The empirical research of teamwork competency factors and prediction on academic achievement using machine learning for students in Thailand

Introduction. Teamwork competencies are important for achieving the success of education, developing a meaningful and lifelong career, bringing new ideas, helping to solve problems, academic achievement, and building morale. The current problems with teamwork competency factors are still vague and unclear, and lack of predictive data on education. The research objectives were to analyse factors of students’ teamwork competencies, to confirm factors of students’ teamwork competencies, and to predict the effect of teamwork competencies on academic achievement using machine learning.

Methods. Participants were students in an advanced professional innovation programme undergoing an empowerment process. They were divided into two groups: 205 students for exploratory factor analysis achieved through stratified random sampling and 418 students for confirmatory factor analysis, correlation analysis, and prediction of academic achievement, also achieved via stratified random sampling. Instruments included a teamwork competency self-assessment digital form, which had item-total correlations between 0.67 and 0.77 and a Cronbach’s alpha coefficient of reliability equal to 0.98. The data were analysed by summary statistics (mean, standard deviation), correlation analysis, exploratory factor analysis, confirmatory factor analysis, regression analysis and decision trees.

Results. The results showed that teamwork competencies factors included building a team relationship (BTR), participation in team exchanges (PTE), adapting and creating a team atmosphere (ACT), and supporting a team (STE), which explained 65.752% of the total variance. Teamwork competency factors fit the empirical data (chi-square=618.54, df=565, p=0.059, GFI=0.93, AGFI=0.90, RMSEA=0.015), and teamwork competency sub-factors were correlated with the total score by 0.97, 0.94, 0.95 and 0.92, respectively. In addition, the machine learning predicted by regression BTR, PTE, and ACT were predictive of academic achievement, explaining 60.80% of the variance in this variable, and predicted by decision trees ACT and PTE were predictive of academic achievement as well.

Practical significance. The novelty created by this research is that innovative product of teamwork competencies factor, that is suitable for a studied and modern context, and prediction of machine learning that will increase empirical strength and create a methodological novelty of empirical research that uses multi-stage, multi-methods and robust validation. The utility of practice, the colleges apply to students for accurate measurement, good academic achievement and leads to reflection and improvement of teamwork for performance efficacy, bringing success to individuals and society.

Keywords: teamwork competencies, exploratory factor analysis, confirmatory factor analysis, machine learning, regression analysis, decision trees

For Reference:
With regard to what will ensure successful productivity, at the heart of today's world is teamwork. Teamwork competency is currently fundamental to guarantee optimal working performance of individuals. This means that a great deal of importance is being given to this activity in educational circles [1]. Teamwork is an important competency for working and elevating organizations in Thailand [2]. Thailand's education curriculum is developing a competency-based curriculum in which teamwork is an important requirement to develop for learners at both basic and vocational education levels [3]. In addition, teamwork is vital because an effective team increases the probability of achieving a set purpose and results for any project, process, product, or service, including learning [4; 5]. Therefore, teamwork competency is an extremely important basis for guaranteeing productivity. It is also a concept that underlies the achievement of objectives of working effectively. As such, it is important to emphasize it in the education of students.

In addition, teamwork competencies are important for achieving the success of education, developing a meaningful and lifelong career, bringing new ideas, helping to solve problems, providing support, and building morale. These can be linked with the concept of group cooperation, which is a very important component of personal achievement [6] that involves tasks and can accelerate success [7; 8]. It can improve communication and increase the efficiency of the individual, bringing benefits to students by helping to build positive relationships and helping sensitive students overcome their fears and learn how to deal with criticism. It is necessary to have teamwork between students, between students and teachers, and among parents and educators. In addition, teamwork is a popular approach for achieving high standards in the performance of duties, and it can lead to a high level of satisfaction amongst members based on the organization’s goal.

When teamwork competency is useful, it is valuable for productivity and highly valued by organizations that need cooperation between their members to achieve their objectives [9]. In addition, teamwork competence improves the system by providing a learning analytics tool to support the process [5]. To implement the concept of teamwork competency in an organization, it is important to know the factors that will be used. There are many factors for measuring teamwork competency. Suprapto et al. [10] propose five task-related interactions—communication, coordination, balanced contribution, aligned effort, and mutual support—and two social interactions, cohesion and affective trust. Salas et al. [11] propose eight factors of teamwork, namely, team leadership, mutual performance monitoring, backup behaviour, adaptability, team orientation, shared mental models, mutual trust, and closed-loop communication. Symons et al. [12] propose teamwork skills comprising communication, leadership, cooperation, and situation awareness, and Hoegl and Gemuenden [13] propose six facets: communication, coordination, balance of member contributions, mutual support, effort, and cohesion. The factors of teamwork competency are still vague and lack measurement consistency. When the context changes, there is a chance that the factors will change. Therefore, the factor structure is an interesting issue to study in relation to these concepts.
The above problems with teamwork competency factors are still vague and unclear. Across different contexts, the teamwork competency factors may change. Therefore, it is necessary to study the teamwork competencies factors as they apply to students in the context of various activities to ensure that the teamwork competency factors are consistent with the actual state of the context. This allows for accurate measurement, interpretation for teamwork competencies that looks like multidimensionality and leads to reflection and improvement of teamwork for performance efficacy [14]. Furthermore, it has resulted in good academic achievement and learning outcomes, bringing success to individuals and society.

The research objectives were to analyse the factors of students' teamwork competencies, to confirm those factors of students' teamwork competencies, and to predict the effect of teamwork competencies on academic achievement using machine learning.

**Literature review**

1. **Definition of teamwork competency**

Teamwork was behaviors under the control of individual team members through effort they put into team tasks, their manner of interacting with others on the team, and the quantity and quality of contributions they make to team discussions. It can conclusion definitions three types: ability, soft skill, and attribute as follows:

- **Definition of teamwork competency as ability** as the concept of the Organisation for Economic Cooperation and Development (OECD) [15] defines competence as "the ability to respond to the demands or carry out tasks successfully" This concept refers to attitudes, abilities skills, and performance abilities. As can be seen, the concept of competence includes knowledge, know-how, and knowledge to be, so people acquire and develop skills to foster their development as individuals and as professionals, and Salas and Cannon-Bowers [16] define as the ability of team members to work together, communicate effectively, anticipate and meet each other’s demands, and inspire confidence, resulting in a coordinated collective action.

- **Definition of teamwork competency as soft skill** as the concept of Gibert, Tozer, and Westoby [17] defines teamwork and collaboration are expected from scientists, soft skills that contribute to scientific collaboration or teamwork was provided, Parratt et al. [18] define teamwork as a ‘soft skill’ employability competence desired by employers, and McIntyre and Salas [19] define teamwork was a critical component of team performance and requires an explanation of how a team behaves.

- **Definition of teamwork competency as an attribute** as the concept of Martinez, Martin, & Alonso [20] said that the development of teamwork leaves evidence of three types: individual (participation, cooperation, monitoring, leadership, efficiency, etc.), group (mission and objectives, standards, map of responsibilities, etc.) and results, and Carmenado, Rodríguez, and Gajardo [21] defines teamwork competence refers to a set of actions, strategies, procedures, and methodologies used by a group of people to achieve objectives and/or goals, sharing responsibilities.
2. Factors of teamwork competencies

In terms of teamwork competencies, many factors fit different situational contexts. They can display factors representing each concept, as shown in Table 1.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brannick et al. [22]</td>
<td>situational awareness, leadership decision making, communication, adaptability, decision making, assertiveness</td>
</tr>
<tr>
<td>Cannon-Bowers et al. [23]</td>
<td>adaptability, shared situational awareness, performance monitoring and feedback, leadership/team management, interpersonal relations, coordination, communication</td>
</tr>
<tr>
<td>Stevens and Campion [24]</td>
<td>conflict resolution, collaborative problem solving, communication, goal setting and performance management, planning and task coordination</td>
</tr>
<tr>
<td>Hoegl and Gemuenden [13]</td>
<td>communication, coordination, balance of member contributions, mutual support, effort, and cohesion.</td>
</tr>
<tr>
<td>Salas et al. [11]</td>
<td>feedback, adaptability, orientation, coordination and situation awareness</td>
</tr>
<tr>
<td>Thomas et al. [25]</td>
<td>information sharing, inquiry, assertion, goal sharing, teaching, plan evaluation, workload management, environmental awareness, leadership, communication</td>
</tr>
<tr>
<td>Cole and Crichton [26]</td>
<td>leadership, team management, role competence, conflict resolution</td>
</tr>
<tr>
<td>Healey et al. [27]</td>
<td>communication, cooperation, coordination, leadership, monitoring</td>
</tr>
<tr>
<td>Rousseau, Aubé, and Savoie [28]</td>
<td>preparation of work accomplishment, work assessment behaviours, task-related collaborative behaviours, team adjustment behaviours, management of team maintenance</td>
</tr>
<tr>
<td>Frankel et al. [29]</td>
<td>communication, cooperation, coordination, situational awareness</td>
</tr>
<tr>
<td>Cortez, Nussbaum Woywood, and Aravena [30]</td>
<td>team orientation, team leadership, monitoring, feedback, back-up, coordination, communication</td>
</tr>
<tr>
<td>Reader et al. [31]</td>
<td>team communication, team coordination, team leadership, team decision making</td>
</tr>
<tr>
<td>Olupeliyawa, Hughes, and Balasooriya [32]</td>
<td>shared understanding, team leadership, team support, communication</td>
</tr>
<tr>
<td>Weaver et al. [33]</td>
<td>attitudes (mutual trust, collective efficacy, team/collective orientation psychological safety), behaviour (closed-loop communication, team leadership, mutual performance monitoring, backup/supportive behaviour, conflict management, mission analysis, team adaptation), cognition (accurate and shared mental models, cue-strategy associations)</td>
</tr>
<tr>
<td>Skjerve, Kaarstad, and Holmgren [34]</td>
<td>attitudes towards colleagues and the plan, back-up behaviour, communication, coordination, decision making, leadership, learning, refreshing of competencies.</td>
</tr>
<tr>
<td>Nadal et al. [35]</td>
<td>identity, communication, performance, regulation</td>
</tr>
</tbody>
</table>

Teamwork competencies are critical to learners' learning. This includes abilities, skills, and attributes in addition to the factors of teamwork competencies that fit different contexts and are unclear. The focus of this research was the study of empirical data. Exploratory factor analysis was used to identify novel teamwork competencies factors. Good factor analysis requires confirmation of those resulting factors; thus, confirmatory factor analysis was used to verify the resulting factors. In addition, teamwork competencies were used to predict the effects of academic achievement [36; 37], prediction using machine learning as a set of methods that can automatically detect patterns in data, and then use the uncovered patterns to predict future data [38]. The aspect type of machine learning is supervised learning consisted of regression by linear regression and classification by decision trees [39]. The research conceptual framework is shown in figure 1.
1. General Background of Research

This research was empirical research focus on innovative product of teamwork competencies factor, that is suitable for a studied and modern context, and prediction of machine learning that will increase empirical strength and create a methodological novelty of empirical research that uses multi-stage, multi-methods and robust validation.

The steps were as follows: The first step was exploratory factor analysis of teamwork competency. The second step was confirmatory factor analysis of teamwork competency. The third step was testing the correlation between factors of teamwork competency and the total score. Finally, examination the effect prediction of the teamwork competency factors on academic achievement using machine learning. The research steps are depicted in figure 2. The methodology of this research, including participants, instruments, and data collection and analysis, are describe below.

2. Research Participants

1) A total of 205 students from an advanced professional innovation programme undergoing an empowerment process were selected via stratified random sampling for exploratory factor analysis. Fabrigar & Wegener [40] and MacCallum et al. [41] recommend a sample size of approximately 200 to 250 participants for adequate factor analysis.

2) A total of 418 students from the same programme were similarly selected via stratified random sampling for confirmatory factor analysis, correlation analysis, and prediction of academic achievement. The minimum adequate sample size for confirmatory factor analysis
is 200 [42] or a ratio of a sample size to model variables ≥10 [42-44]. This research had 40 indicators from the previous step (exploratory factor analysis), so the minimum sample size for confirmatory factor analysis was 400.

3. Instrument
The teamwork competency self-assessment (in digital form) included 44 indicators. The examination of instrumentation quality appears content validity by expert judgement found that item content validity index (I-CVI) range between 0.80 and 1.00, and scale content validity index (S-CVI) =0.96, which acceptable I-CVI of .78 or higher and an S-CVI of .90 or higher [45], and try-out the instrument during an activity, it was verified with 109 students to determine the Item-total correlations ranged between 0.40 and 0.78. Indicators with item-total correlations below 0.50 were deleted [43,46]. After four such indicators were deleted, item-total correlations (40 indicators) were re-calculated and ranged between 0.67 and 0.77, with a Cronbach’s alpha coefficient of 0.98, reflecting strong internal reliability.

In addition, the instrument was verified with random 55 students to determine the correlated between the teamwork competency self-assessment and the assessor's observations while participating in learning activities using the Pearson's product-moment correlation coefficient ranged between 0.71 and 0.86, reflecting strong concurrent validity.

4. Data Collection and Analysis
The data were collected during an activity for study factors of teamwork competency. Subsequently, one semesters of space were spaced, so proceeded to collect the data of the academic achievement to predict. The data were analysed using summary statistics (mean, standard deviation), correlation analysis, exploratory factor analysis, confirmatory factor analysis, regression analysis, and decision trees.

Research Results

1. Results of exploratory factor analysis of teamwork competency
The 40 indicators of teamwork competencies derived from the development process of instrument brings to the process the exploratory factor analysis step. The analysis results revealed that the indicators were correlated between 0.346 and 0.762. The Kaiser-Meyer-Olkin measure of sampling adequacy was equal to .964, reflecting a high degree of intercorrelation among the indicators and the appropriateness of factor analysis [43]. In addition, Bartlett’s test of sphericity yielded a value of 7010.104 (df=780, p=.000), and anti-image correlations fell between 0.946 and 0.978, all above the threshold of .70 [43]. The total variance explained was 65.752%, as shown in Table 2.

The communalities were between 0.546 and 0.748, reflecting variance accounted for based on each indicator’s correlations with all of the other indicators, which was above the threshold of .50 [43]. Factors of teamwork competency were constructed based on the highest loadings of each indicator. However, factor loadings representing a correlation between the indicators and the factors above .40 were considered using pragmatic reasoning [47,48] and showed that the first factor comprised indicators 10, 13, 16, 17, 19, 21, 22, 24,
25, 26, 27, 34, 38, 43 and 44. This factor was building a team relationship (BTR). The second factor comprised indicators 1, 2, 3, 4, 5, 6, 7, 8, 9, 14, 15, and 18. This factor was participation in a team exchange (PTE). The third factor comprised indicators 29, 30, 31, 32, 33, 35, 36, and 37. This factor was adapting and creating a team atmosphere (ACT). The fourth factor comprised indicators 28, 39, 40, 41, and 42. This factor was supporting a team (STE). The factor loadings in Table 3 show values above .40.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Total variance explained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eigenvalue</td>
</tr>
<tr>
<td>1</td>
<td>8.459</td>
</tr>
<tr>
<td>2</td>
<td>7.518</td>
</tr>
<tr>
<td>3</td>
<td>5.552</td>
</tr>
<tr>
<td>4</td>
<td>4.772</td>
</tr>
</tbody>
</table>

### Table 2
Total variance of teamwork competency factors

### Table 3
Teamwork competency factors
23. Strengthen unity within the team. (BTR11) .536 .480 .702
24. Resolve conflicts within a team. (STE1) .500 .536 .690
25. Build morale in the team. (ACT1) .631 .681
26. Express your creativity to your teammates. (ACT2) .417 .691 .723
27. Prepare the information that will be required within the team. (ACT3) .632 .674
28. Promote a team environment. (ACT4) .616 .645
29. Offer ways to improve team development to be effective. (ACT5) .429 .559 .675
30. Continue to engage with teammates. (BTR12) .554 .634
31. Behave within the team in both leadership and followership roles. (ACT6) .552 .583
32. Adapt to changing situations within the team. (ACT7) .524 .674
33. Consult with teammates. (ACT8) .472 .470 .648
34. Work with fellow members with different characteristics. (BTR13) .455 .423 .610
35. Transfer skills to teammates. (STE2) .573 .661
36. Promote awareness of teamwork. (STE3) .684 .734
37. Reflect on team performance evaluation. (STE4) .703 .748
38. Plan guidelines for supporting teamwork. (STE5) .711 .741
39. Take into account your team’s goals for success. (BTR14) .485 .465 .645
40. Be a good member of the team. (BTR15) .648 .682

Note: Factor loadings above .40 are shown, \( h^2 = \text{communality} \)

2. Results of confirmatory factor analysis of teamwork competency

In testing the assumptions of confirmatory factor analysis, we found that the indicators were correlated at a medium to high level, between 0.481 and 0.758. The Kaiser-Meyer-Olkin measure of sampling adequacy was .980, and Bartlett’s test of sphericity result was 16103.942 (df=780, p=.000), reflecting that the data were adequate and appropriate for factor analysis.

The results of the correlations between the indicators and their corresponding latent factors indicated that factor BTR had correlations between 0.78 and 0.84, PTE between 0.73 and 0.81, ACT between 0.76 and 0.84, and STE between 0.80 and 0.83. All indicators were significant. For the criteria for determining factor loadings, we refer to Diamantopoulos and Siguaw [49], who suggested that factor loadings are significant at \( p < .05 \) and a critical t-value \( \geq 1.96 \).

Squared multiple correlations (R\(^2\)) reflecting the extent to which a measured indicator’s variance was explained by a corresponding latent factor indicated that factor BTR explained between 0.61 and 0.70 of its indicators’ variances, PTE between 0.53 and 0.60, ACT between 0.59 and 0.71, and STE between 0.64 and 0.69. The R\(^2\) values for all the variables were greater than 0.50, which showed the reliability of the variables. The criteria for determining R\(^2\) \( \geq 0.50 \) showed adequate reliability [50].

Construct reliability (CR), reflecting the internal consistency of the measured indicators representing a latent construct, was 0.70, 0.66, 0.70, and 0.72 for BTR, PTE, ACT, and STE, respectively. The average variance extracted (AVE), reflecting the mean variance extracted for the factor loadings on a construct, was equal to 0.66, 0.60, 0.66, and 0.67, respectively. For the criteria for determining construct reliability, we refer to Diamantopoulos and Siguaw [49]; Hair et al. [43] suggested \( \geq 0.60 \). For average variance extracted, we also refer to Diamantopoulos and Siguaw [49]; Hair et al. [43] suggested \( \geq 0.50 \).
Assessment of the overall model revealed that the model fit with empirical data produced the following: chi-square=618.54, df=565, p=0.059, goodness-of-fit index (GFI)=0.93, adjusted goodness-of-fit index (AGFI)=0.90, and root mean squared error of approximation (RMSEA)=0.015. For the criteria for assessing model fit, the chi-square test fundamentally measures the difference between the observed and estimated covariance matrices, with a small chi-square value indicating no statistically significant difference between the matrices [49]. GFI is a model suitability index, whereas AGFI is a GFI fit index criterion adjusted to the ratio of the degrees of freedom, where ≥0.90 indicates a good fit [51]. RMSEA explains the residuals contained in the model, where < .06 indicates a good fit [52]. The results are shown in figure 3.

**Figure 3** Results of confirmatory factor analysis of teamwork competency
3. Result of correlation between the factors and total score of teamwork competency

Correlations between the factors of teamwork competency BTR, PTE, ACT, and STE and the total score of teamwork competency were equal to .97, .94, .95, and .92, respectively. Correlations above 0.50 represent strong correlations according to Cohen [53]. These results indicate validity [54], as shown in Table 4.

Table 4

<table>
<thead>
<tr>
<th></th>
<th>TOTAL</th>
<th>BTR</th>
<th>PTE</th>
<th>ACT</th>
<th>STE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BTR</td>
<td>.97**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTE</td>
<td>.94**</td>
<td>.85**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT</td>
<td>.95**</td>
<td>.89**</td>
<td>.85**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>STE</td>
<td>.92**</td>
<td>.85**</td>
<td>.84**</td>
<td>.89**</td>
<td>-</td>
</tr>
</tbody>
</table>

** p < .01, TOTAL = Sum of all factor scores.

4. Prediction of teamwork competency factors on academic achievement using machine learning

Prediction using machine learning as supervised learning consisted of regression by linear regression and classification by decision trees [39] as follow:

1) Regression analysis

The correlations between the teamwork competency factors BTR, PTE, ACT, and STE and academic achievement (AA) were equal to .76, .74, .74, and .69, respectively. The mean (M) and standard deviation (S) of the teamwork competency factors were as follows: BTR (M=66.57, S=7.94), PTE (M=52.08, S=6.11), ACT (M=35.06, S=4.44), STE (M=21.68, S=2.88) and AA (M=3.44, S=0.26). The test of multicollinearity showed that the factors of teamwork competency BTR, PTE, ACT, and STE did not have multicollinearity (correlations between .84 and .89, tolerance=.17, .22, .14, and .18, and variance inflation factor (VIF)=6.02, 4.55, 7.35, and 5.42, respectively).

The prediction of the teamwork competency on academic achievement by machine learning applied on linear regression found that scatterplots of BTR, PTE, and ACT have the data fit regression lines show the overall trend of a set of data predict on academic achievement at good to very good level, but STE not fit regression line as the data spread out line, as shown in Figure 4.

The effects of BTR, PTE, and ACT on academic achievement were statistically significant at the .05 level. The factors with the largest effects were as follows: BTR, PTE, and ACT. However, STE was not associated with AA. Together, the teamwork competency factors were highly associated with AA (multiple correlations =.782) and could explain 60.80% of the variance in academic achievement, as shown in Table 5.
Figure 4 Results of machine learning by regression

Table 5

<table>
<thead>
<tr>
<th>Factors</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.670</td>
<td>.070</td>
<td></td>
<td>23.704</td>
</tr>
<tr>
<td>BTR</td>
<td>.012</td>
<td>.002</td>
<td>.354</td>
<td>4.712</td>
</tr>
<tr>
<td>PTE</td>
<td>.013</td>
<td>.003</td>
<td>.305</td>
<td>4.654</td>
</tr>
<tr>
<td>ACT</td>
<td>.012</td>
<td>.005</td>
<td>.207</td>
<td>2.488</td>
</tr>
<tr>
<td>STE</td>
<td>-.005</td>
<td>.006</td>
<td>-.050</td>
<td>-.701</td>
</tr>
</tbody>
</table>

R=.782, R Square=.612, Adjusted R Square=.608, Std. error=.163 (F=162.688, df=4, p=.000)

2) Decision trees

Prediction of BTR, PTE, ACT, and STE on academic achievement level: very good (3.50-3.99), good (3.00-3.49), fairly good (2.50-2.99), and fair (2.00-2.49). The prediction of the teamwork competency on academic achievement by machine learning applied on classification by decision trees found that:
Model Summary as follows: Specifications: Maximum Tree Depth=3, Minimum Cases in Parent Node=100, Minimum Cases in Child Node=50. Results: Number of Nodes=6, Number of Terminal Nodes=4, Depth=2.

Prediction of ACT on academic achievement very good level (Node 3) at significant level .05 and can be predicted 84.8%. And PTE on academic achievement very good level (Node 5) at significant level .05 and can be predicted 70.4%, for acceptable decision trees considered prediction exceed 70.0 % show the best decision tree [55]. The model has Re-substitution =.234 (Std. Error=.021), Cross-Validation =.304 (Std. Error=.022), as shown in Figure 5 and Table 6.

Figure 5 Results of machine learning by decision trees
Table 6

<table>
<thead>
<tr>
<th>Node</th>
<th>fair n(%)</th>
<th>Fairly good n(%)</th>
<th>Good n(%)</th>
<th>Very good n(%)</th>
<th>Total n(%)</th>
<th>Predicted category</th>
<th>Variable</th>
<th>Chi square</th>
<th>df</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1(0.60%)</td>
<td>21(13.20%)</td>
<td>122(76.73%)</td>
<td>15(9.43%)</td>
<td>159(38.04%)</td>
<td>good</td>
<td>ACT</td>
<td>178.805</td>
<td>6</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>0(0.00%)</td>
<td>0(0.00%)</td>
<td>70(52.24%)</td>
<td>64(47.76%)</td>
<td>134(32.06%)</td>
<td>good</td>
<td>ACT</td>
<td>178.805</td>
<td>6</td>
<td>.000</td>
</tr>
<tr>
<td>3</td>
<td>0(0.00%)</td>
<td>0(0.00%)</td>
<td>19(15.20%)</td>
<td>106(84.80%)</td>
<td>125(29.90%)</td>
<td>very good</td>
<td>ACT</td>
<td>178.805</td>
<td>6</td>
<td>.000</td>
</tr>
<tr>
<td>4</td>
<td>0(0.00%)</td>
<td>0(0.00%)</td>
<td>54(67.50%)</td>
<td>26(32.50%)</td>
<td>80(19.14%)</td>
<td>good</td>
<td>PTE</td>
<td>18.531</td>
<td>1</td>
<td>.000</td>
</tr>
<tr>
<td>5</td>
<td>0(0.00%)</td>
<td>0(0.00%)</td>
<td>16(29.63%)</td>
<td>38(70.37%)</td>
<td>54(12.92%)</td>
<td>very good</td>
<td>PTE</td>
<td>18.531</td>
<td>1</td>
<td>.000</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>21</td>
<td>211</td>
<td>185</td>
<td>418</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Resubstitution = .234 (Std. Error=.021), Cross-Validation = .304 (Std. Error=.022)

Remark: Growing Method: CHAID

Discussion

According to exploratory factor analysis, the building team relationships factor can explain the most variance. This may be because of the nature of building relationships within the team, which can make the team stronger and more fundamentally capable of performing teamwork. Egea [56] stated that team success occurs through team building and the leader’s relationship with the team [57]. In addition, Tjosvold, West, and Ken [58] stated that when teams succeed at their tasks, they strengthen interpersonal relationships. The teamwork competency factors comprised four factors: building team relationships, participation in team exchanges, adapting and creating a team atmosphere, and supporting a team. These four factors fit the empirical data, related construct, and were validated. The indicator/item development process entails item selection by checking content validity, analysing the item-total correlations, and factor analysis to ensure a quality model, as represented by statistical values. The teamwork competency factors differed from those in past studies, but there were also some similarities. From the four factors of teamwork competency, the building of team relationships is associated with factor in the field of communication, which are important aspects of teamwork found in the research of Hoegl and Gemuenden [13]; Brannick et al. [22]; Thomas et al. [25]; Healey et al. [27]; Skjerve, Kaarstad, and Holmgren [34]; Nadal et al. [35], participation in team exchanges is associated with factor in the field of cooperation found in the research of Salas et al. [11]; Hoegl and Gemuenden [13]; Healey et al. [27]; Reader et al. [31], adapting and creating a team atmosphere is associated with factor in the field of adaptability found in the research of Salas et al. [11]; Brannick et al. [22], and supporting a team is associated with factor in the field of team support found in the research of Olupeliyawa, Hughes, and Balasooriya [32]. Therefore, it is important to apply factors of teamwork competency to improve and develop the quality of learners to be accurate in the current phenomena.

Prediction of teamwork competency on academic achievement using machine learning by regression method found that the teamwork competency factors: building a team relationship, participation in team exchanges, and adapting and creating a
team atmosphere, and decision trees method found that adapting and creating a team atmosphere, and participation in team exchanges were predictive of academic achievement. That means there are up to two very important characteristics from both analyses were participation in a team exchanges, and adapting and creating a team atmosphere, but building a team relationship, it is also important in cases where predictions are made with regression. Overall are factors that have the characteristics of engagement and creating an atmosphere. According to Onyemuche’s [36] research, adapting to the team to produce good learning outcomes or achievements influences students’ academic achievement. Ooko’s [59] research showed an impact of teamwork on achievement. In addition, Tang [37] found that teamwork competencies are better predictors of academic performance than personality traits.

Nevertheless, supporting a team may be characterized as a teamwork control mechanism. Whether it is solving problems in a team, planning, reflecting results, or promoting awareness, it is a mechanism for controlling teamwork. It may not have a direct effect on learning outcomes or achievement, but there may be opportunities for an indirect effect, which should be seriously developed indirectly as a support for effective teamwork.

**Conclusions**

Teamwork competency factors are important for learning in today’s world and the current problems with teamwork competency factors are still vague and unclear, and lack of predictive data on education. Teamwork competency factors appear to include building a team relationship (BTR, 15 indicators), participation in team exchanges (PTE, 12 indicators), adapting and creating a team atmosphere (ACT, 8 indicators), and supporting a team (STE, 5 indicators). Together, the four factors explained 65.752% of the total item variance. The teamwork competency factors fit the empirical data, as shown by chi-square=618.54, df=565, p=0.059, GFI=0.93, AGFI=0.90, and RMSEA=0.015. The teamwork competency factors were correlated with the total score at .97, .94, .95 and .92, respectively. In addition, machine learning predicted by regression BTR, PTE, and ACT were predictive of academic achievement, explaining 60.80% of the variance in this variable, and predicted by decision trees ACT and PTE were predictive of academic achievement as well. Implication for research and practice, the colleges apply to students for accurate measurement, good academic achievement and leads to reflection and improvement of teamwork for performance efficacy, bringing success to individuals and society.

**Recommendations**

Regarding practical recommendations, applying the findings from the resulting teamwork competency factors and important on academic achievement should lead to the development and follow-up of students' teamwork competencies in routine activity aspect and apply on in-depth, in addition, it should be used to define practical planning strategies towards teamwork in order to develop the organization in a quality and sustainability. Future
research should create a digital teamwork competency guide to apply to students, using experimental research to study manual efficacy. Moreover, package programme to assess teamwork competencies, including assessment implementation, assessment interpretation, and assessment reflection, in real-time and personality aspect should be developed.

Acknowledgements

This research was supported by the students of high-level professional innovation scholarship. The authors thank for support for this research.

REFERENCES


Information about the authors

Chaiwichit Chianchana
(Thailand, Bangkok)
PhD in Educational Measurement and Evaluation
Associate Professor in the Faculty of Technical Education
King Mongkut’s University of Technology North Bangkok
E-mail: chaiwichit.c@fte.kmutnb.ac.th
ORCID ID: 0000-0002-8138-6069

Samart Swangjang
(Thailand, Bangkok)
PhD in Educational Administration
Lecturer in the Faculty of Technical Education
King Mongkut’s University of Technology North Bangkok
E-mail: samart.s@fte.kmutnb.ac.th
ORCID ID: 0000-0002-0098-7330