Identification of Dysfunctional Cooperative Learning Teams Using Taguchi Quality Indexes

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ABSTRACT
In this study, dysfunctional cooperative learning teams are identified by comparing the Taguchi “larger-the-better” quality index for the academic achievement of students in a cooperative learning condition with that of students in an individualistic learning condition. In performing the experiments, 42 sophomore mechanical engineering students are randomly assigned to the two learning conditions and are formed into mixed-ability three-member groups. The probability of erroneously identifying a functional team as dysfunctional is quantified using a control chart. The identification results are verified by examining the smaller-the-better and larger-the-better Taguchi quality indexes for the students’ off-task behavior frequency and attitudes toward cooperative learning, respectively. The methodology and findings presented in this study provide a useful basis for the development of technology-assisted solutions for monitoring and analyzing the performance of cooperative learning teams.

Keywords
Academic achievement, Cooperative learning, Dysfunctional team, Taguchi quality index

Introduction
The underlying principle of cooperative learning is one of interdependence (Johnson & Johnson, 1989; Smith, Sheppard, Johnson, & Johnson, 2005). Positive interdependence (i.e. cooperation) prompts an interaction effect in which the individuals within the group encourage one another and facilitate one another’s efforts to learn (Johnson, Johnson, & Smith, 1998; Smith et al., 2005). Many studies have shown that when implemented successfully, cooperative learning fosters a spirit of helping, encouraging, and mutual support, and results in a notable improvement in the learning performance of each team member (Felder, 1995; Felder, Felder, & Dietz, 1998; Johnson, Johnson, Roy, & Zaidman, 1986; Johnson et al., 1998; Prince, 2004; Smith et al., 2005; Springer, Stanne, & Donovan, 1999).

However, when students with different genders, abilities, personalities, learning styles, and work ethics are forced to work together as a group, difficulties invariably arise. In the worst case scenario, some students with an initially positive attitude toward cooperative learning may begin to doubt its effectiveness, while others who were initially resistant to cooperative learning may become even more so (Felder & Brent, 1994). Cooperative teams having such members invariably become dysfunctional over time, leading to an inevitable loss in the benefits of cooperative learning.

As a result, it is desirable for instructors to identify dysfunctional teams at their earliest stages of development such that they can implement appropriate remedial actions in a timely manner. School administrators and education researchers also have an interest in identifying dysfunctional teams. For example, school administrators may wish to analyze the degree of success (or failure) of cooperative learning within their campus in order to tailor their existing teaching strategies or to formulate new strategies for the future. Similarly, in studying the interactions and dynamics within cooperative teams, education researchers may find it useful to identify dysfunctional teams such that their effects can be excluded from the analysis.

Consequently, a requirement exists for a reliable method of identifying dysfunctional cooperative teams to support the developers of educational systems in designing technology-assisted solutions for educators and academics wishing to monitor and analyze the performance of cooperative learning teams.

Purpose of study
Given the importance of identifying dysfunctional teams, the problem of examining how this might actually be achieved in practice has received surprisingly little attention. Some researchers (Hwong, Caswell, Johnson, &
Johnson, 1993) suggested gauging the extent of goal and resource interdependence (i.e. the sharing of a common learning goal and common learning resources) among the individual team members as a means of establishing the success (or otherwise) of the cooperative learning condition. Meanwhile, other researchers (Johnson, Johnson, Stanne & Garibaldi, 1990) analyzed the interaction patterns among the students within the group in order to test for the presence of a successful cooperative learning condition. However, crucially, goal interdependence, resource interdependence, interaction patterns and all the other measures used in previous studies indicate only the success or failure of the cooperative learning condition, i.e. they provide no clues as to the effect of this cooperative learning mode on the academic performance of the individual teams.

Instructors can often identify dysfunctional teams intuitively based upon their informal observations of the group dynamics within the classroom. However, formal measurement and assessment procedures are required to provide a more systematic and objective basis on which to formulate instructional decisions. Kaufman, Felder, & Fuller (2000) asserted that peer ratings are an effective means of identifying dysfunctional cooperative learning teams. Similarly, Haller, Gallagher, Weldon, & Felder (2000) suggested asking students to write “minute papers” to indicate whether or not they felt their teams to be functioning in a healthy and efficient manner. However, the reliability of both methods is fundamentally dependent upon the truthfulness and objectivity of the responses received from the students (Marin-Garcia and Lloret, 2008; Smith et al., 2005).

By contrast, the academic achievement of a group of students can be measured objectively simply by referring to the students’ previous test scores. Academic achievement reflects not only the level of each individual student’s learning performance, but also the degree of cooperation within the group. Yager, Johnson, & Johnson (1985) reported that cooperation within a team promotes a Group-to-Individual knowledge transfer which improves the mean academic performance of the team. In addition, since all of the members in a successful cooperative learning team master the collective knowledge possessed within the team as a result of this knowledge transfer mechanism, it seems reasonable to infer that the test scores within the team will exhibit a greater uniformity than those of students in an individualistic learning condition (Archer-Kath, Johnson, & Johnson, 1994). Thus, the present study asserts that the students’ level of academic achievement, in particular the mean and standard deviation of the students’ test scores, represents a viable means of identifying dysfunctional cooperative teams.

However, while the mean and standard deviation of the test scores within a group provide undoubted insights into the academic performance of the team, both metrics represent only one aspect of the students’ learning performance. Specifically, the mean indicates the central tendency of the test scores, while the standard deviation represents their uniformity. Thus, using one metric alone, or using both metrics together but in an inappropriate way, may easily lead the instructor (or education researcher) to reach false conclusions regarding the degree of cooperation and support within the group. Taguchi and other Quality Engineering researchers have advocated various theories and practices for combining quality characteristics in such a way as to obtain an improved quality measure (Fowlkes & Creveling, 1995; Lochner & Matar, 1990). The resulting quality indexes have been used throughout industry to improve the quality of a wide variety of products and processes (Phadke, 1989; Wu & Wu, 2000). In this study, Taguchi quality indexes are used as a means of identifying dysfunctional teams within an educational context.

Students within a successful cooperative learning team not only exhibit a greater intrinsic motivation to learn than those who study alone (Johnson & Johnson, 1978; Smith et al., 2005), but also attain a higher level of academic achievement (Smith et al., 2005; Yager et al., 1985). However, in dysfunctional cooperative teams, some team members stop collaborating with their peers and work alone, while others simply socialize with members of their own team (or others) and spend significantly less time on-task as a result. In the worst-case scenario, the behavioral problems of one team member may prompt conflicts among the other members, thereby reducing the learning performance of the entire team. As a result, students within a dysfunctional cooperative team tend to achieve a lower academic performance than those who study in an individualistic learning mode. Consequently, in developing a methodology for identifying dysfunctional teams, this study considers both cooperative and individualistic learning conditions and deems a team to be dysfunctional if its members exhibit a lower academic performance than that of students working alone (as evaluated using the Taguchi larger-the-better quality index).

**Off-task behavior frequency and attitudes toward cooperative learning**

The time that students spend on-task has long been considered an indication of the students’ attitudes toward the subject matter. The positive interdependence goal structure inherent in successful cooperative learning teams
(Johnson & Johnson, 1999), and the resulting actions of helping, encouraging, and supporting one another, create a strong sense of team identity which is instrumental in enhancing accountability at both the individual and the group level (Johnson et al., 1998; Smith et al., 2005). Consequently, compared to students in an individualistic learning environment, students within a successful cooperative learning team tend to exhibit less off-task behavior in class (Hwong et al., 1993). However, many obstacles exist in establishing a successful team, including a lack of team maturity, the history or old norms of the team members, obstructive individual behaviors, and so forth (Johnson & Johnson, 2002). Consequently, an increased level of off-task behavior is to be expected in dysfunctional cooperative learning teams. Therefore, in this study, the Taguchi-based identification of dysfunctional cooperative learning teams is validated by reference to the results obtained from off-task behavior frequency observations performed within the classroom.

Previous research has shown that when students feel supported by their peers, cooperative attitudes are more likely to emerge. For example, students who perceive themselves to participate frequently in cooperative learning tasks compared to those who do not sense a greater degree of encouragement from their peers (Johnson, Johnson & Anderson, 1983; Johnson et al., 1986). Therefore, in this study, the students’ perceptions of the level of personal support received from their peers are also used as a means of verifying the results obtained from the Taguchi-based approach for the identification of dysfunctional cooperative learning teams.

**Taguchi quality indexes**

Taguchi method is a methodology for finding the optimum settings of the control factors to make the product or process insensitive to noise factors. It has been successfully applied to a wide variety of problems in many different fields, including the electronics, automotive, photography, steel, and chemical processing fields. In fact, the application of the Taguchi method is widely regarded as one of the major factors in accounting for the international dominance of Japanese companies in these industries and others (Phadke, 1989).

Taguchi proposed various generic signal-to-noise (SN) ratios for evaluating the quality of engineering products or processes. Of these ratios, those most commonly used include the smaller-the-better (SB) ratio, the larger-the-better (LB) ratio and the nominal-the-best (NB) ratio (Fowlkes & Creveling, 1995). The NB ratio takes into account the process mean and variance and provides an easy-to-use performance criterion (Lochner & Matar, 1990; Wu & Wu, 2000). In nominal-the-best type problems, the quality characteristic is continuous and nonnegative. Its target value is nonzero and finite. This type of problem occurs frequently in engineering design. Keeping the water in a tank at a constant temperature and achieving target thickness in an electroplating job are two typical nominal-the-best type problems. The objective function (the NB ratio) to be maximized for such problem is written as $SN=10 \log(\frac{\mu^2}{s^2})$, where $\log()$ is the base 10 logarithm function, $\mu^2$ is the square of the mean of the response and $s^2$ is the variance of the response. It is called the signal-to-noise ratio because $s^2$ is the effect of noise factors and $\mu^2$ is the desirable part of the data (the signal). Maximizing SN is equivalent to minimizing sensitivity to noise factors. Moreover, the NB ratio provides the basis on which the other two SN ratios are derived (Lochner & Matar, 1990; Wu & Wu, 2000).

In detecting the presence of dysfunctional cooperative learning teams, this study utilizes both the SB ratio and the LB ratio. In smaller-the-better type problems, the response values or quality characteristics have non-negative values and the desired value of the response is zero (Lochner & Matar, 1990). In the present study, the students’ off-task behavior frequency falls neatly into this category of problem. The smaller-the-better SN ratio is formulated as $SN = -10 \log(\Sigma y_i^2/n)$, where $\Sigma$ is the summation operation, $n$ is the number of data points, and $y_i$ is the i-th individual response value. The SB ratio can also be written as $SN = -10 \log(s^2+\mu^2)$. In other words, the SB signal-to-noise ratio takes account of both the variability in the response data and the closeness of the average response to the target value (i.e. zero). Specifically, the SN ratio increases as the variability and average value of the response reduces (Fowlkes & Creveling, 1995; Lochner & Matar, 1990). For larger-the-better type problems, the response values or quality characteristics have non-negative values and the aim is to increase the value of the response toward the largest number possible (preferably infinity). In the present study, this definition neatly fits the problem of evaluating the students’ academic achievement and their attitudes toward cooperative learning. Larger-the-better problems are the reciprocal of smaller-the-better problems, and thus the larger-the-better SN ratio is formulated as $SN= -10 \log(\Sigma y_i^2/n)$ (Fowlkes & Creveling, 1995; Lochner & Matar, 1990). Note that regardless of the SN ratio chosen as a quality index, the objective of the Taguchi design procedure is always to increase the value of the SN ratio, i.e. a
higher SN ratio is always indicative of a better quality (Fowlkes & Creveling, 1995; Lochner & Matar, 1990; Phadke, 1989; Wu & Wu, 2000).

**Method**

**Subjects**

The experimental stage of this study was conducted in the spring semester of 2006 using 42 mechanical engineering sophomore students from National Pingtung University of Science and Technology in southern Taiwan. The students were randomly assigned to a cooperative learning condition or an individualist learning condition such that each condition contained 21 students. Within the cooperative learning condition, the 21 individuals were assigned to three equally-sized “high-ability”, “medium-ability” or “low-ability” groups in accordance with their average test scores in the previous semester. Within each ability group, one member was chosen at random and assigned to a cooperative learning team. This process was repeated iteratively until each of the 21 students had been assigned to a learning team. Thus, on completion of the assignment process, the 21 individuals were organized into a total of seven learning teams, with each team comprising one high-ability member, one medium-ability member and one low-ability member. Having been assigned to one of the seven groups, the students were informed that they were to remain within the same group for the entire semester and were to work in a cooperative fashion in solving the learning tasks assigned to them. For ease of comparison, the 21 students in an individualistic learning condition were also randomly assigned to seven “teams” stratified in terms of the members’ academic ability. However, in this case, the students were instructed to work alone at all times. The results presented in Table 1 confirm the heterogeneous nature of the cooperative and individualistic learning teams. In addition, the results obtained from a \( t \) test showed no significant differences in the mean test scores of the students within the two conditions, \( t=0.15, p=0.88 \). Therefore, it was inferred that the two learning conditions were equivalent in terms of the students’ academic abilities prior to the experimental stage of the study.

**Table 1. Average scores of teams within different ability groups in previous semester**

<table>
<thead>
<tr>
<th>Team</th>
<th>Cooperative Learning</th>
<th></th>
<th>Individualistic Learning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability group</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Mean</td>
</tr>
<tr>
<td>A</td>
<td>75</td>
<td>70</td>
<td>64</td>
<td>69.67</td>
</tr>
<tr>
<td>B</td>
<td>73</td>
<td>67</td>
<td>66</td>
<td>68.67</td>
</tr>
<tr>
<td>C</td>
<td>71</td>
<td>68</td>
<td>61</td>
<td>66.67</td>
</tr>
<tr>
<td>D</td>
<td>77</td>
<td>71</td>
<td>66</td>
<td>71.33</td>
</tr>
<tr>
<td>E</td>
<td>76</td>
<td>71</td>
<td>60</td>
<td>69.00</td>
</tr>
<tr>
<td>F</td>
<td>82</td>
<td>69</td>
<td>62</td>
<td>71.00</td>
</tr>
<tr>
<td>G</td>
<td>77</td>
<td>68</td>
<td>65</td>
<td>70.00</td>
</tr>
</tbody>
</table>

**Course**

The experimental study was confined to the Planar Dynamics course, a mandatory course for each of the 42 students. The course comprised four teaching units, namely Unit 1 - Kinematics, Unit 2 - Energy Method, Unit 3 - Force and Acceleration Method, and Unit 4 - Impulse and Momentum Method. Units 1 and 3 each had a duration of six weeks, while Units 2 and 4 both lasted for three weeks. In addition to the regular 3-hr/wk day-time classes, the students also attended mandatory homework classes (7-hr/wk) in which they studied in accordance with their assigned learning condition under the supervision of two teaching assistants.

**Independent variables**

In this study, the independent variable is the learning method (i.e. cooperative or individualistic). In the cooperative condition, the students were instructed to work together as a team, thereby promoting that each team member worked diligently, mastered the assigned material, freely offered their ideas and suggestions, listened to one another, shared
ideas and materials, and praised and helped one another. The cooperative learning teams were carefully implemented in such a way as to develop positive interdependence, face-to-face interaction, individual accountability, social skills, and group processing (Johnson & Johnson, 1978, 1989, 1999). Note that a detailed review of the implementation procedures required for successful cooperative learning teams can be found in previous studies (Oakley, Felder, Brent, & Elhajj, 2004; Smith et al., 2005), and thus the details are deliberately omitted here.

In the individualistic learning condition, the students worked on their own, avoided interaction with their peers, sought help only from the instructor or teaching assistants, and worked at a self-regulated pace. Interaction between the students in the individualistic learning condition was actively discouraged, and the students were constantly reminded to work alone when performing the assignments given to them in class or in the evening homework sessions.

Throughout the entire semester, only one student dropped out of the course. In addition, the attendance records showed that the two groups of students in the different learning conditions had an approximately equal attendance rate, and thus an equal learning time. Furthermore, for the duration of the course, two trained teaching assistants were engaged to help the instructor enforce the two learning conditions. Specifically, the assistants moved around the class encouraging students in the cooperative condition to work together in solving the assigned tasks, while reminding those in the individualistic condition to study alone.

**Dependent variables**

The dependent variables in the present study include the students’ academic achievement, their off-task behavior frequency, and their attitudes toward cooperative learning. The students’ academic achievement was measured by means of four unit tests, given at the end of each teaching unit, respectively. Each test lasted for three hours and consisted of six to eight engineering problems chosen from the exercise section of the course textbook (Hibbeler, 2004). In completing each test, the students in each learning condition worked individually and were assigned a score in accordance with their own performance. A solution flowchart was prepared in advance by the instructor for each test item to indicate the key intermediate stages and results in the solution procedure. Using these flowcharts, the students were awarded partial credits even if their final solutions were incorrect. The test papers were graded independently by the two teaching assistants, and the two sets of results were then compared to ensure their reliability. In analyzing the test results obtained over the course of the semester, the scores achieved by each student for the four unit tests were averaged to obtain a single measure of the student’s academic achievement.

The frequency of the students’ off-task behavior was measured by conducting classroom observations (Hwong et al., 1993; Marin-Garcia and Lloret, 2008; Slavin, 1992) during the homework classes. The observation sessions were conducted on five separate occasions around the mid-point of the semester. In performing the observations, off-task behavior was defined as one or more students within a cooperative team talking with members of another team, walking around the classroom, breaking eye contact with their team members or the learning materials, dozing, or simply socializing. The observation sessions were conducted by the two teaching assistants using an off-task record form and an MP3 device with a 20-second cued loop designed to provide a consistent aural cue for a 10-second “observe” period and a 10-second “record” period. Inter-observer reliability was calculated by dividing the total number of agreements between the results obtained by the two observers by the sum of the agreements and disagreements (Hwong et al., 1993; Slavin, 1992). The average reliability index was found to be 0.85, and thus it was concluded that the observation results were sufficiently consistent for analysis purposes (Slavin, 1992). In analyzing the observation results, a point was given for each off-task behavior observed, and the total number of points recorded by the two observers for each team was then averaged to obtain an overall result. Finally, the results obtained for each team over the five observation sessions were used to calculate the corresponding value of the smaller-the-better SN ratio in accordance with the formula given in Section Taguchi-quality-indexes.

The attitudes of the students toward cooperative learning were evaluated at the end of each teaching unit using the peer-personal-support subscale developed by Johnson et al. (1983). The subscale comprised five items (Cronbach alpha reliability: 0.78) designed to determine each respondent’s perceptions regarding whether or not the other team members cared about their feelings, liked them the way they were, really cared about them, liked them as much as they liked the other members in the team, and thought it was important to be their friend, respectively. Each item on the subscale was configured in the form of an affirmative statement and was evaluated using a 5-point scale, where 1
indicated the respondent’s absolute disagreement with the statement and 5 indicated the respondent’s absolute agreement. Thus, a higher score revealed a more favorable attitude on the part of the respondent to the cooperative learning approach. In analyzing the survey results for each student, the scores obtained over all of the items were summed and the result was then divided by the total number of items on the subscale (i.e. 5). The results obtained for each respondent over the four surveys were then averaged to obtain a single measure of the respondent’s attitude toward cooperative learning. Finally, the results obtained for each team over the four surveys were used to calculate the corresponding value of the larger-the-better SN ratio in accordance with the formula given in Section Taguchi-quality-indexes.

Results and Discussion

Traditional method

Table 2(a) presents a statistical analysis of the unit test scores for the seven teams in the cooperative learning environment. Note that in compiling the data presented in this table, the mean score for each team was obtained by averaging the scores for the three team members (N=3) within the group, while the standard deviation was obtained by taking the square root of the variance of the scores obtained by each team member in the group. Table 2(b) presents the statistics of the test scores of the 21 students in the individualistic learning condition.

<table>
<thead>
<tr>
<th>Cooperative Team</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>48.92</td>
<td>13.76</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>61.75</td>
<td>5.94</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>62.50</td>
<td>13.21</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>51.50</td>
<td>13.05</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>66.00</td>
<td>9.12</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>68.92</td>
<td>8.38</td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>66.50</td>
<td>6.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualistic Learning</td>
<td>21</td>
<td>59.42</td>
<td>8.73</td>
</tr>
</tbody>
</table>

Conventional wisdom suggests that successful collaboration within a cooperative learning team not only improves the mean academic achievement of the team, but also enhances the uniformity of the mean achievement of the individual team members. Thus, the results presented in Table 2(a) suggest that cooperative teams A and D are the most likely candidates for dysfunctional cooperative learning teams since they not only have a lower mean score than the average score of the 21 students in the individualistic learning condition (i.e. 48.92 and 51.50 for teams A and D, but 59.42 in the individualistic learning condition), but also have a higher standard deviation (i.e. 13.76 and 13.05 for teams A and D, but 8.73 for the students in the individualistic learning condition). Teams C and E are the next most likely candidates for dysfunctional teams since even though they have a relatively high mean score (i.e. 62.5 and 66.0, respectively), they both have a large standard deviation (i.e. 13.21 and 9.12, respectively). In general, however, it is difficult to reach a definitive conclusion regarding the status of a team if the team has only a small mean score or a large standard deviation (e.g. teams C and E).

Taguchi method

Table 3(a) presents the Taguchi SN ratio values for the three dependent variables in this study. Note that the results are obtained by substituting the values of the dependent variables for each team into the formulae given in Section Taguchi-quality-indexes. Note also that the value of n given at the head of each column indicates the number of data points used to compute the value of the SN ratio for the corresponding dependent variable. Thus, for the off-task frequency variable (see the third column in Table 3(a)), n has a value of n=5 since the off-task behavior was evaluated over five observation sessions. Meanwhile, the SN ratios for the academic achievement and perceived peer support variables were computed using n=3 since each team comprises three team members and each member contributes one data point to the SN calculation. Table 3(b) presents the SN values of the basis of comparison. Note
that since the off-task behavior frequency was observed only for those individuals within a cooperative learning team, the data presented in the third column of this table is actually the mean SN value of the off-task behavior frequency of the seven cooperative learning teams. As a result, the corresponding SN ratio is computed using $n=35$, i.e. five observations for each of the seven teams. By contrast, the SN ratios for the academic performance and perceived peer support, respectively, are both computed using $n=21$, corresponding to the 21 students within the individualist learning condition. The results presented in the second column in Table 3(a) (i.e. the SN ratio for academic achievement) suggest that cooperative learning teams A and D are dysfunctional since their SN values (32.77 and 33.48, respectively) are smaller than the mean SN ratio (35.15) of the students in the individualist learning condition.

<table>
<thead>
<tr>
<th>Cooperative Team</th>
<th>Academic achievement ($n=3$)</th>
<th>Off-task frequency ($n=5$)</th>
<th>Peer personal support ($n=3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32.77</td>
<td>-14.44</td>
<td>10.85</td>
</tr>
<tr>
<td>B</td>
<td>35.70</td>
<td>-11.40</td>
<td>11.42</td>
</tr>
<tr>
<td>C</td>
<td>35.20</td>
<td>-2.04</td>
<td>11.56</td>
</tr>
<tr>
<td>D</td>
<td>33.48</td>
<td>-15.19</td>
<td>10.97</td>
</tr>
<tr>
<td>E</td>
<td>36.11</td>
<td>-2.55</td>
<td>10.76</td>
</tr>
<tr>
<td>F</td>
<td>36.58</td>
<td>-10.00</td>
<td>12.56</td>
</tr>
<tr>
<td>G</td>
<td>36.32</td>
<td>0.97</td>
<td>11.60</td>
</tr>
</tbody>
</table>

**Table 3(a). SN ratio for dependent variables of cooperative teams**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Academic achievement ($n=21$)</th>
<th>Off-task frequency ($n=35$)</th>
<th>Peer personal support ($n=21$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualistic Learning</td>
<td>35.15</td>
<td>-11.03</td>
<td>10.74</td>
</tr>
</tbody>
</table>

**Table 3(b). SN ratio for dependent variables of the comparison basis**

**Verification: off-task behavior frequency**

Off-task or on-task behavior frequency observations have been used in many previous studies to investigate the impact of cooperative learning (Johnson, Johnson, Ortiz, & Stanne, 1991; Archer-Kath et al., 1994). In general, the results have shown that successful cooperative learning teams exhibit less off-task behavior in class (Hwong et al., 1993). However, these studies did not prescribe any formal rules to enable the reliable identification of dysfunctional teams. In this study, it is argued that dysfunctional teams exhibit a greater amount of off-task behavior than successful cooperative teams, and consequently have a lower SN ratio. Thus, the results presented in Table 3(a) support the earlier findings that cooperative teams A and D are dysfunctional since their off-task frequency SN ratios (i.e. -14.44 and -15.19, respectively) are much (3 dB) lower than those of the other teams.

In this study, the observation sessions were deliberately performed around the middle of the semester in order to allow the cooperative teams sufficient time to mature (Ortiz, Johnson, & Johnson, 1996). However, they could actually have been conducted at any time during the semester. In other words, the instructor is free to choose both when and how often to conduct the observation sessions. In addition, the observation procedure is straightforward and systematic. Each observation procedure takes only a minute to complete for one team, and several minutes at most to complete for the entire class. Moreover, the observation procedure does not depend on the students' cooperation and has scarcely any impact on the normal teaching activities within the class. These advantages render off-task behavior frequency observations a reliable and convenient tool for the provision of supporting evidence when attempting to identify dysfunctional teams.

**Verification: attitudes toward cooperative learning**

Previous research has shown that students who participate frequently in cooperative learning tasks sense a greater amount of encouragement and academic help from their peers (Johnson et al., 1983). Therefore, in this study, it is argued that members of a dysfunctional team have a less favorable perception of the cooperative learning approach than those of a functional team. Thus, the peer support data presented in the fourth column of Table 3(a) confirm the earlier findings that cooperative teams A and D are dysfunctional.
It is observed in Table 3(a) that team B also has a relatively low off-task behavior frequency SN ratio (i.e. -11.40). However, it has a larger than average SN ratio for academic achievement (i.e. 35.70>35.15) and a relatively positive attitude toward cooperative learning (i.e. 11.42>10.74). Similarly, team E has a non-favorable attitude toward cooperative learning (i.e. 10.76), but has a larger than average SN ratio for academic achievement (i.e. 36.11>35.15). As a result, neither team is considered to be dysfunctional.

Compared with the peer-rating method, attitude surveys such as those conducted in this study are likely to be more favorably received by the team members since they measure each member’s own feelings and emotions rather than asking them to evaluate the behavior and attitudes of their team mates. As a result, the respondents are more likely to answer in an open and truthful manner. However, as with peer-rating methods, the results obtained from an attitude survey are also subjective to a certain extent since different respondents may apply different criteria when interpreting and responding to the survey items. Consequently, it is suggested that while attitude surveys can complement or reinforce the identification results obtained using analytical quality indexes such as the Taguchi SN ratio proposed in this study, they should not be used as the sole basis for identifying dysfunctional teams.

**Absolute quality information**

The SN ratios described in the preceding sections enable a comparison to be made between the “quality” of each team (Fowlkes & Creveling, 1995), e.g. teams A and D perform less successfully than the other cooperative teams. However, to answer the questions “just how much worse are teams A and D than the other teams” or “are teams A and D truly dysfunctional” some form of absolute quality information is required.

Control charts have long been used in the statistical process control field to evaluate the probability of a data point being wrongly classified as failing to satisfy the control limits (Montgomery, Runger, & Hubele, 2001). In a sense, this probability information can be taken as an indication of the absolute quality of each data point (i.e. each cooperative team in the current context). In a control chart, the upper and lower control limits (i.e. UCL and LCL, respectively) and the center line (CL) are defined as follows: $UCL = \mu + k \times \sigma / \sqrt{n}$, $LCL = \mu - k \times \sigma / \sqrt{n}$, and $CL = \mu$, respectively, where $\mu$ denotes the population mean, $\sigma$ denotes the population standard deviation, $\sqrt{}$ denotes a square root operation, $n$ is the sample size, and $k$ is the “distance” of the control limits from the center line and is expressed in multiples of the standard deviation. For the case where the process is in control, the probability of a plotted point falling below the lower limit is equal to 0.02 for $k=2$ and 0.16 for $k=1$.

Table 4(a) indicates the composite academic achievement SN ratios of the seven teams in the cooperative learning condition. Note that in compiling this table, the test scores of the three team members for each unit test are collected and the corresponding value of the SN metric is computed using the larger-the-better formula presented in Section Taguchi-quality-indexes. The composite SN ratio for the team is then obtained by averaging the SN values over the four unit tests. Table 4(b) presents a statistical analysis of the academic performance SN ratio for the 21 individuals in the individualistic learning condition. Since the individualistic condition contains a total of seven notional “teams” and each team has four SN values (i.e. one SN value per unit test), the total number of SN values is equal to N=28 (see second column in Table 4(b)).

<table>
<thead>
<tr>
<th>Cooperative Team</th>
<th>N</th>
<th>Composite SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>32.47</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>35.10</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>34.80</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>32.41</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>34.62</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>36.20</td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>35.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>LCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualistic</td>
<td>28</td>
<td>34.43</td>
<td>3.30</td>
<td>32.78</td>
</tr>
</tbody>
</table>
In the present study, the academic achievement of the students in an individualistic learning condition is taken as the basis of comparison for identifying dysfunctional cooperative learning teams. As a result, the population mean SN value used in constructing the control chart is given by the average SN value presented in the third column of Table 4(b) while the population standard deviation of the SN values is equal to the standard deviation value given in the fourth column of Table 4(b). In other words, the population mean of the SN ratio is equal to \( \mu = 34.43 \) while the population standard deviation of the SN ratio is equal to \( \sigma = 3.30 \). Note that although the four unit tests were conducted sequentially over the course of the semester, all of the SN values were actually calculated and analyzed at the end of the semester. Notionally, this is equivalent to collecting four SN values for each team at the end of the semester. Thus, the sample size is equal to \( n = 4 \). Consequently, the LCL has a value of 32.78 for \( k = 1 \) (see fifth column in Table 4(b)). Therefore, the results presented in the third column of Table 4(a) indicate that cooperative teams A and D are truly dysfunctional since their composite SN values, i.e., 32.47 and 32.41, respectively, are less than the LCL. Note that the probability of misclassifying teams A and D is equal to 0.16. In Table 4(a), cooperative team E has the third lowest SN value, i.e., 34.62. The probability of erroneously classifying team E as dysfunctional due to its small SN value is equal to 0.55. Thus, it follows that only cooperative teams A and D are truly dysfunctional.

**Research limitations**

Generalization of the results of this study is limited by the cultural context of the study (namely a science and technology university in Taiwan), the sample size, characteristics of the subjects, types of tasks, skills of implementing cooperative learning of the instructor, and specific operationalizations of the independent and dependent variables. Nonetheless, despite these limitations, the results obtained in this study are reliable because the following important procedures have been employed: the stratified random assignment of students to conditions, the use of the same instructor to teach both conditions, the use of measurable dependent variables, and the confirmation of the implementation of conditions. In a future study, further investigations will be performed to explore whether the present findings are equally applicable to a broader educational context.

**Conclusions**

This study has proposed a new method for the identification of dysfunctional cooperative learning teams based on students’ academic achievement utilizing the well-known smaller-the-better and larger-the-better Taguchi quality indexes. The feasibility of the proposed approach has been confirmed by performing a series of experimental investigations using 42 sophomore engineering students. The students’ academic achievement was measured by means of four unit tests, given at the end of each teaching unit, respectively. Taken with the supporting evidence provided by off-task behavior frequency observations and peer support surveys, the larger-the-better Taguchi quality index provides a reliable means of identifying dysfunctional cooperative learning teams. Moreover, the probability of erroneously classifying a functional cooperative learning group as dysfunctional can be estimated using a control chart in which the Taguchi quality index is taken as the quality characteristic.

The method proposed in this study for identifying and verifying dysfunctional teams within a cooperative learning environment can be easily incorporated into a technology-assisted solution for instructors wishing to monitor and analyze the performance of cooperative teams on a continuous basis throughout the course of a semester. Such a system could also assist school administrators in computing the means of the unit tests given at the end of each teaching unit such that any dysfunctional teams can be automatically identified at the end of the semester. Utilizing this information, the administrators could then analyze the degree of success (or failure) of the various cooperative learning initiatives on their campus and modify their existing teaching strategies or formulate new strategies as required. Similarly, in identifying the true nature of the interactions and dynamics within cooperative teams, education researchers would also benefit from an automated solution for the reliable identification of dysfunctional teams such that the effects of these teams could be excluded from the analysis. In practice, the methodology presented in this study is well suited to meeting the requirements of all three groups of individuals in the cooperative learning environment.
Thus, the methodology and findings presented in this study represent a useful basis for educational system developers seeking to design technology-assisted solutions for supporting educators in monitoring and analyzing the performance of cooperative learning teams.

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