Research Article

Developing Diagnostic Test on Geometrical Optics (DT-GO) Concept

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Abstract.
The purpose of this research is to develop the instrument of diagnostic test on optical geometry material, especially in the mirror and lens topics, as well as to unveil the misconceptions of students at one of the public schools in Subang Regency. A purposive sampling technique sampling with sample selection utilizing cluster random sampling technique was conducted on a total of 96 respondents. The instrument utilized by modifying the Four Tier Diagnostic Test which was developed by Kaltakci-Gurel (2017) is developing diagnostic test on geometrical optics (DT-GO). The results of the instrument analysis on the validity test, reliability test, difficulty level test, and discriminatory power, state that the instrument was very well utilized and developed. Based on data analysis and discussion, it can be concluded that overall misconceptions had occurred of overall misconceptions that occur in students are 42.04 %, thus they meet the requirements for misconceptions to a moderate level.

Keywords: diagnostic test, Geometrical Optics (DT-GO)

1. INTRODUCTION

Mastery of concepts and principles on physics lessons has an important role in the process of learning experience of learners [1, 2]. Thus, mastery of concepts in the learning experience will be more meaningful so that students can develop their thinking skills. With good thinking skills, learners can solve problems in everyday life. So that mastery of physical concepts can improve the intellectual skills of students and help in solving the problems faced and give rise to meaningful learning [3–5].

Learners who already have an initial concept based on the daily learning experience they have obtained sometimes not all in accordance with scientific concepts [6, 7]. Concepts that do not conform to scientific concepts are called misconceptions or early conceptions. Misconceptions are a problem that is often faced by learners, especially in Physics subjects. Misconceptions on Physics lessons are usually based on experiences or observations of physical phenomena in everyday life [8, 9].

In addition, the cause of misconceptions in physics lessons is due to several things, including: initial knowledge of learners, teachers, textbooks, environment, improper translation of terms, learning strategies, previous learner information, insufficient student information to associate a concept with other concepts, as well as the use of language and media [10–12]. Misconceptions can be detected using a special instrument in the form of diagnostic tests that can reveal the presence of a misconception. Diagnostic tests can be used by teachers to determine the initial conception of learners and the difficulties of students in order to choose appropriate learning methods to overcome student misconceptions [13, 14]. There are several types of diagnostic tests that can reveal misconceptions in learners, including by using interviews, description tests, multiple choice tests, two-tier tests, three-tier tests, and four-tier tests[15].

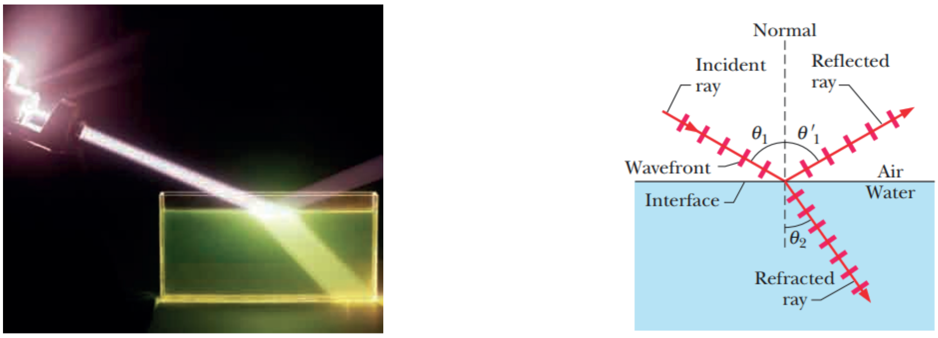
1.1. Misconceptions on Geometrical Optics

Some misconceptions that often occur from sub matter in geometric optics experienced by learners include: (1) shadow formation by flat mirror, (2) shadow formation on convex lenses, (3) direct and indirect observation of real shadows formed by convex lenses, (4) the role of ray diagrams or special rays in shadow formation, (5) the concept of light propagation through different medium refractive indices, (6) graph representation, and (7) light properties [15–18]. This misconception can be caused by several factors, including the initial knowledge of learners, teachers, textbooks, environment, and translation of inappropriate terms [19]. For example, in proving the event of refraction of light, as seen in the following Figure 7.

In accordance with the equation of the Law of Refraction of light from Snellius [20], Which can be written as follows.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad (1)$$

The equation explains that monochromatic rays coming from the less dense medium to the tighter medium will be refracted towards the normal line, and vice versa if the



(a) (b)

Figure 1: (a) a photo shows a beam of incoming rays reflected and refracted by the horizontal water surface. (b) representation of the beam from (a), angle comes (θ_1), reflecting angle (θ_1'), and the refraction angle (θ_2).

monochromatic rays coming from the medium are tighter to the less dense medium will be refracted away from the normal line. While the misconceptions that occur in learners mention that the nature of light (monochromatic light) always propagates straight, even though it passes through different mediums. The number of factors that cause students to become misconceptions should be used as an encouragement so that the problem can be overcome. Therefore, the purpose of this study is to developing Diagnostic Tests on Geometrical Optics (DT-GO) especially on the topic of mirrors and lenses, and describe the misconceptions of learners and the level of confidence of learners.

2. RESEARCH METHOD

This study used mixed methods with *embedded design* [21]. The research used is development research (*Research and Development*) [22] elaborated with a four-tier test diagnostic development procedure by Kaltakci-Gurel (2017) resulting in DT-GO. The development is oriented towards the development of DT-GO instruments on geometrical optics materials.

In the analysis and reconstruction of misconceptions, it turns out that most misconceptions appear in the mirror and lens. The diagnostic tests performed were adapted from procedures performed by Kaltakci-Gurel (2017) namely (1) conducting preliminary studies, (2) Analysis and reconstruction of misconceptions with open questions, (3) compiling and developing DT-GO Instruments with four levels, and (4) instrument validation by experts. The research procedure for the development of Diagnostic Tests on Geometric Optical Materials can be seen in Figure 2 below.

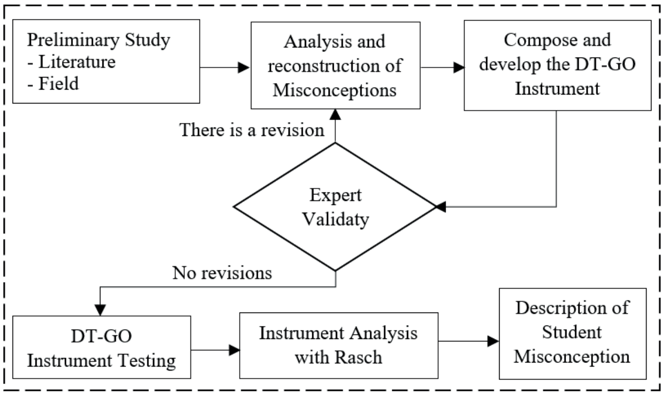


Figure 2: Research procedures.

2.1. Participants

Data retrieval techniques used with *cluster random sampling* techniques [21]. The number of participants was 96 students consisting of 76 women and 20 men on one State High School in district Subang for class XI of the school year 2021/2022. The location of the participants is shown in Figure 3.

Figure 3: (a) Map of the participant's location. (b) Participants' School Places via google map satellite (Source: https://maps.google.com, 2022).

2.2. Instrument Development

Research instruments used in the form of physics questions in geometric optical matter as many as 14 questions of four-level multiple choice consisting of 4 flat mirror questions (numbers 1 - 4), 3 questions about curved mirrors (numbers 5 - 7), 4 questions of curved lenses (numbers 8 - 11) and 3 questions related to the refractive index of materials (numbers 12 - 14). The previous question test instrument was validation by 5 experts, including three lecturers and two physics teachers who already had more than five years of teaching experience. Here is an example of the four levels that have been developed.

1.1 Budi stands at a distance of 2 m in front of the mirror (the mirror is attached to the bomb and made fixed). Budi can see the shadow only from the top of the head to part of the foot, and the bottom of the mirror cuts the rest of Budi's shadow (as seen in figure 1).

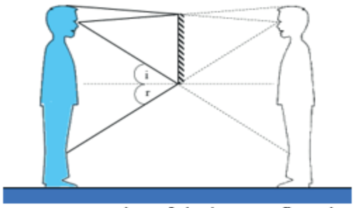


Figure 1. Formation of shadows on flat mirrors

The effort that Budi can do (body movement) so that the shadow of his entire body from the top of his head to toe can be seen is ….

A. Walk forward a few steps closer to the mirror.
B. Take a few steps further from the mirror.
C. Shift a few steps to the left side of the mirror.
D. Shift a few steps to the right side of the mirror.
E. Any effort will not be able to see all parts of the body.

1.2 Are you sure of your answer to question 1.1?
A. Sure B. Not Sure

1.3 Reasons for answer to question 1.1:
A. When moving closer to the flat mirror the angle comes (i) will get bigger so that only a small part of the limbs will be visible, and when away from the flat mirror the angle comes (i) will be bigger so that slowly all parts of the body will be visible.
B. When approaching or away from a flat mirror, the size of the shadow will be the same. The size of the image in a flat mirror that can be seen has nothing to do with the size of the mirror.
C. When approaching or away from a flat mirror, the size of the shadow will remain the same proportionally. The size of the shadow on the flat mirror that can be seen exists in relation to the size of the flat mirror.
D. When moving closer to the flat mirror the angle comes (i) will be smaller so that slowly the whole body will be visible, and when away from the flat mirror the angle comes (i) will be larger so that only a small part of the limbs will be visible.
E. When approaching or away from a flat mirror, the size of the shadow will be different. The size of the shadow inside the flat mirror that can be seen exists in relation to the size of the flat mirror.

1.4 Are you sure of your answer to question 1.3?
A. Sure B. Not Sure

Figure 4: examples of instruments about DT-GO development.

2.3. Data Analysis Techniques

Data analysis is carried out in three stages, namely the first stage of testing the test instrument (validity, reliability, difficulty level and distinguishing power) using Rasch analysis. The second stage by processing learners' answers based on categories of misconceptions. The third stage performs the analysis of data of misconceptions and confidence levels, as well as the comparison of the three using Rasch analysis.

2.4. Question Instrument Analysis DT-GO

The first instrument analysis is carried out on testing the validity of the question, including with the validity of constructs (Uni dimensionality) which is a validity test based on dimensionality items by looking at the value of raw variance explained by measures and unexplained variance 1st contrast. Then the validity of the instrument can also be reviewed from the fit statistic, namely the quality of the item (the suitability of the item measures what should be measured) and the level of difficulty. The quality of the item can be seen on the fit order items of the outfit values MNSQ, ZSTD, and PT Measure Corr.

Second, perform reliability tests through Person reliability, Item reliability, and Cronbach alpha. Third, perform a difficulty level analysis that can be seen using two 13 Item Measure outputs on Ministep software. The goal is to identify the MEASURE value compared to the standard deviation value obtained. Fourth, conducting a differentiating power analysis through Rasch analysis that can be done by identifying the output of table 10 Item Fit Order as in the analysis of Fit Statistic and Difficulty Level.

Students' answers to four-tier questions will be categorized based on six categories of misconceptions, namely Sound Misconception (MC), No Understanding (NU), Partial Negative (PN), Partial Positive (PP), Understanding (SU), and No Coding (NC). The confidence level categories are divided into: Confidence (C), Partial Confidence (PC), and Not Confidence (NC). While the score for the category is adapted from Kaltakci-Gurel, Eryilmaz, & McDermott (2017) research on the assessment of misconceptions and the level of confidence the results indicated by Table 1.

Table 1: Misconception score and confidence level.

Answer	**Misconceptions**	**Confidence Level**
Tier 1	*Wrong* in tier 1 gets score 1	-
Tier 2	-	*Confident* in tier 2 gets a score of 1
Tier 3	*Wrong* in tier 3 gets a score of 1	-
Tier 4	-	*Confident* tier 4 gets a score of 1
Tier 1 dan 3	*Wrong* in tiers 1 and 3 gets a score of 1	-
All Tier 1 – 4	*Wrong* in tiers 1 and 3, and answered confidently in tiers 2 and 4 got a score of 1	*Confident* in tiers 2 and 4 gets a score of 1

To find out the percentage of the level of student's misconception on the question item can be used equations: $P=\frac{f}{n}\times 100\ \%$ (2)

P = percentage of learner answers, *f* = frequency of learners' answers, and *n* = number of learners. The percentage rate of misconception of each item can be categorized as follows:

RESULT AND DISCUSSIONS

To answer research questions as the purpose of this research, the discussion of results and discussions starts from the results of the analysis of the development of

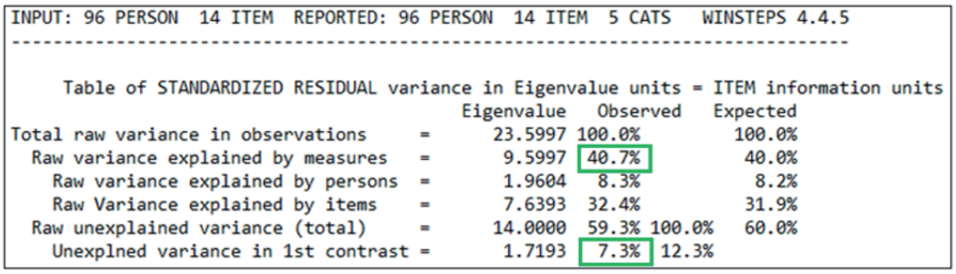
Table 2: Misconception level categories.

Percentage (%)	Category
$70 < M$	high
$30 < M \leq 70$	moderate
$M \leq 30$	low

the DT-GO instrument through four levels. Then continued with a discussion on the description of the level of student misconception based on testing the results of the DT-GO instrument.

2.5. Instrument Analysis Test Four Tier

Before conducting an analysis using Rasch, the research data is made into two categories, namely the conception category and the category of misconceptions. This is done so that the results of the analysis between MC and NU can be distinguished through the category of misconception while the conception category is carried out to distinguish between PP and SU [15]. After getting the difference followed by data processing with Rasch analysis in the conception category with the following steps: The first step, processing the validity of the construct using Winstep 4.4.5 software is shown in Figure 3:



```
INPUT: 96 PERSON  14 ITEM  REPORTED: 96 PERSON  14 ITEM  5 CATS    WINSTEPS 4.4.5
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                            Eigenvalue   Observed   Expected
Total raw variance in observations     =       23.5997 100.0%         100.0%
  Raw variance explained by measures   =        9.5997  40.7%          40.0%
    Raw variance explained by persons  =        1.9604   8.3%           8.2%
    Raw Variance explained by items    =        7.6393  32.4%          31.9%
  Raw unexplained variance (total)     =       14.0000  59.3% 100.0%   60.0%
    Unexplned variance in 1st contrast =        1.7193   7.3%  12.3%
```

Figure 5: Results of the analysis of the validity construct.

Based on Figure 5, when viewed from the raw variance value explained by measures is in the category “According” because the value is more than 40%. In addition, for Eigenvalue and Observed values are in the category of “fulfilled” because the value is less than 3 and the observed value is less than 15% [19, 23]. Therefore, it can be concluded that the instrument is valid for use as a research instrument.

Still in the first step in testing the validity of the instrument about each item (item quality) by using fit statistics. The results of the fit statistic through Rasch’s analysis can be seen in table 3, with the conclusion that there are three questions with the category “According” (1, 13, and 14) and there are 11 questions with the category “Very

Suitable". This is because in the third matter only meets two of the three existing outfits (outfit MNSQ, ZSTD, and PTMEASURE-AL CORR). Problem number 1 does not meet the ZSTD section, while questions number 13 and 14 do not meet the PT-MC section, so all problems in this case are valid and can be used [19, 23].

```
INPUT: 96 PERSON  14 ITEM  REPORTED: 96 PERSON  14 ITEM  5 CATS   WINSTEPS 4.4.5
--------------------------------------------------------------------------------
|     SUMMARY OF 96 MEASURED PERSON
--------------------------------------------------------------------------------
|          TOTAL                        MODEL        INFIT         OUTFIT     |
|          SCORE     COUNT    MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD  |
|-----------------------------------------------------------------------------|
| MEAN      13.8      14.0       -.76     .30      1.00    .04   1.02    .09  |
|  SEM       1.1        .0        .06     .01       .04    .09    .05    .09  |
| P.SD      10.8        .0        .62     .11       .44    .85    .48    .84  |
| S.SD      10.8        .0        .62     .11       .44    .85    .48    .85  |
| MAX.      47.0      14.0        .88     .73      2.25   1.64   2.84   1.94  |
| MIN.       2.0      14.0      -2.25     .19       .31  -2.18    .39  -2.06  |
|-----------------------------------------------------------------------------|
| REAL RMSE    .35 TRUE SD    .51  SEPARATION  1.45  PERSON RELIABILITY  .68 |
|MODEL RMSE    .32 TRUE SD    .53  SEPARATION  1.62  PERSON RELIABILITY  .73 |
| S.E. OF PERSON MEAN = .06                                                   |
--------------------------------------------------------------------------------
PERSON RAW SCORE-TO-MEASURE CORRELATION = .94
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .86  SEM = 3.98

     SUMMARY OF 14 MEASURED ITEM
--------------------------------------------------------------------------------
|          TOTAL                        MODEL        INFIT         OUTFIT     |
|          SCORE     COUNT    MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD  |
|-----------------------------------------------------------------------------|
| MEAN      94.4      96.0        .00     .10      1.01   -.04   1.02    .05  |
|  SEM       7.2        .0        .07     .00       .06    .32    .06    .28  |
| P.SD      25.8        .0        .25     .01       .20   1.15    .23   1.01  |
| S.SD      26.8        .0        .26     .01       .21   1.19    .24   1.04  |
| MAX.     155.0      96.0        .40     .12      1.33   1.70   1.41   1.55  |
| MIN.      59.0      96.0       -.53     .08       .68  -2.11    .57  -2.23  |
|-----------------------------------------------------------------------------|
| REAL RMSE    .11 TRUE SD    .23  SEPARATION  2.12  ITEM   RELIABILITY  .82 |
|MODEL RMSE    .10 TRUE SD    .23  SEPARATION  2.24  ITEM   RELIABILITY  .83 |
| S.E. OF ITEM MEAN = .07                                                     |
```

Figure 6: Person reliability, item reliability, and cronbach alpha.

The second step, processing reliability tests through Rasch analysis with the results in Figure 4. The green box in Figure 6 is a person reliability value with a value of 0.68 (Category Enough), while, reliability items have a score of 0.82 (Good Category). Meanwhile, the Cronbach alpha value has a value of 0.86 (category Very Good). The third step is to look at the difficulty level of each question item, with the results obtained displayed based on Table 3. There are four questions in the Very Difficult category (4, 5, 7, 13), four questions in the Difficult category (6, 10, 12, 14), three questions in the Easy category (1, 9, 11), and three questions in the Very Easy category (2, 3, 8) [23, 24].

The fourth step, processing is done to find out the distinguishing power of each question. Based on Table 3, all question points meet the criteria for distinguishing power with excellent categories of 12 questions and good categories of 2 questions [24]. Based on these four steps, it can be concluded that each question item can meet the criteria of a question that is worthy of use for testing of student misconceptions.

Table 3: Interpretation of fit statistic, difficulty level and differentiating power.

No	Stats Fit				Difficulty Level		Distinguishing Power	
	Out Fit			Interpretation	Measure	Interpretation	PT-MC	Interpretation
	MNSQ	ZSTD	PT-MC					
1	0.57	-2.23	0.78	Suitable	-0.14	Easy	0.78	Excellent
2	0.83	-0.96	0.64	Very Suitable	-0.53	Very Easy	0.64	Excellent
3	1.02	0.17	0.62	Very Suitable	-0.28	Very Easy	0.62	Excellent
4	0.93	-0.20	0.59	Very Suitable	0.5	Very Difficult	0.59	Excellent
5	1.05	0.28	0.59	Very Suitable	0.26	Very Difficult	0.59	Excellent
6	1.02	0.16	0.50	Very Suitable	0.21	Difficult	0.5	Excellent
7	1.09	0.40	0.46	Very Suitable	0.4	Very Difficult	0.46	Excellent
8	0.91	-0.39	0.61	Very Suitable	-0.29	Very Easy	0.61	Excellent
9	0.86	-0.57	0.69	Very Suitable	-0.04	Easy	0.69	Excellent
10	1.38	1.47	0.51	Very Suitable	0.06	Difficult	0.51	Excellent
11	1.28	1.25	0.50	Very Suitable	-0.17	Easy	0.5	Excellent
12	0.77	-0.91	0.65	Very Suitable	0.09	Difficult	0.65	Excellent
13	1.18	0.72	0.35	Suitable	0.33	Very Difficult	0.35	Good
14	1.41	1.55	0.32	Suitable	0.06	Difficult	0.32	Good

2.6. Overview of Student Misconceptions on Geometrical Optics Materials

2.6.1. Categories of Student Misconceptions

Here are the results of the analysis of the processing category of misconceptions on geometric optical materials that can be divided into 4 sub-materials, namely flat mirrors, curved mirrors, curved lenses and refractive indexes of materials.

Table 4: Recapitulation percentage of learners' misconceptions on geometrical optics materials.

	MC	NU	PN	PP	SU	NC
Flat mirror	42.19	15.63	31.77	2.60	7.81	0
Curved Mirror	46.18	21.88	28.47	1.04	2.43	0
Curved Lens	37.76	17.71	33.59	3.13	7.81	0
Bias Index	42.01	19.79	34.72	1.39	2.08	0
Average	42.04	18.75	32.14	2.04	5.03	0

Based on Table 4, the average misconception that occurs in optical materials is 42.04% with medium categories. The most misconceptions in the curved mirror sub-material, especially in question number 5 of 51.04% with the medium category. The students who have the highest misconceptions are 3 people, namely at 24F, 54F and 71F with a percentage of 86% with a high category. This shows that there are still learners who have a high degree of misconceptions in geometrical optics materials [8, 9] and need to get special attention, especially by doing a more meaningful learning process [15, 25]. One of today's learnings that can be used to reduce student misconceptions is by using the blended learning process, for example with the flip classroom method [26] which is based on cognitive conflict [16].

2.7. Learner Confidence Level Category

Here is a graph of the relationship between the confidence level of learners to the question items shown in Figure 5. From the results of data processing, the confidence level of learners has a percentage of 69% to answer all the questions given.

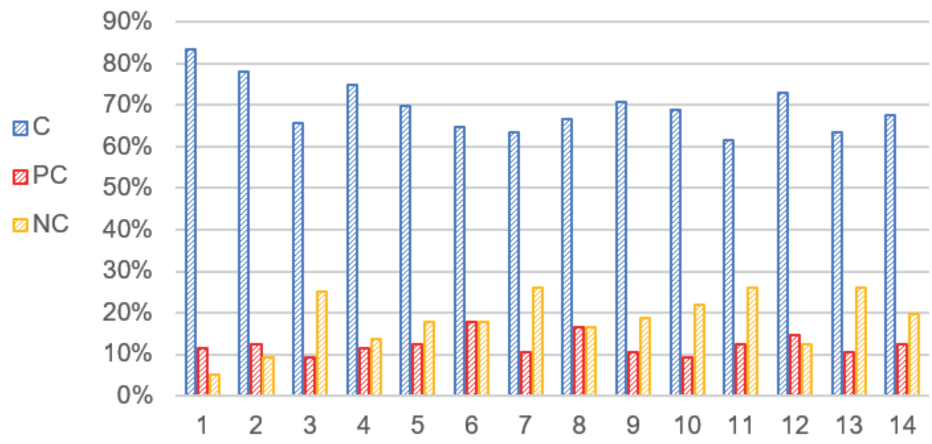


Figure 7: Relationship between the level of self-incompetence of learners to question items.

Based on Figure ??, the confidence level (C) of learners is highest on question item number 1 with a percentage of 83%. While the level of confidence (C) of learners is lowest on question item number 11 with a percentage of 61%. Then the level of insecurity (NC) of learners is highest on question items 7, 11 and 13 with a percentage of 26%. The Rasch model can describe more specifically the relationship between the misconceptions that occur in each learner and the level of trust [19]. Misconceptions often occur when learners have a high level of confidence in answering questions based on their personal experiences without being scientifically proven. The development of diagnostic instruments to assess learners' misconceptions on geometrical optics helps teachers to design and improve the learning process on the topic [15].

3. CONCLUSION

This research aims to develop problem instruments on optical geometry materials (DT-GO) especially on the topic of mirrors and lenses, and describe students' misconceptions and learners' confidence levels. The results of the processing of analysis of the instruments that have been developed (DT-GO) state that all instruments are declared valid and reliable. The difficulty and distinguishing power result in an excellent average for use as a diagnostic test on optical material geometry (DT-GO). Learners have the most misconceptions (MC) in curved mirror sub matter, while the average learner understands all geometric optical material (SU) by 5.03%. The confidence level of students answering the question is 83%. So that it can be concluded that the picture of misconceptions in students after being given instruments about the development of DT-GO has an average of 42.04% with a medium category.

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