DOCUMENT RESUME

ED 354 868 IR 015 957

AUTHOR Stuebing, Susan; And Others
TITLE Technology-Rich Learning Environments in Elementary and Secondary Schools: An Interactive Study of Physical Settings and Educational Change.
INSTITUTION Apple Computer, Inc., Cupertino, CA.; New Jersey Inst. of Technology, Newark.
PUB DATE 92
NOTE 45p.; Paper prepared for the Annual Meeting of the American Educational Research Association (San Francisco, CA, April 20-24, 1992).
AVAILABLE FROM Apple Computer, Inc., Learning Technologies Group, 20525 Mariani Ave., MS: 301-3E, Cupertino, CA 95014 (free).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Computer Assisted Instruction; *Educational Change; *Educational Facilities; Educational Strategies; Educational Technology; Elementary Secondary Education; Facility Guidelines; Longitudinal Studies; School Business Relationship; *Teacher Attitudes
IDENTIFIERS *Apple Classrooms of Tomorrow; Floor Plans

ABSTRACT

This paper reviews an ongoing study on the physical settings of education with technology at the elementary and high school levels. The study, which is multi-disciplinary in nature, is based in sites in the process of change in teaching strategies, using learning technology as a catalyst for this change to take place. The focus of the study is on the physical environment changes in two Apple Classrooms of Tomorrow Longitudinal Research Centers and examines the following issues: (1) the physical environment as an obstruction to learning with technology; (2) teacher belief systems connected to the organization and use of technology for learning; (3) support for teachers as a means of altering their perceptions of the importance of physical environment to create change; (4) possible changes in an existing classroom to enhance cooperative learning and student-centered learning; (5) and the architectural or physical changes necessary to enhance learning. The addendum, which comprises more than half the document, contains floor plans for incorporating technology in the rooms in the elementary and high school. (Contains 11 references.) (ALF)

Technology-Rich Learning Environments In Elementary and Secondary Schools: An Interactive Study of Physical Settings and Educational Change

Susan Stuebing, New Jersey Institute of Technology
Jacqui Giddings, Apple Classrooms of Tomorrow
Leslie Knox Cousineau, New Jersey Institute of Technology

Architecture and Building Science
School of Architecture
New Jersey Institute of Technology
Newark, New Jersey, 07102

AppleLink: STUEBING.S

Apple Classrooms of Tomorrow
20525 Mariani Avenue
MS 76-SE
Apple Compute, Inc.
Cupertino, CA, 95014

Prepared for the AERA Annual Meeting 1992
San Francisco, California

Technology-Rich Learning Environments In Elementary and Secondary Schools: An Interactive Study of Physical Settings and Educational Change

Susan Stuebing, New Jersey Institute of Technology
Jacqui Giddings, Apple Classrooms of Tomorrow
Leslie Knox Cousineau, New Jersey Institute of Technology

1.Introduction

This paper reviews an ongoing study on the physical settings for education with technology at two age levels: elementary and high school. The study, which is multi-disciplinary in nature, is based in sites in the process of change in teaching strategies. Learning technology is a catalyst for this change to take place. During 1990 and 1991, Architecture and Building Science, an applied research group at the School of Architecture at the New Jersey Institute of Technology, studied two Apple Classrooms of Tomorrow Longitudinal Research Centers.

Objectives of the Study

The study focuses on the physical environment changes with the introduction of technology as a tool for learning and asks the following:

1. Is the physical environment an obstruction to learning with technology?
2. What teacher belief systems are connected to the organization of the physical environment and use of technology for learning?
3. Can support for teachers alter the perception of the importance of the physical environment to create change in the classroom?
4. What changes can be made in an existing classroom setting to enhance cooperative learning and student-centered learning?
5. What architectural or physical changes should be made to enhance learning?

As a multi-faceted project, with teacher support and training as a major component, the study considers: (1) the role of the teacher; (2) a changing educational process; (3) teacher belief systems and (4) support for teacher problem solving.

Physical Environment and Restructuring Education

Technology has been shown to engage students (Schofield & Verban, 1988, Dwyer, Ringstaff and Sandholtz, 1990), however obstructions to change in the classroom are many. These obstructions are based in part on teacher belief systems and educational organization (Cohen, 1988 and Dwyer 1990). Our research indicates that the physical environment can also be an obstruction . The classroom organization must be understood and designed appropriately to meet the needs of students and teachers. Often, the classroom is considered an inflexible given and is not included as part of the analysis of educational change. With changes in teaching and learning to cooperative learning and peer tutoring, the traditional classroom and school organization needs to be organized differently. This study identifies obstructions and looks toward possible solutions.

Alternative modes of learning and teaching with technology suggests that change must take place systemically (Sheingold, 1990). These changes have been shown to result in improved educational achievement (Gearhart et al., 1990, Dwyer, Ringstaff and Sanholtz, 1991). The physical environment contributes to the system of change and can reinforce these educational goals. Learning with intensive use of interactive technologies presents unique design problems.

> "Computer systems intended to aid people, especially groups of people, must be built to fit the needs of these people. And there is no way that a system can work well with people, especially collaborative groups, without a deep, fundamental understanding of people and groups." (Norman,1991)

Little research has been undertaken to specifically look at the design of physical classroom with technology. This paper reviews findings of this work in progress.

2. Research Settings

The sites for this study are at elementary and high schools within existing structures. All are long term research sites for the Apple Computers Schools of Tomorrow, an education research group of Apple Computer, Inc.. No changes to the physical setting required additional funding for construction . The types of physical changes could be made in any school with learning technology.

The elementary school is a one story building built in the 1950's with additions in 1960 and 1991. The ACOT classrooms (one at each grade) are housed in two classroom types. Grades 4, 5 and 6 are in individual classrooms in a double loaded corridor

(sometimes referred to as an "egg crate classroom). Grades 1, 2 and 3 are located in clustered classrooms with 2 classrooms with limited communication. Both classroom types are considered standard size (29' x 32', and 30' x 33' respectively). The class size averages between 28 and 32 students. The schools are housed in "traditional"physical settings making this study relevant to many schools and their buildings.

The high school is housed in a multi-story building built in the 1940's. Four classrooms are used for the ACOT classrooms for grades (9-12). Two of these classrooms are standard sized classrooms(33' x 45') and two are oversized classrooms.(40' x 43'). The class size is approximately 28 students.

The classrooms have been equipped with a wide variety of technology including personal computers, portable computers, laserdisc players, video cameras, scanners, voice recorders, CD players and on-line communication devices. Access to computers and other technologies allow teachers and students to explore new uses of technology in all aspects of their teaching and learning.

ACOT is a long term research project (since 1985) that explores interactive computer technologies and educational change. The project provides its teachers with information about current learning theories and exposes them to new curriculum ideas to foster change in the way teachers and students think and use technology for learning. ACOT adheres to a philosophy that instruction should be learner centered. This constructivist approach does not diminish the role of the teacher, but rather changes the role of the teacher from being primarily a lecturer who transfers knowledge to students, to that of being a mentor or coach who guides students in their construction of their knowledge (ACOT, Philosophy and Structure, 1991).

3. Research Methods and Data Collection

Research involved an interactive problem solving approach, collaborating with teachers and research staff through observation, reflection and design. This collaboration ensures an accurate assessment of existing conditions and assists in the assimilation of ideas, beliefs and background data. This study documents physical organization, aesthetics, function, climate and comfort in technology rich learning environments.

The research is comprised of six phases: (1) Observation and review, (2) Discussion, (3) Design, (4) Intervention, (5) Assessment and (6) Analysis and Reporting. The study is interactive, in that, the teachers are part of the research team with the architect and educator serving as change agents."With this change there has been a corresponding shift in change agent roles from disseminator of curriculum ideas and materials to process consultant or trainer" (Beaton, 1985) The study draws on important parallel work on teachers beliefs and practices (Dwyer, Ringstaff and Sanholtz, 1991).

(1) Observation

The ABS-NJIT research team made initial classroom observation, and documented each of the classrooms through drawings and photographs. Teachers and students were interviewed. The observation were compared with research over the five years of the ACOT project as documented by independent researchers.

(2) Discussion

Through discussion and interview sessions, teachers identified issues of concern with the technology environment as they impact teaching goals. Teacher beliefs relating to the physical environment were identified through this process.

(3) Design

Based on educational goals, teachers redesigned their classrooms with scale models built by the ABS-NJIT team. Through this method, teacher teams studied and develop learning environment options congruent with teaching goals. The redesigns did not involve major architectural changes. The changes could all be categorized as affecting organization, circulation or relationship between activities. The designs developed with the scale models were documented in drawings. (Scale models are used by architects to envision space. In this case, we used 1/4"= 1'-0" and 1/2"= 1'-0"

This participatory design process, in the tradition of architectural exploration served two goals. First by viewing the classroom organization from an alternative vantage point, the teachers were able to reflect on the issues of the physical environment and identify connections to teaching issues (i.e.. overcrowding in the classroom as it relates to the ability to serve as a "coach"). Each school kept a study model to continue to explore the organization of the physical environment. Secondly, teachers were able to envision ways they could alter their teaching environment to meet their needs.

(4) Intervention

Following the scale model study, the teachers reconfigured their classrooms incorporating the study ideas. Photographs of the scale models and drawing of the schemes were provided as a reference for these modifications. The reorganization of the classroom included, moving furniture, marker boards, reconfiguring the technology network and in some cases introducing or reducing the amount of furniture in the room. In the elementary school, three of the classes moved to newly constructed classrooms during this process. The scale models reflected this change and prepared the teachers to organize their new environment. In some cases, the process of reorganization was assisted by the ACOT staff. Some changes took hours to make.

(5) Assessment

Assessment was based on discussions with teachers, discussions with researchers and ACOT staff, and classroom observations by ABS/NJIT researchers. The findings reported in this paper were organized through meetings and further discussions with other researchers within the ACOT research team. This process of assessment is also one of reflection, "reflect on teaching, to question old patterns, and to speculate about the causes behind changes they were seeing in their students" (Dwyer,et al. 1990). After reflection and discussion with teachers, the classroom were modified a second time by many of the teachers.

(6) Data Collection and Documentation

Data for this study was collected by the ABS/NJIT research team (Stuebing, Petrakaki and Knox). Data was collected during the school year of 1990-91 and 1991-92 in the form of interviews with teachers and students, observations, meeting notes, photographs, diagrams, architectural drawings, lighting levels and dimensional measurements. As well the analysis for this study includes hundreds of hours of observational data by independent researchers prior to this research and ongoing through the research period (e.g., Gearhart, Herman , Baker, Novak, and Whittaker,1990; Phelan, 1989; Tierney, 1988) .

Variables and Limitations

The existing furniture and the existing building elements such as the building envelope, services and partitions were considered as static elements. The study did consider a number of programmatic variables which change over time and affect the school and classroom environment. These changing variables include:

(1) the number of students in the classroom;

(2) quantity and type of learning technology;

(3) teaching/learning modes (small group, large group and individual work);

(4) special projects (short term);

(5) shared space for two classes; and

(6) time allocated to learning activities (class periods, etc.).

5. Results

Our research indicates that changes to the traditional classroom design should consider:
(1) Support for teachers to address the learning environment; (2) Teacher Belief systems;
(3) Changing teaching and learning modes; and (4) Physical obstructions can effect comfort and learning.

1. Teachers should be given support to better understand and address their classroom settings.

The introduction of technology and change in teaching strategies occurred in the classrooms prior to the initiation of the study. Data collected by outside researchers indicates the introduction of computers in the classroom required physical change. By necessity, the introduction of up to twenty computers in a traditional classroom setting required physical change. This change was often time consuming and required support for the teacher to organize the technology rich environment.

> "I'm finding the arrangement of the room to be somewhat of a problem. It's getting very full of equipment and we're kind of crowded. I like to move around the room as I teach and this makes movement difficult"
>
> - Teachers Log, High School, October,1988.

> "I mentioned before that next year we are planning to do more small group instruction. ... I am in the process of creating a corner in the back of the classroom where I can do some lab type activities with small groups of kids."
>
> - Teachers Log, High School, March 1988

> "We rearranged furniture last Friday. We moved all the computers from the center to around the walls, to make room for the robotics project in the center of the room . We hooked up the network. It took an afternoon to get it done but " just to give you an idea of flexibility"....
>
> - Teachers Log, High school, May, 1989

When the study first began, many classrooms were organized by the teachers with traditional modes of physical organization. In the high school while two of the rooms allowed for individual work with technology, traditional settings for teacher lecture modes predominated the four classrooms. Two of the classrooms were organized for lecture mode. Group work was encouraged by the introduction of three round tables. Technology was accessible at desks with upper storage (hutches). These hutches lined the perimeter of the wall. Little or no definition was developed for group work or student collaboration in these settings.

Through an interactive problem solving approach, teachers collaborated, designed and reflected on potential classroom organization. As well, the educational process of change began to demand alternative settings. The teachers gradually began to alter their classrooms to match their needs. Some teachers changed their classroom organizations more rapidly than others. Some readily explored alternative organizations, changing the classroom on a weekly basis to find the appropriate organization. In one sixth grade class, the teacher involved the students in the reorganization process, and explored and tested several classroom organizations.

4. Perspectives

Eduction is supported by a system of tools, people and environment. "As early as the second year of the project, teachers began to modify their teaching arrangement..." (Ringstaff, 1988). A modified physical environment may be an indicator of change in teaching style , and as a compliment to teaching with technology as a tool and cooperative learning (or students learning in groups). The classroom environment can better respond to the needs of these educational goals. "The same principles that apply to development of computer systems of individuals are not sufficient for groups. It isn't that they do not apply, but rather that group activity is vastly different than individual activity and has its own needs and requirements." (Norman, 1991)

Teacher belief systems in relationship to the organization of technology and the physical setting is a major concern of this research. "The introduction of computers into the classroom changes the teachers' role, as well, leading to decreases in teacher-directed activities and a shift from didactic approaches to a constructivist approach" (Schofield & Verban, 1988). Teacher beliefs are based on previous experience and reluctance to change due to failure of other innovations (Fullan, 1982). To address the restrictions of teacher belief systems, the research team supported change (or became change agents) by offering information, tools and reflection as discussed by Beaton, 1985. Collaboration, team teaching and authentic learning were considered activities which the physical setting and organization of technology should support.

This research is related to a larger process reported in the work of Ringstaff, Sandholtz and Dwyer (1991). Their work develops a model for understanding change in teaching and learning as an evolutionary process having five phases: Entry, Adoption, Adaptation, Appropriation and Invention. As a part of the educational process, these phases can be seen present in this interactive research on the organization of the technology and classroom environment. The process of change of the physical learning environment, therefore suggests a need for teacher support and more information regarding the appropriate environmental strategies for learning with technology.

These changes were largely a matter of moving furniture and technology. While minimal in terms of the range of possible alterations, they were easily within the control of the teacher(s). Changes also took place in the relationship of space to time, particularly, at the high school where the team of teachers shared four classrooms. The attributes of each room were more carefully studied and scheduling began to more closely match the needs of the learning activities. The coordination of the classroom schedule was not based on a weekly template but rather began to reflect teaching and learning needs for environments.

Innovation was seen at both the high school and the elementary schools. Teachers began to design supports for their environment. One teacher designed a presentation station for whole class presentations with the computer (using liquid crystal display panels) to address the length of set up time for overhead displays. The elementary teachers designed with the assistance of the ABS research team storage cabinets. These storage cabinets would allow for significant change in classroom organization by addressing the need for individualized and personalized storage.

2. **Embedded beliefs can limit the possibilities for change in the physical learning environment and teaching opportunities with technology.**

The teacher's role in the classroom is critical to change from a curriculum centered education system to a "child centered" education, and from individual tasks rather than collaborative tasks (Ringstaff, et al. 1991). Historically, teacher belief systems relevant to the physical organization of the classroom is based in part on a curriculum centered orientation. The traditional organization of the classroom was organized with individual desks, all students facing to the front of the room and the teacher lecturing at the front of the classroom.

Our ongoing research indicates that the process of change in the classroom environment is controlled in part by teacher belief systems. Teacher belief systems relative to the physical environment, limit the number of possible options for change. We found several prominent beliefs which were contrary to the goals of authentic learning and cooperative learning, or a highly interactive, social and creative kind of learning environment.

For example in the elementary school we found two predominant teacher beliefs: (1) that all students need an assigned desk; and (2) the lower grade elementary school teachers indicated that they needed (or preferred) to be able to see all the computer screens at the same time.

These two teacher beliefs predict the arrangement of the classroom and in turn limit the number and types of activities which might take place. Teachers that indicated that all students needed an assigned desk, could not place shared technology (such as a computer) on one students' desk and not another. Therefore the classroom required a desk for each student and a desk or table for each computer (in some cases a table). Through our observations, we found that the assigned desks were used infrequently and that work was conducted on the floor, in between the assigned desks and at the computer stations. This belief was defended as the assigned desks enabled (1) ease of attendance by sight; (2) personalization and identity for the students; (3) disciplinary activity, (4) test taking and (5) a place for students to store belongings.

The lower grades organized the technology in a line to allow for the teachers to see all the computer screens at one glance. This linear organization allowed for students to work with the student next to them. We observed students asking one another clarifying questions, however the organization did not appear to enhance group work.

At the high school level, teacher belief systems were also present. Included in these were: (1) all students must face the front of the class; (2) all students must have a desk, (3) in lower grades (Grade 9) students greater physical control and organization, and (4) a preference for one computer for every student in lower grades.

Again, each of these beliefs predict the organization of the classroom and the types of activities which take place. The classroom designated specifically for the 9th grade was the most structured environment, with all students facing the front of the room. The activities which we observed in these rooms were primarily entire class instruction or individualized work. The class was crowded with computers and desks, making it difficult for the teacher to play the role of "coach" or even to physically reach the student to answer questions.

3. **Change in the physical environment fosters change in teaching and learning. Appropriate settings can encourage collaborative work.**

"the freedom to move around the classroom encourages collaborative learning ... allows them to work closely together, and also allows them to draw on each other for their strengths"
-High school teacher, Stuebing interview.

High School students and teachers expressed a greater degree of interaction in classrooms which were designed and organized to enhance group learning. This room also contained more powerful technology, the students and teachers preferred the physical organization of the room. This arrangement allowed for (1) greater amount of space in the room; (2) carpeting ("a warmer more homelike feeling"); (3) provision of areas for group work (the classroom was redesigned to allow for small group work); and (4) greater degree of flexibility for a variety of activities within the room.

Prior to the redesign, we observed that the technology was organized in the high school in two ways. In the smaller classrooms, there was a relationship of one computer, one desk, one student with an orientation to the front of the room. In these rooms, the teachers generally gave full group instruction, made desk assignments and circulated through the room to answer questions.

In the larger rooms, the technology was organized around the perimeter of the classroom (in part for access to electricity). A full group instruction area included tables (two students to a table) in rows, facing front to the board. This setting was used for full group instruction. Some of the technology stations were set in a major circulation path. Work was consistently interrupted by circulation.

These classrooms were reorganized in two ways. First, in the smaller classrooms, the rooms were reorganized with desks in clusters of four to six students to a cluster. The marker board was moved to a short end of the classroom. A circulation path was more clearly allowed in this configuration. As well, students could work together in groups with a greater ease.

In the larger classrooms, different configurations with the lecture area were explored. These included totally removing the tables. Group work space was defined with small cluster areas. Hutches served as low partitions to divide space, to house equipment and provide work stations. All technology work stations were removed from the circulation path. The small work areas for groups also appeared to help to give greater definition to the group tasks and away from distractions of the larger classroom:

"Work stations are better for the students. They break the room up into smaller groups so that students can no longer gather in groups of about 10 friends which can be unproductive ... smaller group space helps students to focus on their work."

-High school teacher, Stuebing interview.

Elementary school teachers had previously addressed a number of issues regarding the organization of the classroom and group learning. Many of the desks were organized in groups to allow for group learning activities. In many cases group activities were conducted on the floor (accommodated by carpeting).

The lower elementary grades organized with the technology in a line allowed the teachers to see all the computer screens at one glance and allowed for students to work only with the student sitting next to them. This linear organization reinforced the "computer lab" like setting in the classroom, or technology as an activity and not a supportive tool for learning activities.

The desks in an upper elementary classroom were arranged in groups of four with a technology station adjacent to each group. Each had access to two computers. In this way, students could work in groups and use technology as they required it for their group work.

In discussions with teachers in both the high school and the elementary school, teachers expressed a need for more contact with the students. Often this was limited by overcrowding in the classroom and lack of ease of access to the students. One elementary teacher indicated that she found the class so crowded that she found herself standing in one place and taking questions from students and replying regardless of the distance. By the end of the day she was exhausted from this process.

Individual desks were less preferred to large tables by teachers for group activities. The teachers also expressed a need for different sized spaces for different types of activities. Flexibility in the classroom needed to allow for different types of activities. Set up time for shared equipment was an obstruction to certain activities. The presentation station which often required reorganization was a major problem in the high school classroom. Teachers said that they could take up to 15 minutes for set up of a presentation during a 50 minute class period. In this way, aspects of the classroom which were flexible needed to very quickly changeable. The high school eventually opted for a permanent presentation station within the lecture area which could be used as a work station by students during times in which presentations were not being made.

4. **The technology rich classroom requires greater architectural consideration and sophistication whether for retrofit or new construction.**

The use of learning technologies in the classroom introduces a series of issues which are design and curriculum based. From a systemic view of education, the physical environment has direct impacts on both educational processes and the use of interactive technologies. Solving physical environment issues often creates dilemmas between the design of the classroom, technology and furniture, and the educational program. An educated, informed decision making process is critical to resolving physical environment dilemmas without negative impacts on educational goals or on the ability to optimize the use of interactive technologies. From the first year of this study, the following findings relating to the physical environment have surfaced:

Space: More space is required for technology-rich classrooms.

Flexibility: Interactive technologies do not necessarily increase flexibility due to networking requirements. Due to set up time, computers with peripherals may need to configured with diverse configurations for greatest flexibility.

Furniture: and furniture arrangements need to provide adequate space to allow for technology and to allow for work space. Furniture should be carefully selected to provide for appropriate work settings.

Comfort and climate: Needs are heightened with the introduction of technology. As well, the lack of appropriate climate and comfort conditions can reduce the ability of students to work in groups (for example acoustical arrangements). Loud and quiet areas should be provided within the school environment.

Networking: Electrical servicing and networking capabilities can limit the diversity of activities in technology-rich learning environments.

Storage: Needs are greatly increased in technology-rich classrooms. The configuration of storage systems can be used to promote learning.

DISCUSSION AND RECOMMENDATIONS

"I can do more in things in this environment than I can in the classroom (traditional) because there is more space to do projects.... fewer projects are assigned in the traditional setting because its too much work for the kids."

Teacher interview
Stuebing

From this research, the technology rich learning environment demands an increased consideration of the physical conditions from a perspective of organization, and from a technical architectural and engineering perspective. Physical organization should be in keeping with the needs of the teacher and pedagogical goals. Change must be integrated into teachers' belief systems as well as the setting. While alterations in the physical environment can aid teaching methods, the pre-disposition of the teacher needs to be addressed.

Most educational settings for the next ten to twenty years will not be in new facilities or even renovated facilities. This research takes an existing condition and makes organizational changes to the environment. Teaching modes could be enhanced by redesigning the physical environment to accommodate changes in learning modes: small group or cooperative learning, individual work and large group work. At the same time, introducing technology to a traditional classroom environment requires physical changes to maximize the potential benefit of technology as a tool for learning. At a minimum, networking and electrical service must be provided. The location of technology and networking should be organized in such a way as to allow: (1) ease of access to resources; (2) sufficient space for other forms of work and resources, such as paper and pencils; (3) a variety of technology rich conditions for diversity, particularly for individual and group work.

There is a relationship between change in the environment, change in activity and altering teacher beliefs. Success at any of these levels, will begin to inform and affect the other two. The preference is for parallel change to take place with adequate time for reflection and modification. As activities change in the classroom, demands are put on the physical environment (for example the need for more space to do project work). If these demands are not met, the activity will gradually be discouraged. If the environment is designed appropriately, then the activity will be encouraged. The success of this combination encourages the teacher to explore alternative avenues. If met with continued resistance, pre-held beliefs will be reinforced and traditional modes of teaching will be resume.

The appropriate physical environment with learning technology is largely anecdotal. This research is a beginning toward understanding the issues involved. Further study is required. While many school districts are developing new school settings in "Schools of the Future". Little work has been done to explore the effect of these alternative settings on educational process. The next step is to expand this research to other school settings, as well as to work toward greater change in the physical environment as it relates to use of technology, teaching and learning modes, and obstructions to change, explorations and innovation in education.

REFERENCES

Apple Classrooms of Tomorrow, (1991) Philosophy and Structure, Cupertino, CA, Apple Computers.

Beaton, C. , (1985) " Identifying change agent strategies, skills, and outcomes: the case of district-based staff development specialists", doctoral dissertation, University of Oregon.

Blomeyer,Jr., R.L. and Martin, D.(1991). CASE STUDIES IN COMPUTER AIDED LEARNING, London, England, Falmer Press.

Cohen, D.K. (1988). ' Teaching practice: Plus ca change... ", P. Jackson (Ed.) CONTRIBUTING TO EDUCATIONAL CHANGE: PERSPECTIVES ON RESEARCH AND PRACTICE, Berkeley, CA: McCutchan.

Dwyer, D., Ringstaff, C. & Sandholtz, J. (1990, April). " The evolution of teachers' instructional beliefs and practices in high-access-to- technology classrooms" Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Dwyer, D.; Ringstaff, C.; and Sandholz, J.H. (1991); "Trading places; When Teachers Utilize Student Expertise in Technology- Intensive Classrooms",: Paper presented at the American Educational Research Association Annual Meeting, Chicago,

Fullan, M., , (1981), THE MEANING OF EDUCATIONAL CHANGE: New York, N.Y., Teachers College Press.

Gearhart,M. Herman,J., Baker, E., Novak, J. & Whittaker, A. (1990). "A new mirror for the classroom: Using technology to assess the effects of technology on instruction." Paper presented at Apple Classrooms of Tomorrow Symposium, Cupertino, CA.

Norman, D. (December 1991) , "Collaborative Computing: Collaboration First, Computing Second, Computer Supported Collaborative Work, *Communications of the ACM* , vol. 34, no. 12.

Schofield, J.W., & Verban, D.(1988) Computer usage in teaching mathematics: Issues which need answers. In D. Grouws and T.Cooney (Eds.) THE TEACHING OF MATHEMATICS: A RESEARCH AGENDA (Vol. 1). Hillsdale, N.J., Erlbaum.

Sheingold, Karen and Tucker, Marc S., Editors, (1990), RESTRUCTURING FOR LEARNING WITH TECHNOLOGY; Center for Technology in Education, Bank Street College of education and National Center on Education and the Economy; New York.

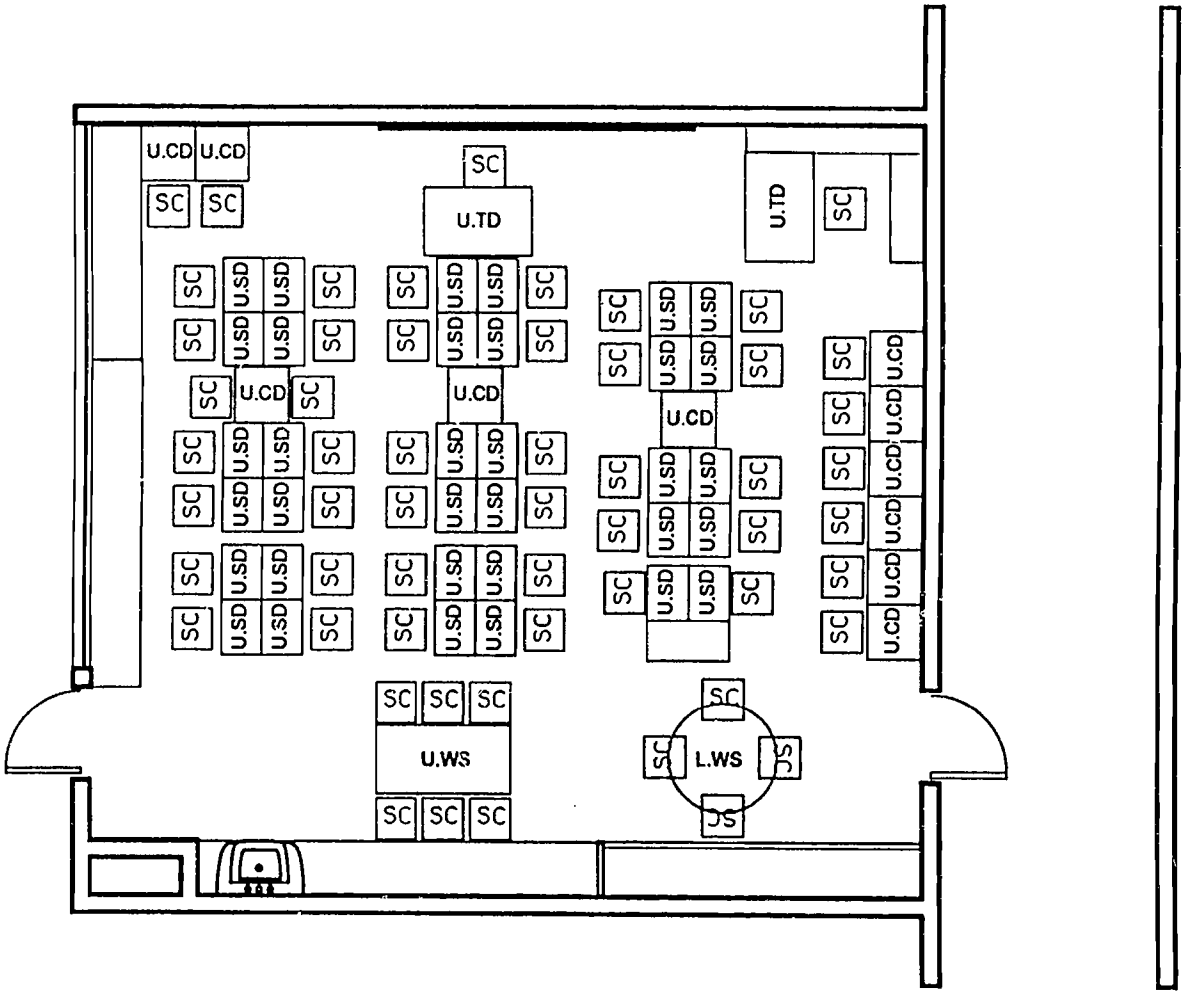
ADDENDUM

Elementary School Plans

LOWER GRADES FURNITURE	UPPER GRADES FURNITURE	
L.SD	U.SD	Student Desk
L.CD	U.CD	Computer Desk
L.WS	U.WS	Work Station
L.AD		Aides Desk
L.TD	U.TD	Teacher Desk

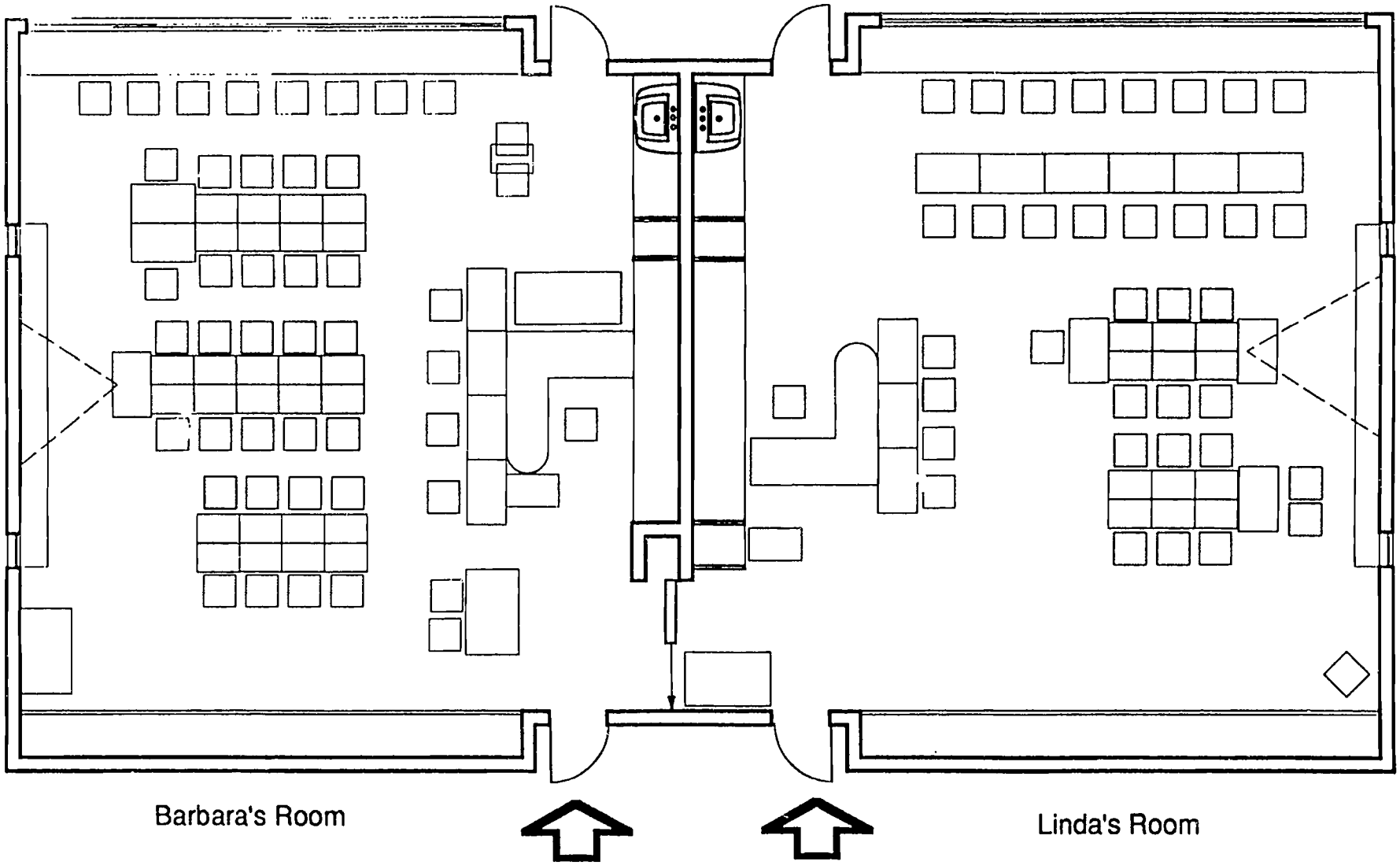
VARIOUS FURNITURE

FC	File Cabinet
	Door
SC	Student Chair
BC	Bookcase
OP	Overhead Projector

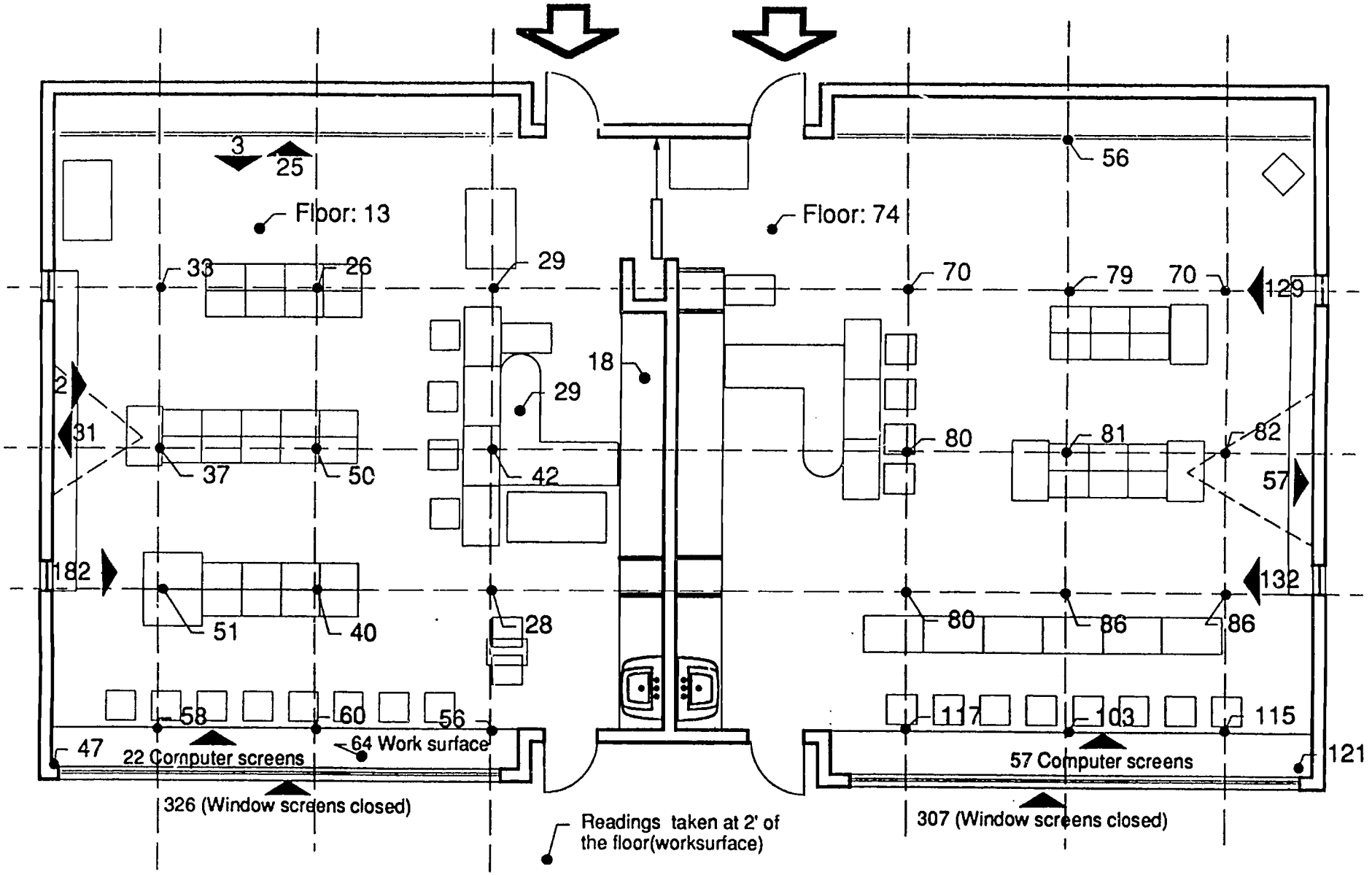


Class. Existing

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



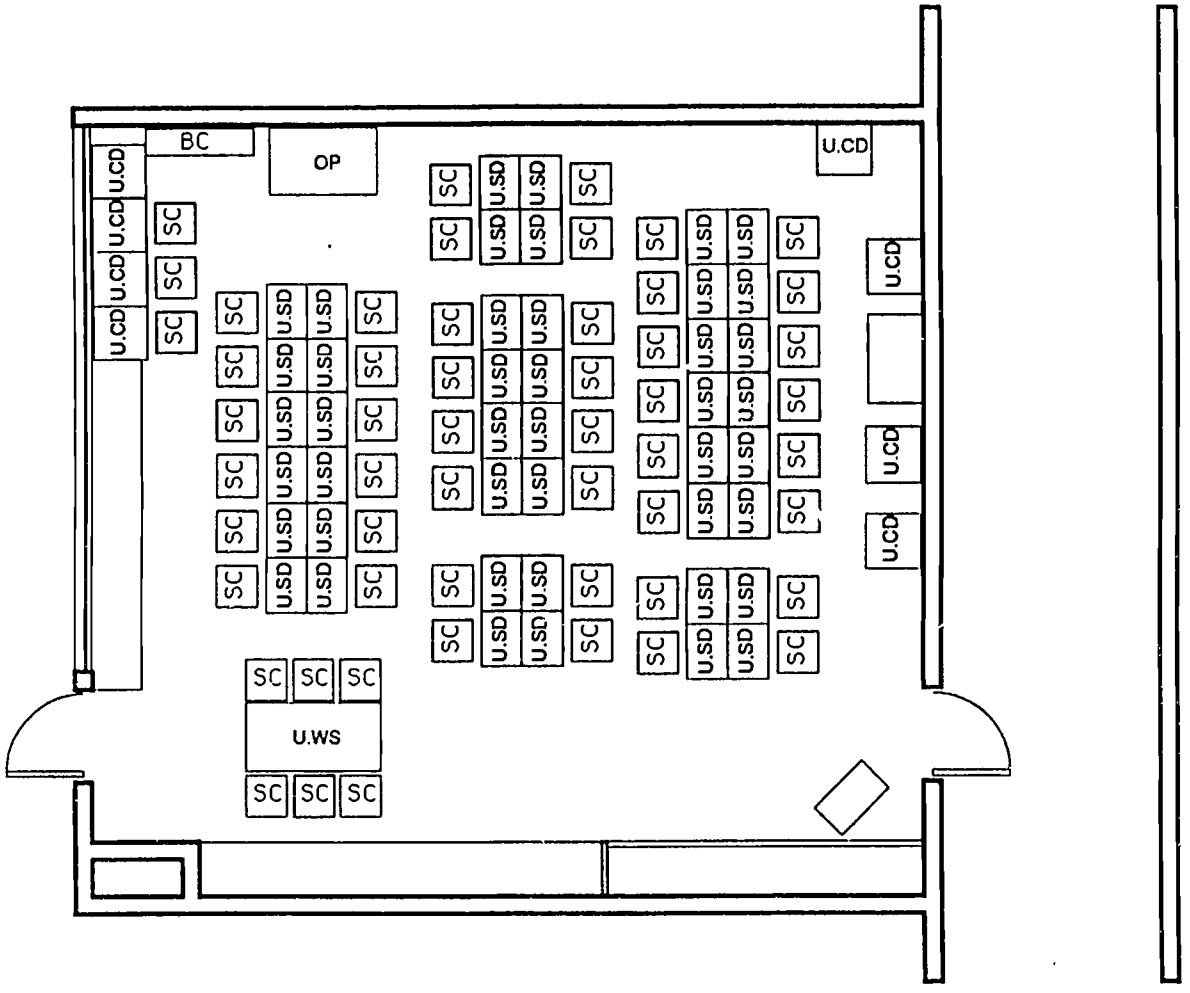
Classroom Layout
Stevens Creek Elementary School, Coupertino, CA
NJIT/Architecture and Building Science-APPLE CLASSROOMS OF TOMORROW PROJECT



Incident and Reflective Ambient Light Readings(in Foot Candles) - 12:00 noon

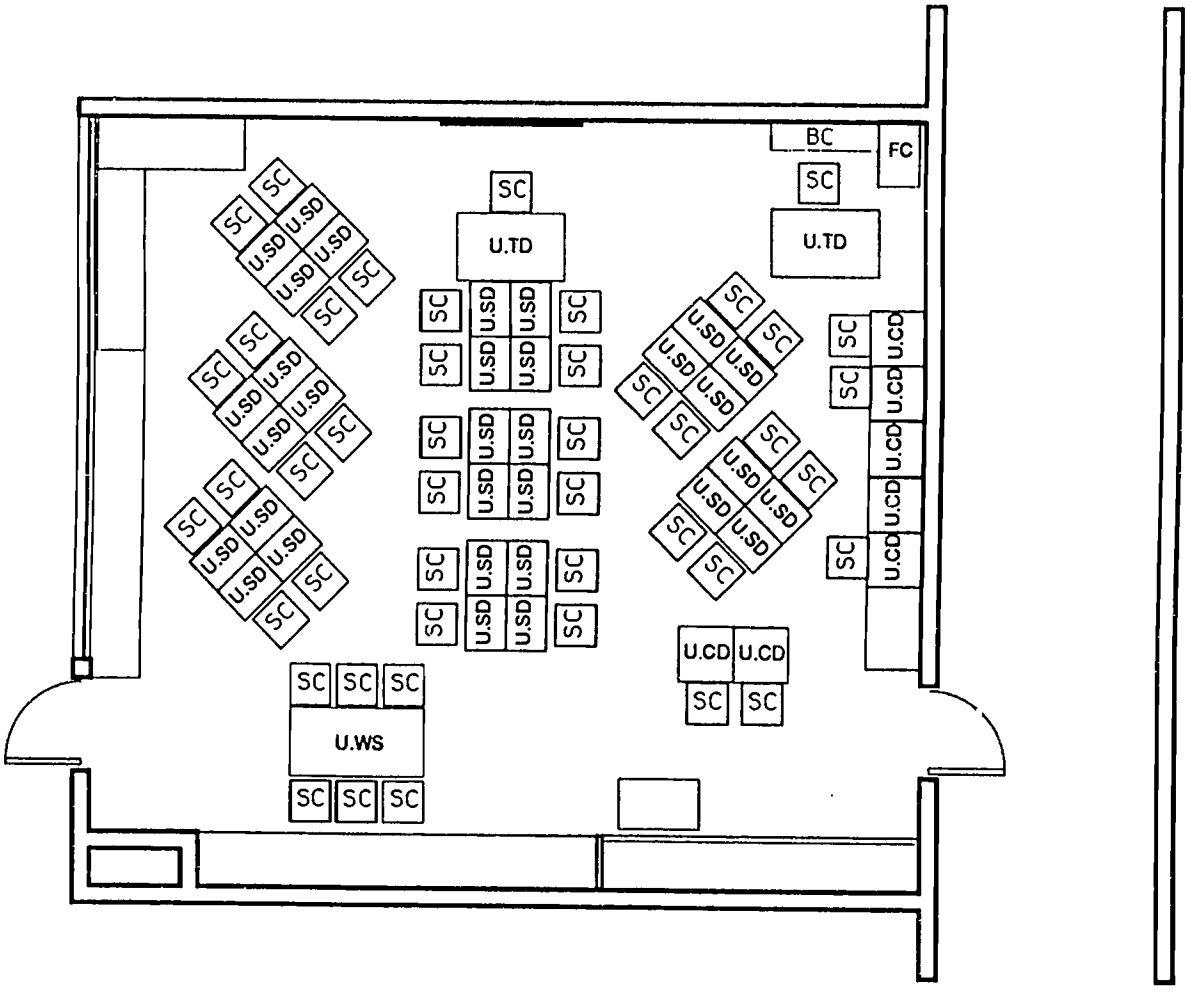
Stevens Creek Elementary School, Coupertino, CA

NJIT/Architecture and Building Science-APPLE CLASSROOMS OF TOMORROW PROJECT



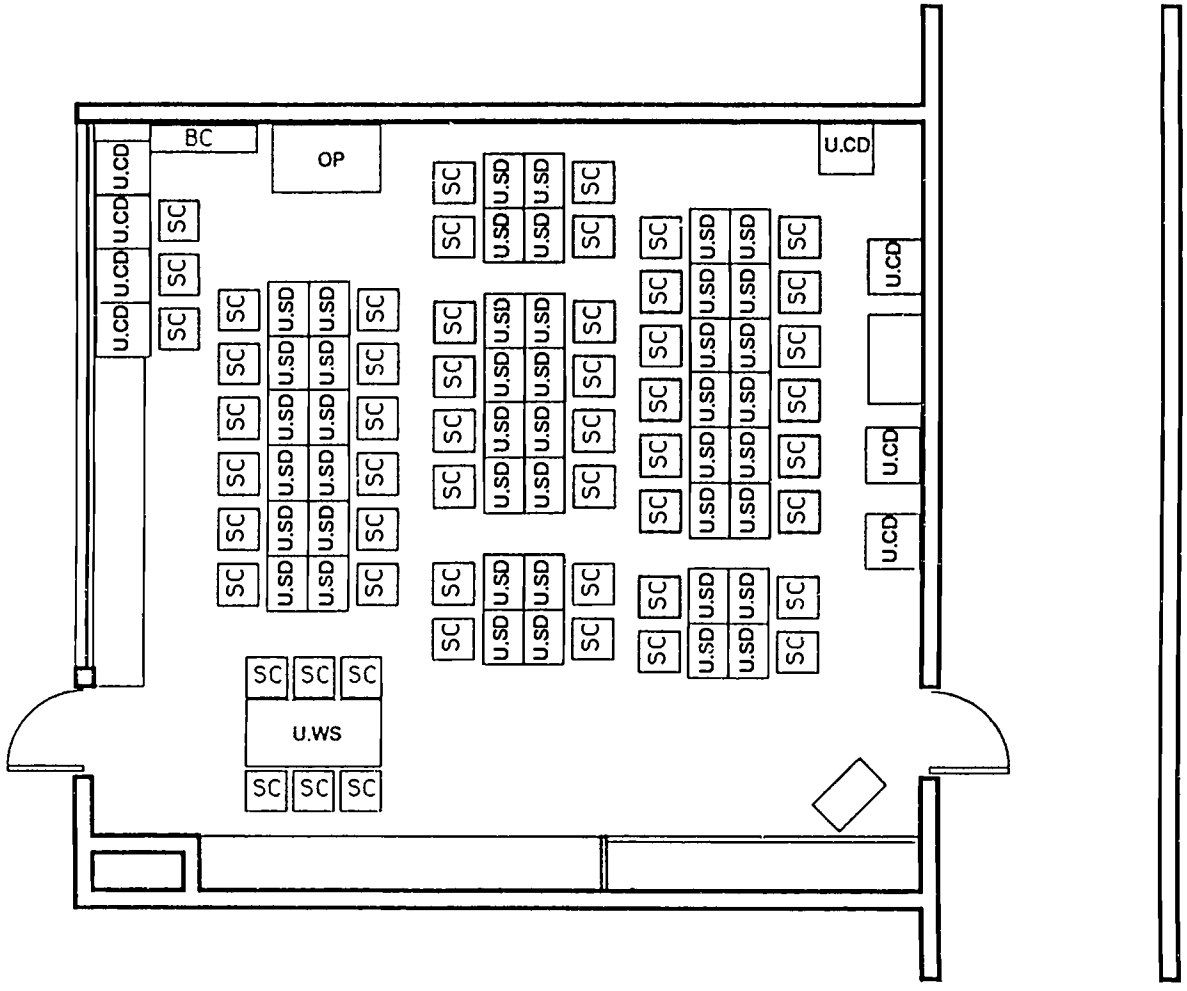
CLASS.Existing

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



CLASS.EXISTING

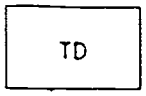
NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



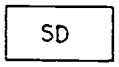
CLASS.Existing

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT

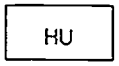
High School Plans



Teacher Desk



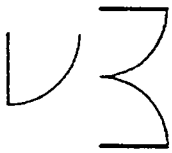
Student Desk



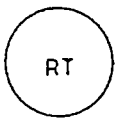
Hutch

Student Chair

Teacher Chair

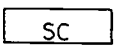


Doors

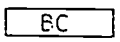


Round Table

File Cabinet

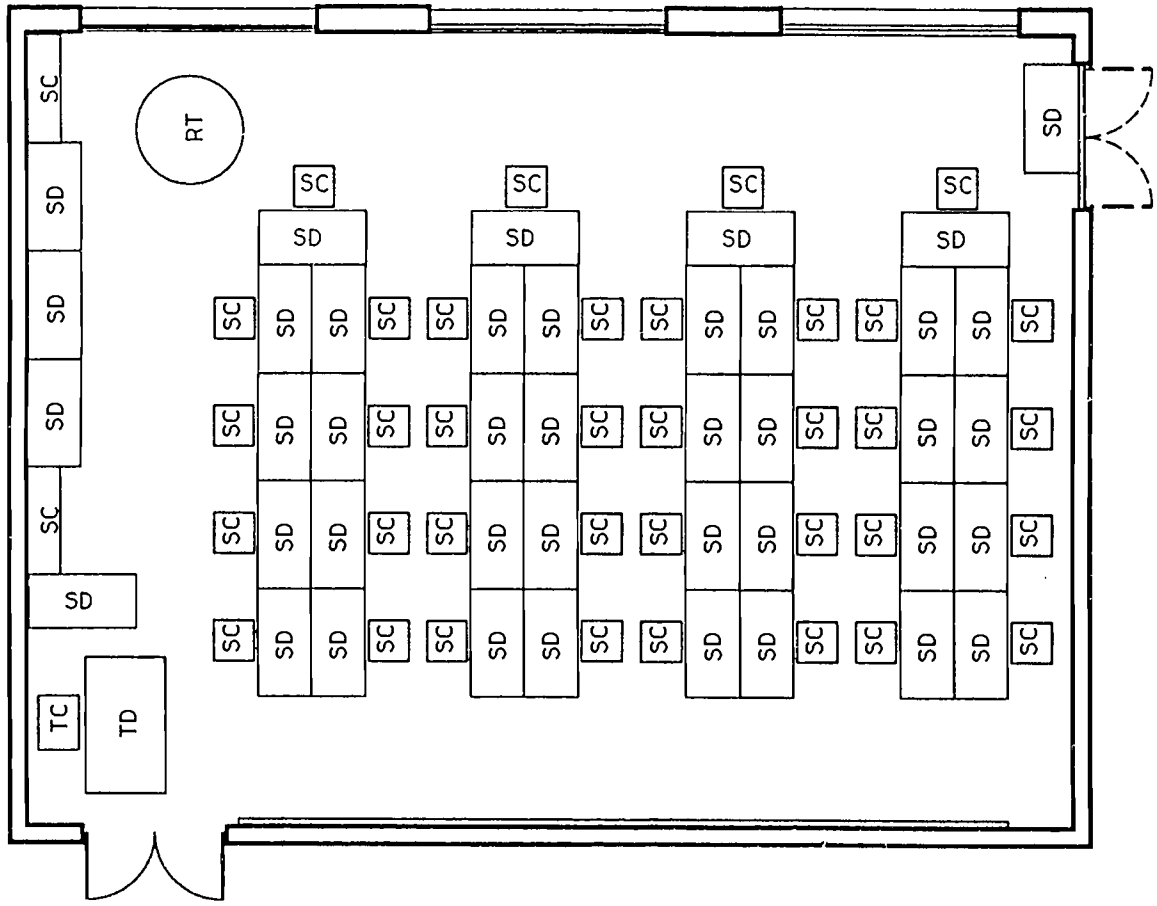


Storage Cabinet



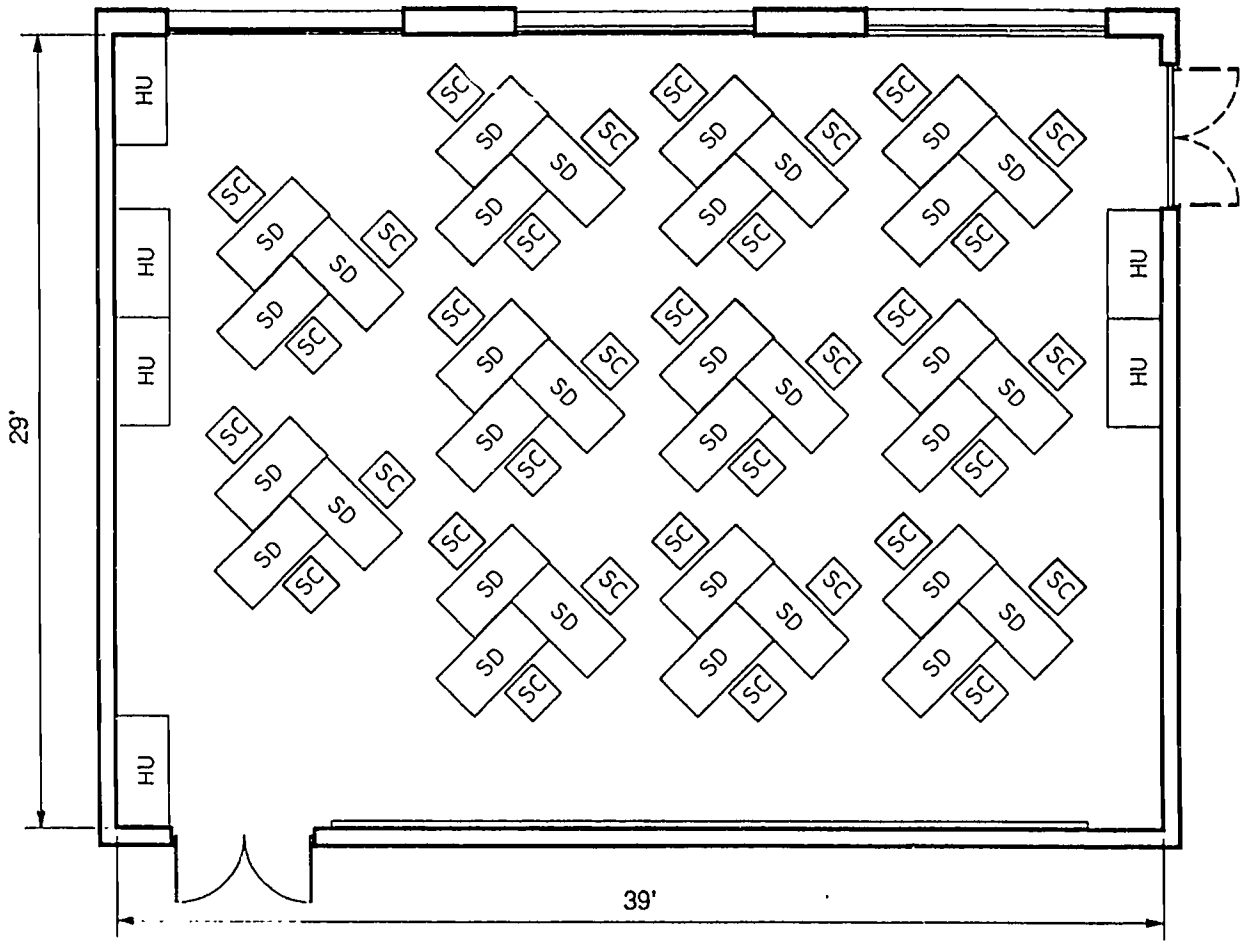
Bookcase

Refridgerator



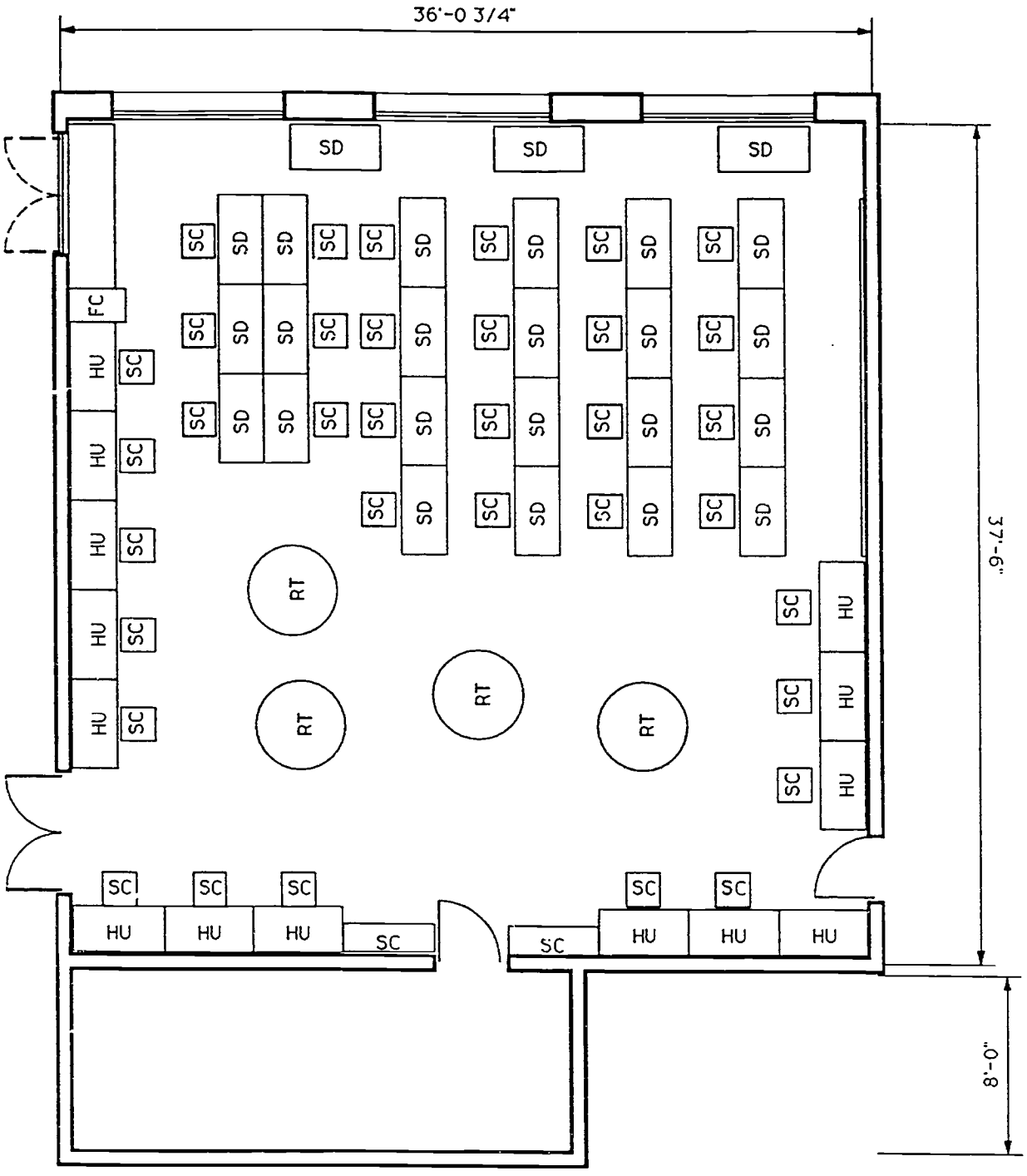
Room 318.Exis

NJIT/Architecture and Building S
APPLE CLASSROOMS OF TOMORROW PR



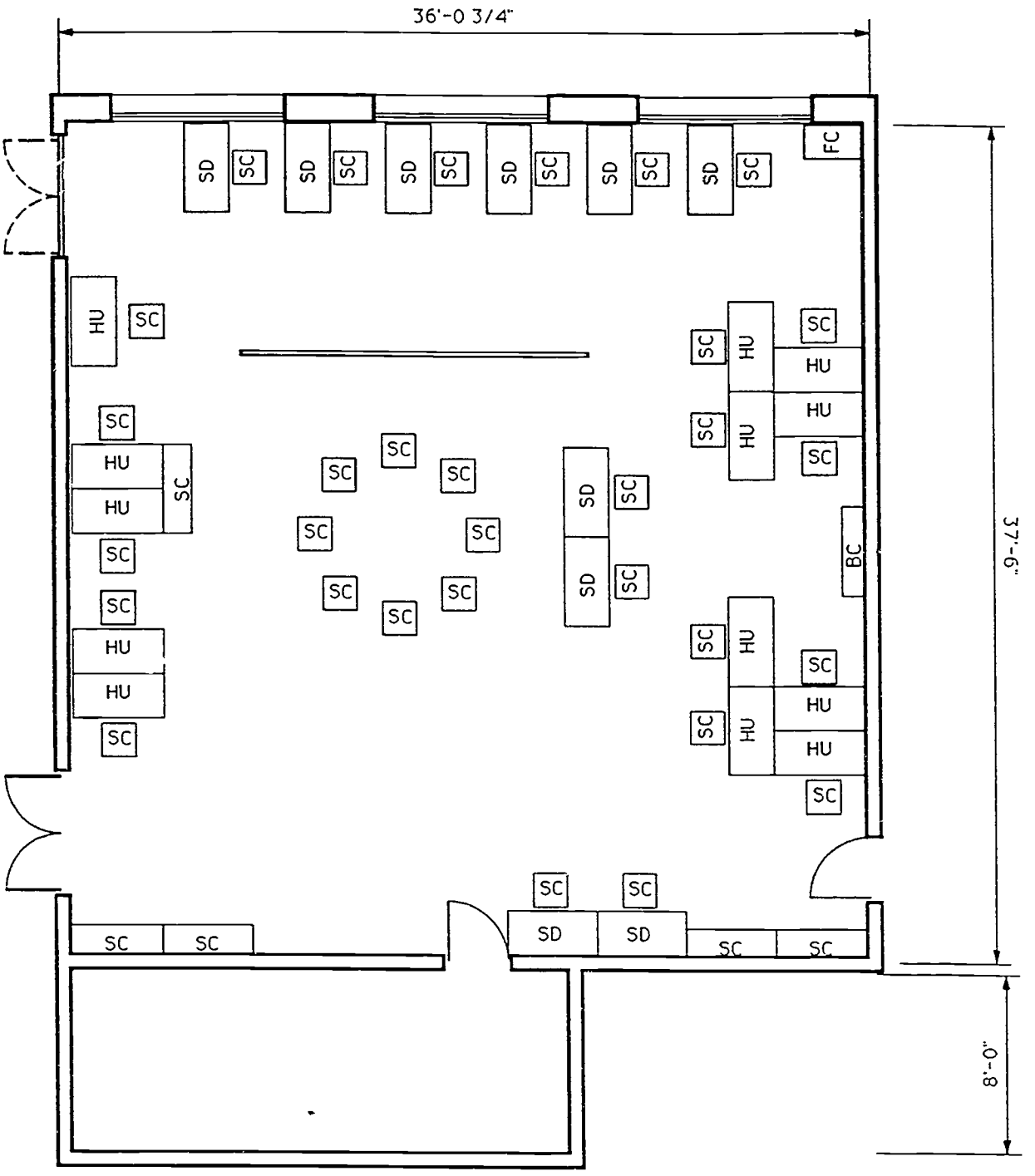
Room 318.Proposed

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



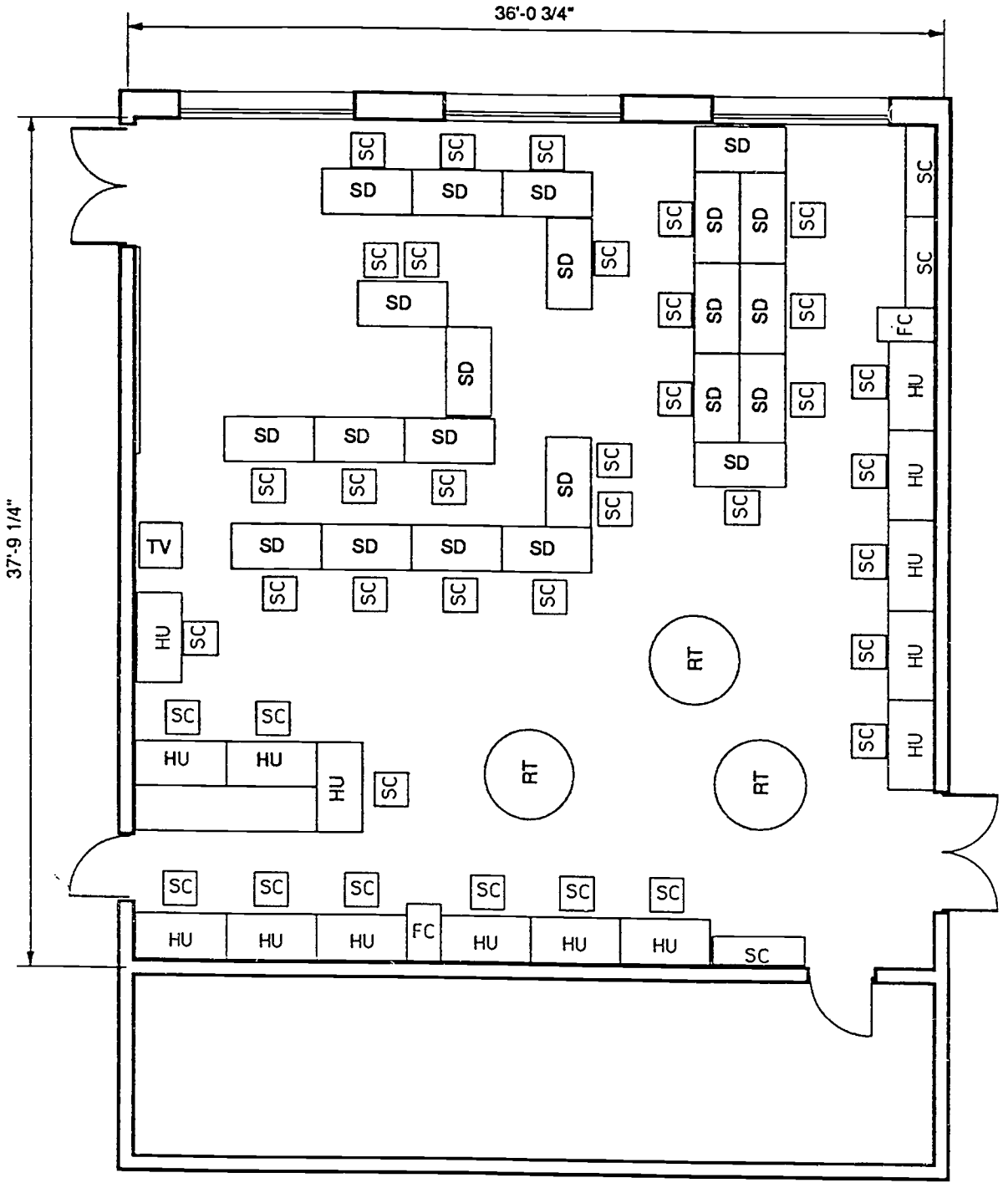
Room 319. Existing

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



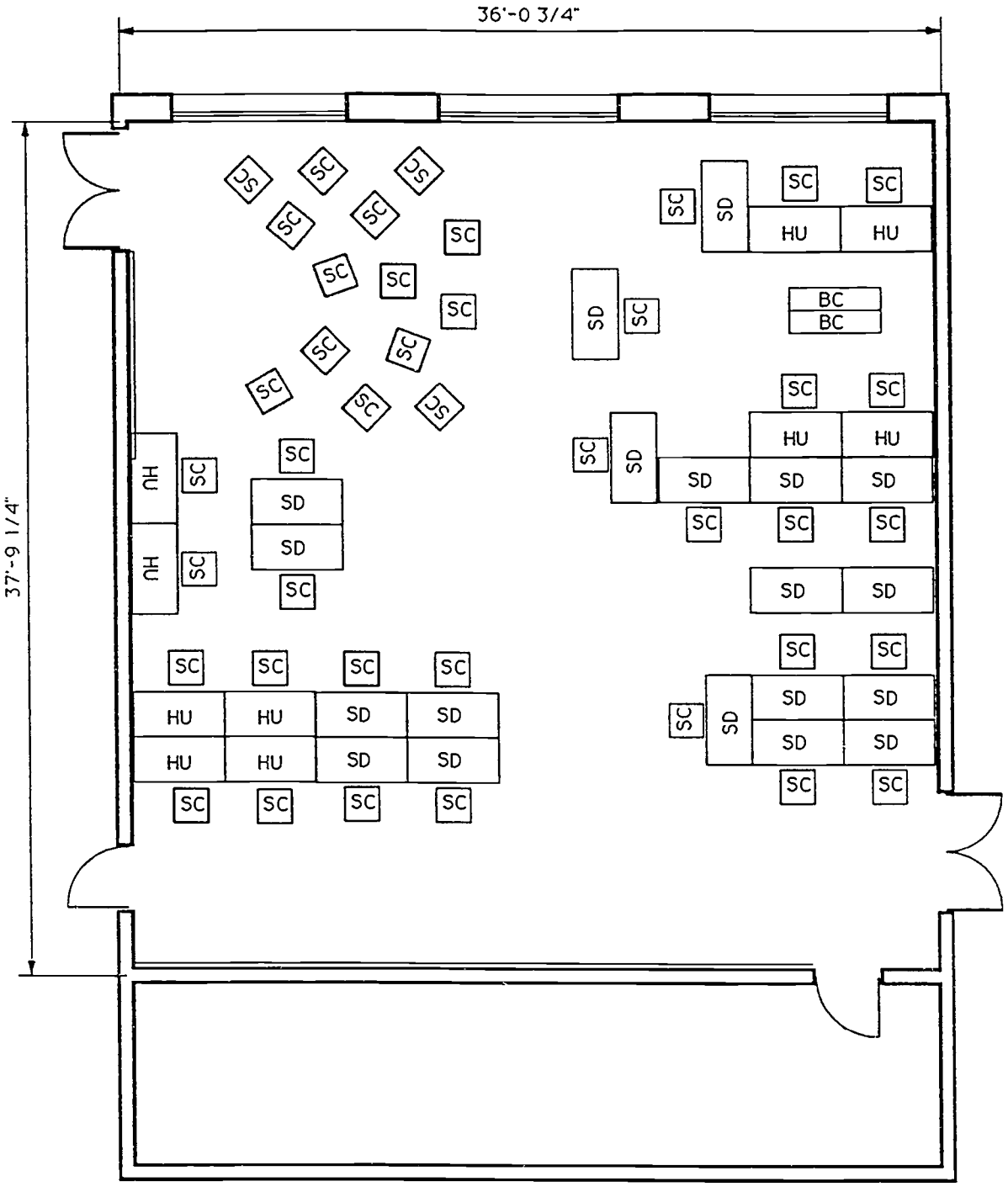
Room 319. Proposed

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



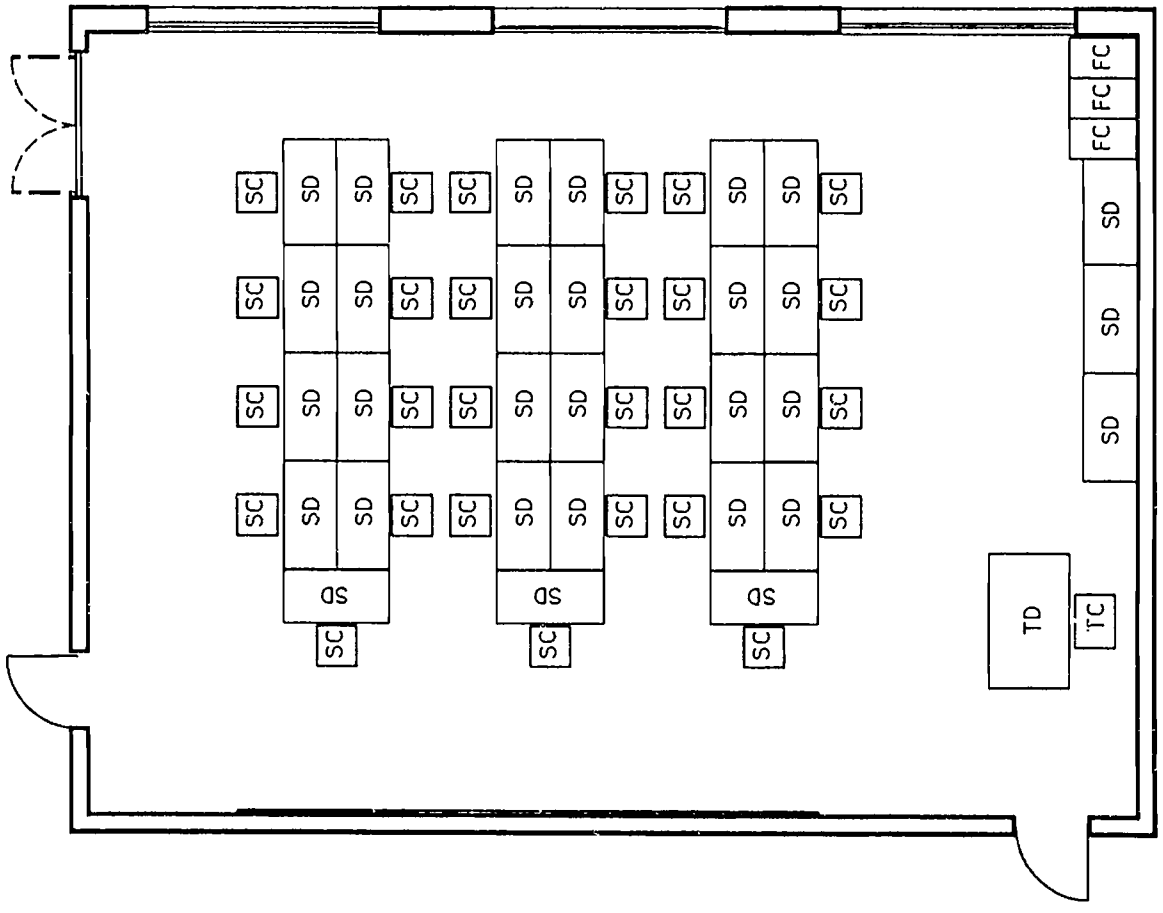
Room 320. Existing

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



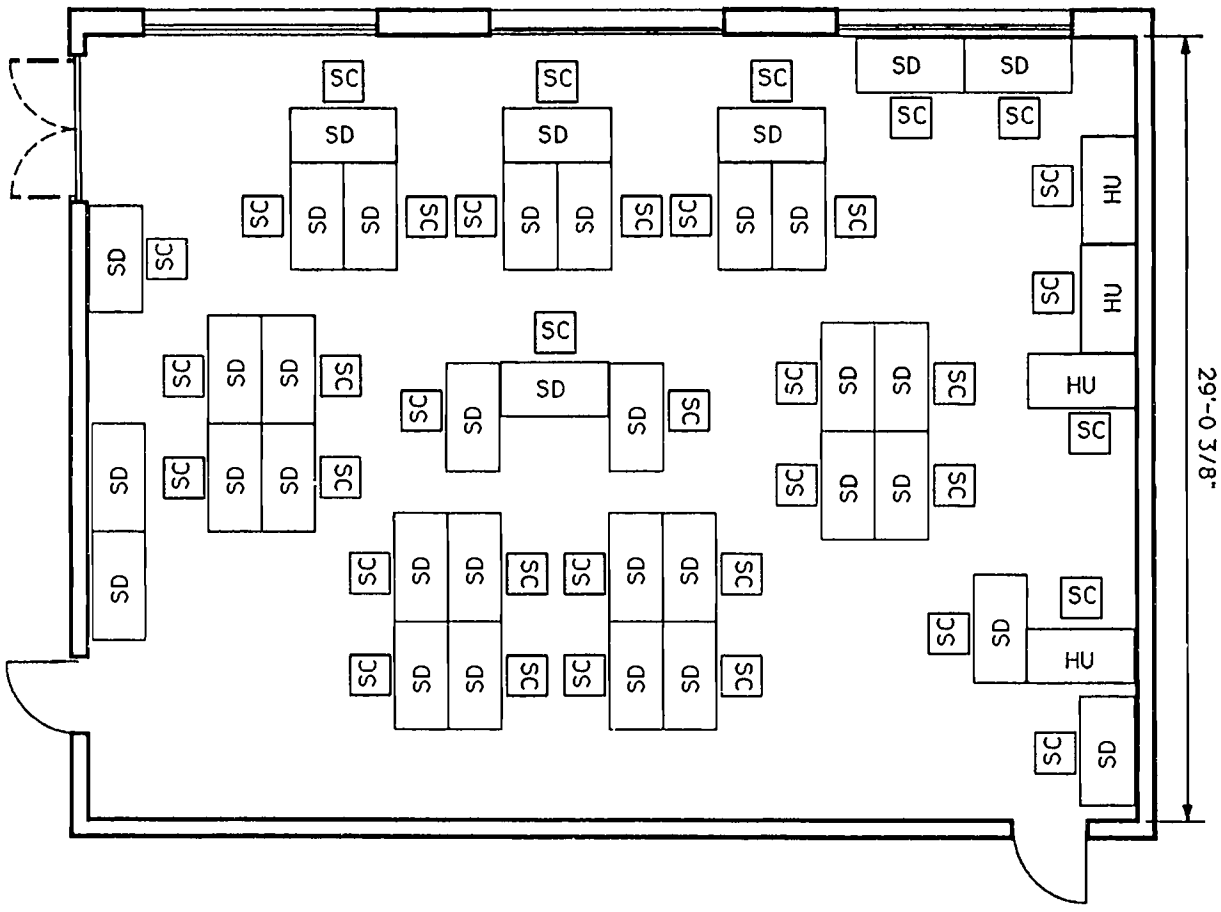
Room 320. Proposed

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



Room 321. Existing

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT



Room 321.Proposed

NJIT/Architecture and Building Science
APPLE CLASSROOMS OF TOMORROW PROJECT