THE VALIDITY AND RELIABILITY OF FIVE-TIER CONCEPTION DIAGNOSTIC TEST FOR VECTOR CONCEPTS

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Abstract

Misconceptions has commonly found in Physics concepts, including in Vector concepts. For example, students assumed when an object moves at a certain path and returns to the original position using different path, the displacement is not zero. Meanwhile, according to the Vector concept, the object displacement is zero when it moves and returns to the original position. This discrepancy is called misconception. Such misconception needs to be identified. One of them is by multi-tiers conception diagnostic test. This study was aimed to develop a five-tier conception diagnostic test for Vector concepts and determine the validity (both internal and external aspects) and the reliability. Two groups of students were involved in this work: 25 students to collect common reasons (three-tier questions) and 65 students to calculate the validity and reliability scores. The internal validity was justified by two pointed lecturers at Physics Dept. UNESA. The external validity contains content and construct aspects. The content aspect was determined based on false positive (FP) and false negative (FN) scores, each should be <10%. The construct aspect was calculated by the Pearson's product-moment correlation(r_{xy}). The reliability (r_{11}) was determined using Alpha Cronbach with $r_{theoretic}$ = 0.244 and 5% significance level. The internal validity score = 95%, the FP and FN scores = 3.5 and 9.0% respectively which means that the developed instrument is valid. The r_{xy} = 0.656 and r_{11} = 0.898 which are > $r_{theoritic}$. Therefore, the developed instrument is valid and reliable to diagnoses student's conception on the Vector concepts.

Keywords: Vector concepts, five-tier conception diagnostic test, validity, reliability

Abstrak

Miskonsepsi, secara umum, banyak ditemukan pada konsep Fisika, termasuk pada konsep-konsep Vektor. Sebagai contoh, peserta didik (PD) menganggap apabila suatu benda bergerak pada lintasan tertentu dan kembali pada posisi semula melalui lintasan lain, maka perpindahan tersebut tidak nol. Sementara menurut konsep Vektor, perpindahan suatu benda dikatakan nol apabila benda tersebut bergerak dan kemudian kembali pada posisi semula. Perbedaan keduanya disebut miskonsepsi. Miskonsepsi seperti itu perlu diidentifikasi. Salah satunya adalah dengan tes diagnostik konsepsi *multi-tier*. Penelitian ini ditujukan untuk mengembangkan sebuah tes diagnostik konsepsi berformat *five-tier* untuk konsep Vektor dan menentukan tingkat validitas dan reliabilitasnya. Dua kelompok PD dilibatkan dalam pekerjaan ini, yaitu 25 PD untuk menjaring alasan yang umum dikemukakan oleh siswa (pertanyaan three-tier) dan 65 PD untuk menghitung skor validitas (baik aspek internal maupun eksternal) dan reliabilitas tes tersebut. Validitas internal diuji oleh dua dosen Jurusan Fisika UNESA yang ditunjuk. Validitas eksternal terdiri dari aspek konten dan konstruk. Aspek konten ditentukan berdasarkan skor *false positive* (FP) dan *false negative* (FN), dimana tiap skor tersebut harus <10%. Aspek konstruk dihitung dengan persamaan korelasi *Pearson Product Moment* (r_{xy}). Reliabilitas (r_{11}) ditentukan menggunakan *Alpha Cronbach* dengan r_{teori}= 0.244 dan taraf signifikasi 5%. Skor validitas internal = 95%, skor FP dan FN masing-masing = 3.5 dan 9.0% yang berarti bahwa instrumen yang telah dikembangkan ini valid. Nilai r_{xy}= 0.656 dan r_{11}= 0.898 yang nilainya > r_{teori}. Karena itu, instrumen ini valid dan reliabel untuk dipergunakan untuk mendiagnosis konsepsi PD pada konsep-konsep Vektor.

Kata kunci: Konsep-konsep Vektor, *five-tier diagnostic test*, validitas, reliabilitas

INTRODUCTION

An effective learning process can be achieved when the process is able to help students understand a concept and achieve learning outcomes very well (Anggrayni & Ermawati, 2019; Suprapto et al., 2017). According to Kaniawati (2017), students can be considered understand a Physics concept when they are able to explain the concept clearly based on their knowledge. Unfortunately students' knowledge on Physics concepts is often different from the related physics concept taught at school, as has been discovered by the author when the author was

carrying out practical teaching activities at Tebu Ireng senior high school in Jombang East Java.

On that occasion, the author taught Vector concepts to the students. For example, students assumed that when an object moves at a certain path and returns to the original position via a different path, the displacement is not zero. Meanwhile, according to the Physics concept (Tyndall, 2013), an object displacement is zero when it moves and returns to the original position, either the object moves using the same or different path. The discrepancy between students' understanding and the concept taught by teacher causes misconception in students' mind (Rohmanasari & Ermawati, 2019; Jauhariyah et al., 2018).

Misconception on the Vector concepts was also reported by Khotimah, et al., (2018) and Sari, et al., (2017). They explained that students found difficulties to understand the unit vector, how multiply two vectors, how to add and substract two vectors, both graphically and analytically. Generally, the students' initial knowledge on called preconception (Lutfiyah & Setyarsih, 2016; Suliyanah, et al., 2018). Therefore, student's misconception should be detected earlier to prevent misconceptions in subsequent concepts. To do that, a conception diagnostic test is required, either using interviews, concept maps or multi-tiers conception diagnostic test (Wiyono et al, 2016).

Recently, the commonly used multi-tiers conception diagnostic test is a four-tier format of diagnostic test (Ermawati, et al. 2019). Such diagnostic test consists of: (1^{st}-tier) several answer options, (2^{nd}-tier) level of confidence in choosing the correct answer, (3^{rd}-tier) several options of reasons in choosing the correct answer on the 1^{st}-tier and (4^{th}-tier) the level of confidence in choosing the correct reason on the 3^{rd}-tier.

However, according to Anam, et al. (2019) and Bayuni et al. (2018), the four-tier diagnostic test is not optimal yet to justify students' conceptions. One of the reasons is that the students could answers the multiple choice questions and provide the reasons that they think were right. The test examiner (in this case the teacher), does not yet have sufficient data to assess whether students have understood the concepts being tested or not. Based on this, a 5^{th}-tier question in the form of an open question should be added into the four-tier test. The aim is to give an opportunity for the examiner to confirm himself on the students' understanding on the concepts asked in the questions. For the students, the 5^{th}-tier question will also facilitate them to express their understanding on the chosen answers and reasons on the 1^{st}- and 3^{rd}-tiers questions.

Given that the characteristic of each question on the four-tier format of diagnostic test varies, the additional and required confirmation (i.e. the 5^{th}-tier question) can also vary. Therefore the 5^{th}-tier question should be adjusted based on confirmation need. For example, when the intended confirmation requires a deeper explanation on a certain concept, the 5^{th}-tier question should be a concluding question. When the confirmation requires an illustration, the 5^{th}-tier question should be a drawing question. Such idea is followed in developing a five-tier conception diagnostic test.

Further, when in a four-tier diagnostic test, a student is said to understand the concept when the answer pattern is ″correct-sure-correct-sure″, each representing the answers of the 1^{st} through the 4^{th}-tier questions. In a five-tier format test, the 5^{th}-tier answer should be added as an extra consideration to justify students' conception level. Table 1 resumes the combination patterns of students' answers and the conception levels proposed in five-tier test format.

Table 1. Combination of students' answers in a five-tier diagnostic test and the conception levels (Amin, et al., 2016; Anam, et al. 2019)

No	1st tier	2nd tier	3rd tier	4th tier	5th tier	Conception Level
1	Correct	Sure	Correct	Correct	*(SD/SC)*	*SC*
					(PD/PC)	*ASC*
					(MD/MC)	*LK*
					(UD/UC)	
					(ND/NC)	*UnC*
2	Correct	Sure	Correct	Not Sure	*(PD/PC)* or *(MD/MC)* or *(UD/UC)*	*LK*
3	Correct	Not Sure	Correct	Sure		
4	Correct	Not Sure	Correct	Not Sure		
5	Correct	Sure	Wrong	Not Sure		
6	Correct	Not Sure	Wrong	Sure		
7	Wrong	Sure	Correct	Not Sure		
8	Wrong	Not Sure	Correct	Sure		
9	Wrong	Sure	Correct	Not Sure		
10	Wrong	Not Sure	Correct	Not Sure		
11	Correct	Sure	Wrong	Sure		
12	Wrong	Sure	Correct	Sure		
13	Wrong	Sure	Wrong	Not Sure	*(PD/PC)* or *(MD/MC)* or *(UD/UC)*	*NU*
14	Wrong	Not Sure	Wrong	Sure		
15	Wrong	Not Sure	Wrong	Not Sure		
16	Wrong	Sure	Wrong	Sure	*(MD/MC) or (UD/UC) or (ND/NC)*	*MSC*
17	There is "tier" which not answered or the answer more than one					*UnC*

Note:

SD/SC= Scientific Drawing/Conclusion, PD/PC= Partial Drawing/Conclusion, MD/MC = Misconception Drawing/Conclusion, UD/UC = Undefined Drawing/Conclusion, ND/NC= No Drawing/Conclusion.

SC= Scientific Conception, ASC= Almost Scientific Conception, LK= Lack of Knowledge, NU= No Understanding on Conception, MSC= Misconception, UnC= Un-Code.

Furthermore, Table 2 lists categories of student's answers on the 5^{th}-tier question based on the combination listed in Table 1, the description and the score.

Table 2. A description of drawing or conclusion and the score in five-tier diagnostic test (Dikmenli, 2010; Köse, S., 2008)

No	The Category of Drawing or Conclusion	Description	Score (%)
1	***Scientific Drawing/Conclusion (SD/SC)***	Students provide correct answers with drawing/conclusion are in accordance with physics concept.	100
2	***Partial Drawing/Conclusion (PD/PC)***	Students provide drawing/conclusion are partly in accordance with physics concept.	99-70
3	***Misconception Drawing/Conclusion (MD/MC)***	Students provide wrong answers and the drawing/conclusions are different with the physics concept.	69-40
4	***Undefined Drawing/Conclusion (UD/UC)***	Students provide answers that cannot be understood or the drawing/conclusion do not meet the physics concept.	39-1
5	***No Drawing/Conclusion (ND/NC)***	Students don't provide answers.	0

Based on the fact that students' misconceptions need to be detected and addressed immediately, this paper is therefore intended to develop a five-tier conception diagnostic test on Vector concepts and determine the validity and reliability of the developed instrument.

METHOD

The first version of the five-tier conception diagnostic test for Vector concepts developed in this work, i.e. three-tier format (an open-ended test) consists of 20 questions was written based on the literature studies. The developed instrument was then tested to 25 students' commencement at year 2019 in Physics Dept. Universitas Negeri Surabaya (UNESA). The aim was to collect common reasons, i.e. the answer on the 3th-tier questions.

Gaining the common reasons, a 20-questions of five-tier format test was developed and the resulting instrument was validated internally by two pointed lecturers at the Department. The aim was to gain critical feedback, both on the content, the construct and the language aspects. There are four indicators to assess the content validity, i.e. (a) the conformity between the item test and the Vector concepts; (b) the suitability of the item test with the question indicators; (c) the suitability between the item test and the order of the content; (d) Clarity of questions, answers and reasons for answers. The indicators of construct validity covers: (a) clarity of the instruction for doing this test; (b) the suitability between the test items, the Bloom's taxonomy and the basic competencies; (c) the effectiveness of the test items for identifying students' conception; (d) the choice of answer reasons (the 4th-tier) can reveal the causes of misconceptions originated from students; (e) the distractor's choices in the 4th-tier are rational and homogeneous with the answers in the 1st-tier; (f) tables, graphs and other illustrations are suitable to the problems. There are three indicators in language aspects, i.e. (a) the test is well written in Indonesian language; (b) the questions should be precise, clearly stated and avoid any multiple interpretations; (c) the questions should be communicative. The % of internal validity is evaluated using Equation 1.

$$P = \frac{S_R}{N.P_A.R} . 100\ \% \quad (1)$$

Where P is % internal validity; S_R is the total score given by each validator; N is the maximum score in questionnaire; P_A is total questions in questionnaire and R is the numbers of validators.

Table 3 provides the interpretation of the internal validity values of this developed diagnostic test and the criteria.

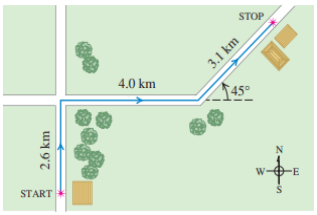
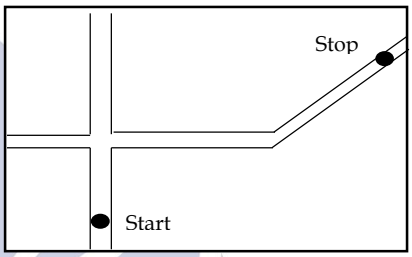
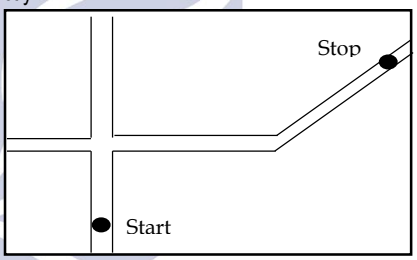
Table 3. Interpretation of Internal Validity and the Criteria (Riduwan & Akdon, 2013)

Score (%)	Score Interpretation of Criteria
0 - 20	Invalid
21 - 40	Less valid
41 - 60	Quite valid
61 - 80	Valid
81 - 100	Very valid

Based on the feedback given by the two internal validators, the author revised the developed instrument. Table 4 shows one of the revised version of five-tier diagnostic test questions on Vector concepts developed in this work; the 20-numbers of questions becomes the final version.

Table 4. One of 20 diagnostic-test questions on Vector concepts developed in this work – the final version

Tier	Question and Multi-tier test
1st tier	**Problem and the available answers** Seorang karyawan pos mengendarai truk pengiriman barang yang melalui rute seperti gambar berikut!  **Gambar 1**. Rute Pengiriman Barang oleh Karyawan Pos dari titik *start* menuju titik *stop* (Freedman and Young, 2013, p:29) Tentukan perpindahan truk dari titik *start* hingga titik *stop*! a. 6,1 km arah timur b. 7,9 km arah timur laut c. 9,7 km arah timur laut

Tier	Question and Multi-tier test
	d. 11,2 km arah utara e. 12,1 km arah utara A postal employee drives a freight truck via the route of the picture below!  **Figure 1**. A postal employee's route from the starting point to the end point (Freedman and Young, 2013, p:29) Determine the displacement of the truck from the starting point to the stopping point! a. 6.1 km to the east b. 7.9 km to the northeast c. 9.7 km to the northeast d. 11.2 km to the north e. 12.1 km to the north
2nd tier	**The confidence level in choosing the correct answer** Apakah kamu yakin terhadap jawabanmu? ○ Yakin ○ Tidak yakin Are you sure with your answer? ○ Sure ○ Not sure
3rd tier	**Possible reasons in choosing the correct answer** Alasan pilihan jawaban: a. Perpindahan didefinisikan sebagai seberapa jauh suatu objek menempuh lintasan tertentu. b. Perpindahan ditentukan dengan menambahkan tiap bagian lintasan yang ditempuh oleh suatu objek. c. Perpindahan dan jarak tempuh suatu objek adalah dua hal yang sama. d. Perpindahan didapatkan dengan memperhatikan posisi awal dan akhir suatu objek serta menentukan jarak terpendek di antara keduanya. e. Semakin jauh perpindahan suatu objek, semakin besar jarak tempuhnya. f. Perpindahan didapatkan dengan memperhatikan posisi awal dan akhir benda kemudian menghubungkan keduanya satu sama lain. Reasons in choosing an answer: a. Displacement is defined as how far an object goes through a certain path. b. Displacement is determined by adding each part of the path taken by an object. c. The displacement and distance of an object are two things in common. d. Displacement is obtained by considering the initial and final position of an object and determining the shortest distance between them. e. The farther away an object is, the greater the distance. f. Displacement is obtained by observing the initial and final position of an object and then connecting the two to each other.
4th tier	**The confidence level in choosing the correct reason** Apakah kamu yakin terhadap alasanmu? ○ Yakin ○ Tidak yakin Are you sure about your answer? ○ Sure ○ Not sure
5th tier	**A drawing or concluding question** Gambarkan skema perpindahan objek seperti pada soal di atas yang dimulai dari titik *"start"* dan diakhiri pada titik *"stop"* dengan benar!  Draw the object displacement based on question above starting from the "start" point and ending at the "stop" point correctly! 

The final version of the questions in Table 4 was then tested to 65 students in science class 1 and 2, senior high school 1 Waru, Sidoarjo, East Java in order to obtain the data on external validity (contents and construct aspects) and reliability. The content aspect was evaluated by calculating the score % of false positive (FP) and false negative (FN). FP is the five-tier answer combination in No. 11 in Table 1 (correct-sure-wrong-sure-wrong), while FN is the answer combination in No. 12 (wrong-sure-correct-sure-wrong); and the scores were applied to Equation 2 and Equation 3 below.

$$\%FP = \frac{\sum FP}{\sum items \ x \ \sum PD} x \ 100\% \quad (2)$$

$$\%FN = \frac{\sum FN}{\sum items \ x \ \sum PD} x \ 100\% \quad (3)$$

In that case, $\sum$FP is the total combination of students' answers (correct-sure-wrong-sure-wrong); $\sum$FN is the total combination of students' answers (wrong-sure-correct-sure-wrong); $\sum$items is numbers of questions (=20) and $\sum$PD is number of students. According to Kirbulut & Geban (2014), the content aspect of validity (i.e. each FP and FN) should be < 10 %.

The construct aspect of validity was determined using the Pearson Product Moment (Equation 4). The instrument is valid when the value of $r_{xy} > r_{theoretic}$ (Arikunto, 2013).

$$r_{xy} = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}} \quad (4)$$

Where r_{xy} is a correlation between *x* and *y*; *x* is the difference between the number of correct answer scores on the 1st-and 3rd-tier, *y* is the difference between the total score of confidence on the 2nd- and 4th-tier.

The reliability of the instrument was determined using the Alpha Cronbach's (r_{11}) in Equation (5) (Sugiyono, 2015). The instrument is reliable when the value of $r_{11} > r_{theoretic}$. Since the total numbers of students involved in this work is 65, therefore the $r_{theoretic}$ and the significant level taken were 0.244 and 5 %, respectively.

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_b{}^2}{\sigma_t{}^2}\right) \quad (5)$$

Where r_{11} is a reliability coefficient of the developed instrument; *k* is the sum of question; $\Sigma\sigma_b{}^2$ is the sum of variant in each question, while $\sigma_t{}^2$ is the total variant. Table 5 shows the criteria of reliability index.

Table 5. The reability index using Alpha Cronbach's criteria (Arikunto, 2013)

Reliability Index (r)	Criteria
0.800-1.000	Very high
0.600-0.799	High
0.400-0.599	Moderate
0.200-0.399	Low
-1.000-0.199	Very low

RESULTS AND DISCUSSION

Table 6 shows the internal validity assessed by the two pointed lectures at Physics Dept. UNESA on the instrument developed in this work.

Table 6. The internal validity of the five-tier diagnostic test on Vector concepts developed in this work.

Validity	Aspects	Validator 1	Validator 2	Percentage (%)	Criteria
Content	a	4	4	97	Very valid
	b	4	4		
	c	4	4		
	d	3	4		
Construct	a	3	4	96	Very valid
	b	3	4		
	c	4	4		
	d	4	4		
	e	4	4		
	f	4	4		
Language	a	3	3	92	Very valid
	b	4	3		
	c	4	4		
Average				**95**	**Very Valid**

Based on data in Table 6, according to Riduwan and Akdon (2013) and supported by Taslidere (2016), the developed diagnostic test is very valid since the average score is 95. Table 7 depitcs the content (FP and FN) scores of the external validity of the developed dignostic test.

Table 7. The content (FP and FN) scores of external validity of this five-tier diagnostic test

Question Number	False Positive (FP)	False Negative (FN)
1	4	5
2	3	5
3	3	3
4	1	10
5	2	2
6	1	7
7	4	9
8	8	7
9	2	6
10	1	6
11	2	5
12	3	7
13	5	9
14	0	1
15	1	3
16	0	8
17	1	4
18	0	7
19	0	8
20	0	6
Total	41	118
Total students ($\sum$students)	65	
Equation x $\sum$students	0.07	
%	**3.5**	**9.0**

Based on the data in Table 7, it was seen that the FP and FN scores are 3.5 and 9.0 % respectively, both < 10%. The scores fulfill the criteria for content external validity (Kirbulut & Geban, 2014; Rusilowati 2015). In other words, the developed instrument is *valid*. Table 8 presents

the score of the construct aspect of validity, while Table 9 shows the reliability score of instrument.

Table 8. The construct aspect score of the external validity of the developed instrument.

Question Number	Coefficient of Correlation (r_{xy})	$r_{theoritic}$	Criteria
1	0.569	0.244	Valid
2	0.325		Valid
3	0.420		Valid
4	0.366		Valid
5	0.368		Valid
6	0.575		Valid
7	0.334		Valid
8	0.535		Valid
9	0.690		Valid
10	0.505		Valid
11	0.579		Valid
12	0.548		Valid
13	0.676		Valid
14	0.535		Valid
15	0.708		Valid
16	0.742		Valid
17	0.732		Valid
18	0.750		Valid
19	0.723		Valid
20	0.786		Valid

In Table 8, all the developed questions were identified to be valid because $r_{xy} > r_{theoretic}$ (Miftakhul & Ermawati, 2019).

Table 9. The reliability score of the developed instrument.

No	Coefficient Correlation (r_{11})	$r_{theoritic}$	Criteria
1	0.898	0.244	Very high

Table 9 shows that the reliability of the instrument is very high as the r_{11} coefficient is 0.898 which is much higher than the $r_{theoritic}$. Thus, the developed instrument is proved to be reliable.

As mentioned above, the 5th-tier form can be a concluding question or drawing question. Table 10 shows an example of the answers of the two students (i.e. student No. 21 and 28) on the 5th-tier drawing questions and the categories.

Table 10. The students (No. 21 and 28)' drawing answers on the 5th-tier question and the categories.

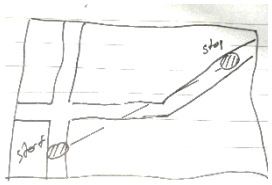
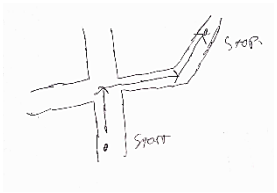
Draw the object displacement from the starting point to the stopping point.	
	
Student No. 21	Student No. 28
Scientific Drawing (SD)	Misconception Drawing (MD)

Table 10 reveals that the two students have different understanding on how to draw the object displacement. The student No. 21 answered that the displacement was obtained by considering the initial and the final positions of the object and determines the shortest distance between them. This is the correct drawing answer, therefore it can be concluded that the student understood the concept well. Based on the Table 2, the answer of student No. 21 is scientific drawing (SD). Meanwhile, the student No. 28 answered that the displacement was obtained by observing the initial and the final position of the object and connecting the two positions using a line. This answer is wrong. Using the category in Table 2, the student No. 18 experienced misconception drawing (MD).

CONCLUSION

The five-tier conception diagnostic test that developed in this work consist of: (1st-tier) several answer options, (2nd-tier) level of confidence in choosing the correct answer, (3rd-tier) several options of reasons in choosing the correct answer on the 1st-tier, (4th-tier) the level of confidence in choosing the correct reason on the 3rd-tier and an open question (5th-tier).

Based on the analyses carried out throughout in this work, the developed five-tier conception diagnostic test for Vector concepts is proven to be valid, both internally and externally, as well as reliable. Therefore the developed diagnostic test is now ready for use to identify conception levels of science class students in senior high school in Vector concepts.

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