Development of questionnaire instrument to assess students’ transformative competencies in science learning

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Abstract. According to the OECD Education 2030 project, students in every country need to be ready as agents of change in the future. Three transformative competencies (Creating New Value, Reconciling Tensions and Dilemmas, Taking Responsibility) which are expected to develop students’ awareness, responsibility and innovation are used as focus of this study. A descriptive research for developing a valid and reliable questionnaire to assess the transformative competencies was conducted to investigate these competencies of junior high school students in Indonesia. It consists of 39 statements with a 5 Likert scale representing each transformative competency. A total of 445 students from 10 schools representing five provinces participated which consisted of students from 7th grade (222), 8th grade (91), and 9th grade (132) with the proportion of male (174) and female (271) students. The questionnaire was distributed on-line in sequence. The analysis results in that the questionnaire has a high reliability index of 0.96 for Cronbach's Alpha (IBM SPSS Statistics 25), 0.94 for Person Reliability and 0.97 for Item Reliability (Winsteps Rasch Model) and good validity index for all items in the questionnaire, because the calculated r value is greater than the r table value. Correlation is significant at the 0.01 level (2-tailed). In general, students' responses are on a "fairly typical of me" scale, except for TC4 statement "I can offer new solutions when there are problems while studying science", which is "not very typical of me". These results provide opportunities for further study to increase student creativity in science learning.

1. Introduction
A project of “The Future of Education and Skills 2030” has been launched by Organisation for Economic Co-operation and Development (OECD) in 2018. Year “2030” that use for this project because children who entering school in year “2018” will become young adults in this year (after 12-years-education). Learning process can facilitate students to find out job, technology and so solution that have not yet been created. The aim of this project is to answer two main questions, namely "what" and "how" knowledge, skills, attitudes and values can be developed in education. Therefore, three further competencies have been constructed, namely “Transformative Competencies” which consists of Creating New Value, Reconciling Tensions and Dilemmas, Taking Responsibility. This project also supports to the UN 2030 Global Goals for Sustainable Development (SDGs) [1]. Furthermore, OECD has been innovated on PISA for Development and the Learning Framework 2030 in line with geopolitical and economic realities. Not only cognitive competencies, but also non-cognitive competencies have been combined into main tests to spread out the context of the SDGs [2].
To prepare students as agents of change in the future, teacher not only concern to students as an individuality but also how they interact with their teachers, peers, families and communities. These relationship can influence in learning process. The framework how young people can regulate their lives and world has been constructed by OECD Education 2030 stakeholders with name “The Learning Compass 2030” [1]. Disciplinary knowledge is schooling core which has direct and practical view. This Learning Compass 2030 has been different with OECD previous project that more focus on generic skills and competencies [3]. Science as main point to endorse the UN 2030 Agenda for Sustainable Development, which meant deliver norms and values, construct the social-ecological systems, work with societal actors, and accountability to overcome the problem [4]. These facts encourage this study to construct the reliable and valid instruments for support agenda of The Future of Education and Skills 2030.

2. Method
A total of 445 students from 10 schools representing five provinces in Indonesia participated in this study, namely Special Capital Region of Jakarta, North Sumatra, South Sumatra, Riau, and West Java. Participants consisted of 222 students from 7th grade, 91 students from 8th grade, and 132 students from 9th grade with the proportion of male students as many as 174 while 271 female students. All participants have the same thing that they are learning science using the Indonesian Curriculum, namely Curriculum 2013. The questionnaire instrument was distributed online using the Google Form application. The collected data were processed with IBM SPSS Statistics 25 and Winsteps Rasch Model to analyze the validity and reliability of the questionnaire.

The questionnaire instrument consist of 39 statements with five Likert scales (1 = not at all typical of me, 2 = not very typical of me, 3 = somewhat typical of me, 4 = fairly typical of me, and 5 = very typical of me). This questionnaire was developed based on three Transformative Competencies (TC), namely (1) Creating New Value, (2) Reconciling Tensions and Dilemmas, and (3) Taking Responsibility developed by the Directorate for Education and Skills-OECD [1]. The competency of "Creating New Value" consists of four indicators, namely Adaptability, Creativity, Curiosity, and Open-mindedness. The competency of "Reconciling Tensions and Dilemmas" consists of four indicators, namely Integrated Way, Inter-relations, Logics and Positions, and Perspectives. The competency of "Taking Responsibility" consists of five indicators, namely Think and Work, Consequences, Evaluation, Accountability, and Reflection.

3. Result and Discussion

3.1. Reliability Index
The first result describes about reliability index of Transformative Competencies Questionnaire. Students' responses were analysed using IBM SPSS Statistics 25 for Cronbach's Alpha and Winsteps Rasch Model for Person Reliability and Item Reliability. These values are presented in Table 1.

| Transformative Competencies (TC) | N of items | Person Reliability | Item Reliability | Cronbach’s Alpha | Category |
|---------------------------------|------------|-------------------|------------------|------------------|----------|
| All competencies                | 39         | 0.94              | 0.97             | 0.96             | Acceptable |
| a. Creating New Value           | 12         | 0.82              | 0.98             | 0.86             | Acceptable |
| b. Reconciling Tensions and Dilemmas | 12   | 0.85              | 0.95             | 0.90             | Acceptable |
| c. Taking Responsibility        | 15         | 0.87              | 0.87             | 0.92             | Acceptable |

The Rasch measurement model provides person reliability index and item reliability index. The person reliability represents the replicable ability of sample group, where this group give close results if do another test with same construct. Meanwhile the item reliability index represents the replicable ability of items package, if these items were given to another sample group will be describe the close result. The reliability index more than 0.8 were accepted as high value while the accepted value for reliability
index is between 0.6 to 0.8 and the value which is less than 0.6 is not acceptable for reliability [5]. Cronbach’s alpha also known as coefficient alpha, indicates the internal consistency among items package with adequacy namely excellent (0.90 and above), good (0.80-0.89), fair (0.70-0.79), marginal (0.60-0.69), and poor (0.59 and below) [6].

3.2. Validity Index

The second result describes about validity index of Transformative Competencies Questionnaire. Students’ responses were analysed using IBM SPSS Statistics 25 for validity index. Value of \( r_{table} \) for 400-599 samples is 0.128 at 0.01 (1%) significance level. If the value of \( r_{test} (r_{xy}) > r_{table} \), then the item in the questionnaire is declared valid. The results of the calculation, all questionnaire items (39 items) are included in the valid category. These values are presented in Table 2.

| No | Transformative Competencies | Indicator                                                                 | Item Code | Item                                                                 | \( r_{xy} \) | Category |
|----|-----------------------------|---------------------------------------------------------------------------|-----------|----------------------------------------------------------------------|--------------|----------|
| 1  | Creating New Value          | Adaptable (An ability or willingness to change in order to suit different conditions) | TC1       | I can still present ideas and solutions even in different groups.    | 0.548        | Valid    |
|    |                             |                                                                           | TC2       | I can follow to the variety of learning methods given by the teacher.| 0.606        | Valid    |
|    |                             |                                                                           | TC3       | I am trying to change the way I learn when studying different science topics. | 0.518        | Valid    |
|    |                             | Creativity (The ability to produce original and unusual ideas, or to make something new or imaginative) | TC4       | I can offer new solutions when there are problems while studying science. | 0.504        | Valid    |
|    |                             |                                                                           | TC5       | I can present ideas or solutions that others have not thought of.     | 0.594        | Valid    |
|    |                             |                                                                           | TC6       | I can give examples or explanations that develop from imagination.   | 0.551        | Valid    |
|    |                             | Curiosity (A strong desire to know or learn something)                    | TC7       | If there is new information, I am very challenged to find the answer. | 0.610        | Valid    |
|    |                             |                                                                           | TC8       | If there is knowledge that is different from what I already have, I will ask a teacher or friend until I understand.. | 0.585        | Valid    |
|    |                             |                                                                           | TC9       | If I don't understand the teacher's explanation, I will look for other sources that can help me understand. | 0.589        | Valid    |
|    |                             | Open-mindedness (The quality of being willing to consider ideas and opinions that are new or different) | TC10      | I can accept if there are new knowledge while studying science.     | 0.646        | Valid    |
|    |                             |                                                                           | TC11      | I use the knowledge that I have to understand new knowledge while studying science. | 0.639        | Valid    |
|    |                             |                                                                           | TC12      | If there is a new knowledge that is a little different from the knowledge I have, I will be open-minded to try to understand it. | 0.679        | Valid    |
| 2  | Reconciling Tensions and Dilemmas | Integrated way (Ability to think with two or more things combined in order to avoids premature conclusions) | TC13      | When I studied science, I thought in various ways to understand science. | 0.690        | Valid    |
|    |                             |                                                                           | TC14      | When studying science, I do activities in various ways to understand science. | 0.629        | Valid    |
|    |                             |                                                                           | TC15      | If I get new information in class, I will not immediately conclude but will look for other sources to corroborate the conclusion. | 0.608        | Valid    |
|    |                             | Inter-relation (Ability to take into account the)                         | TC16      | I thought of understanding science by considering the relationship between opposing ideas. | 0.615        | Valid    |
| No | Transformative Competencies | Indicator | Item Code | Item                                                                 | $r_{xy}$ | Category |
|----|-----------------------------|-----------|-----------|----------------------------------------------------------------------|---------|----------|
|    | interconnections and        | TC17      |           | I undertake activities to understand science by considering the      | 0.631   | Valid    |
|    | interrelations between      |           |           | relationship between opposing ideas.                                |         |          |
|    | contradictory or            | TC18      |           | If there are ideas that don't match, I try to find connections with  | 0.660   | Valid    |
|    | incompatible ideas)         |           |           | other ideas while studying science.                                 |         |          |
|    | Logics and Positions        | TC19      |           | When studying science, I used logic to understand science.          | 0.609   | Valid    |
|    | (Ability to learn to think  | TC20      |           | When studying science, I use the point of view of a certain position | 0.645   | Valid    |
|    | and act from both logics     |           |           | to understand science.                                              |         |          |
|    | and positions)              | TC21      |           | I understand science easier, if I use logic that I make myself.     | 0.609   | Valid    |
|    | Perspectives                 | TC22      |           | When studying science, I tried to think from a short-term and long-  | 0.641   | Valid    |
|    | (Ability to learn to think   |           |           | term perspective/perception.                                       |         |          |
|    | and act from both short- and| TC23      |           | When studying science, I tried to act from both short and long      | 0.575   | Valid    |
|    | long-term perspectives)     |           |           | term perspectives/perceptions.                                      |         |          |
|    |                            | TC24      |           | While studying science, I was able to sort out short-term and long-  | 0.640   | Valid    |
|    |                            |           |           | term viewpoints/perceptions.                                        |         |          |
|    | 3 Taking Responsibility     | TC25      |           | I can think for myself and communicate to friends while studying    | 0.638   | Valid    |
|    | Think and Work              | TC26      |           | science.                                                           | 0.599   | Valid    |
|    | (Ability to think for        | TC27      |           | I can work with friends while studying science.                     | 0.646   | Valid    |
|    | themselves and work with     |           |           | I complete my work according to the division of labor in the group |         |          |
|    | others)                     |           |           | while studying science.                                             |         |          |
|    | Consequences                | TC28      |           | While studying science, I considered the future consequences of my  | 0.649   | Valid    |
|    | (Ability to consider the     | TC29      |           | actions.                                                           | 0.632   | Valid    |
|    | future consequences of one's | TC30      |           | While studying science, I considered future consequences of the     | 0.649   | Valid    |
|    | actions)                    |           |           | thoughts I conveyed.                                               |         |          |
|    | Evaluation                  | TC31      |           | During my study of science, I was able to determine the thoughts     | 0.685   | Valid    |
|    | (Ability to evaluate risk    |           |           | or actions that produced more benefits than risks.                  |         |          |
|    | and reward)                 | TC32      |           | While studying science, I was able to evaluate which thoughts or     | 0.684   | Valid    |
|    | Accountability               | TC33      |           | actions would pose a risk.                                         |         |          |
|    | (Ability to accept           | TC34      |           | When studying science, I was able to determine the thoughts or      | 0.696   | Valid    |
|    | accountability for the       |           |           | actions that produced more benefits than risks.                    |         |          |
|    | products of one’s work)      | TC35      |           | While studying science, I can be accountable for the thoughts that I | 0.688   | Valid    |
|    |                            | TC36      |           | convey.                                                           | 0.536   | Valid    |
|    |                            | TC37      |           | During my study of science, I can be held accountable for the actions |         |          |
|    | Reflection                  |           |           | that I take.                                                        |         |          |
|    |                            |           |           | When studying science in groups, I can accept a friend's job as a   |         |          |
|    |                            |           |           | form of responsibility for that person.                            |         |          |
|    |                            |           |           | During my study of science, I reflected on whether the actions I had | 0.573   | Valid    |
|    |                            |           |           | taken were right or still wrong.                                    |         |          |
Validity index describes degree how item has ability for assessing its aims. There are four types of validity in line with testing goals, namely content validity, predictive validity, concurrent validity, and construct validity [7]. Validity is degree of how empirical evidence and theoretical rationales encourage the testing interpretations [8]. Empirical validity as the criterion predictor, can be low or high, effect from correlation between response and criterion [9].

3.3. Profiling of Students’ Transformative Competencies

Due to the developed questionnaire instrument has the high reliability and validity index, students’ response from participants also can analyze for profiling of transformative competencies description. There are three transformative competencies, namely Creating New Value, Reconciling Tensions and Dilemmas, Taking Responsibility and each profiling shows in Figure 1, Figure 2, and Figure 3.

Transformative competencies on “creating new value” was constructed by four indicators, namely Adaptability (TC1, TC2, and TC3), Creativity (TC4, TC5, and TC6), Curiosity (TC7, TC8, and TC9), and Open-mindedness (TC10, TC11, and TC12). All indicators represent “fairly typical of me” for highest response, except on “Creativity”. Two items describe “somewhat typical of me” and TC4 response on “not very typical of me”. This item is “I can offer new solutions when there are problems while studying science”. This fact gives probability for science teacher how to design a teaching process to trigger and increase students’ creativity especially on how student can overcome the problem by using new strategy or idea. Profile of transformative competencies on “Reconciling Tensions and Dilemmas” are presented in Figure 2.
Figure 2. Transformative competencies on “reconciling tensions and dilemmas”

Transformative competencies on “reconciling tensions and dilemmas” was constructed by four indicators, namely Integrated Way (TC13, TC14, and TC15), Inter-relations (TC16, TC17, and TC18), Logics and Positions (TC19, TC20, and TC21), and Perspectives (TC22, TC23, and TC24). All indicators represent “fairly typical of me” for highest response, except on “Inter-relations” and “Perspective”. These indicators describe “somewhat typical of me”, so that be chance for science learning to improve how students can interrelate between contradictory or incompatible ideas. Moreover, students have ability to think and act from both short- and long-term perspectives. Profile of transformative competencies on “Taking Responsibility” are presented in Figure 3.

Figure 3. Transformative competencies on “taking responsibility”

Transformative competencies on “taking responsibility” was constructed by five indicators, namely Think and Work (TC25, TC26, and TC27), Consequences (TC28, TC29, and TC30), Evaluation (TC31, TC32, and TC33), Accountability (TC34, TC35, and TC36), and Reflection (TC37, TC38, and TC39). Almost all indicators represent “fairly typical of me” for highest response. But, for this competency, there are several items show “very typical of me” which not available for another two competencies before. These items are TC25 “I can think for myself and communicate to friends while studying science”, TC26 “I can work with friends while studying science”, TC36 “When studying science in groups, I can accept a friend’s job as a form of responsibility for that person”, and TC37 “During my study of science, I reflected on whether the actions I had taken were right or still wrong”. This meant, junior high school students have been ability work in team, communicate to each other, and reflect for choosing right or wrong action.
Transformative competencies as the part of OECD project “The Future of Education and Skills 2030” support the UN 2030 Agenda for Sustainable Development. Students in 2030, be expected to create a new job or career which not available today. Career values have been concerned as the integrated part with schooling period which can motivate students to success in the future. These career values include as view on personal, ability, leadership, social status and relation [10]. The intrinsic and extrinsic careers among students be strength on career management [11]. Moreover, parenting behaviours link positively with children’s career adaptability [12]. Vary of career success depend on differences of cultural values, safety and security oriented [13], also personal value for choosing the career types [14]. Science as a part of subject matter in the school, supply students for increasing their competencies which relate with future life. For example, rebuttal ability that used by students for giving argumentation based on evidence [15], system thinking for helping students’ conceptual change [16], STEM project for enter STEM career fields [17], and critical thinking on data and information [18].

4. Conclusion
The developed questionnaire has a high reliability value of 0.96 for Cronbach's Alpha, 0.94 for Person Reliability and 0.97 for Item Reliability. Furthermore, validity index declares good validity for all items in the questionnaire. Generally, students' profiles are on a "fairly typical of me" scale, except for TC4 statement "I can offer new solutions when there are problems while studying science", which is "not very typical of me". These results provide opportunities for further study to increase student creativity in science learning. To sum up, questionnaire instrument to assess students’ transformative competencies can be used for further research.

5. References

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