Philadelphia, PA: Cassell.

Interlink, Inc. (1992). *KNOT-PC Software (Version 4.0)* [Computer program]. Las Cruces, NM: Interlink, Inc.

Jewett, A. E., & Mullan, M. R. (1977). *Curriculum design. Purposes and processes in physical education teaching—learning.* Washington, DC: AAHPER.

Lampert, M. (1986). Knowing, doing, and teaching multiplication. *Cognition and Instruction,* 3,305-342.

Leinhardt, G. (1983, April). *Routines in expert math teachers' thoughts and actions.* Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Leinhardt, G. (1989). Capturing craft knowledge in teaching. *Educational Researcher,* 18,18-25.

Leinhardt, G. & Greeno, J. G. (1986). The cognitive skill of teaching. *Journal of Educational Psychology,* 78,75-95. Leinhardt, G., & Smith, D. A. (1985). Expertise in mathematics instruction: Subject matter knowledge. *Journal of Educational Psychology,* 77,247-271.

McNeil, L. M. (1986). *Contradictions of control. School structure and school knowledge.* New York: Routledge & Kegan Paul.

Onorato, L. A. (1990). Representation of problem schemata. In R. W. Schvaneveldt (Ed.), *Pathfinder associative networks: Studies in knowledge organization* (pp. 255-266). Norwood, NJ: Ablex.

Roske-Hofstrand, R. J., & Paap, K. R. (1992). Discriminating between degrees of low or high similarity: Implications for scaling techniques using semantic judgments. In R. W. Schvaneveldt (Ed.), *Pathfinder associative networks. Studies in knowledge organization.* Norwood, NJ: Ablex.

Schmit, W. H., Porter, A. C., Floden, R. E., Freeman, D. J., & Schwille, J. R. (1987). Four patterns of teacher content decision-making. *Journal of Curriculum Studies,* 19, 439-455.

Schvaneveldt, R. W., Durso, F. T., & Dearholt, D. W. (1989). Network structures in proximity data. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 24, pp. 249-284). New York: Academic Press.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher,* 15(2), 4-14. Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review,* 57, 1-22. Smith, D. C., & Neale, D. C. (1989). The construction of subject matter knowledge in primary science teaching. *Teaching and Teacher Education,* 5, 1-20.

Strauss, A. L. (1987). *Qualitative analysis for social scientists.* New York: Cambridge.

Walkwitz, E., & Lee, A. (1992). The role of teacher knowledge in elementary physical education instruction: An exploratory study. *Research Quarterly for Exercise and Sport,* 63, 179-185.

Wilson, S. M., Shulman, L. S., & Richert, A. E. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), *Exploring teachers' thinking* (pp. 104-124). London: Cassell.