The influence of education and professional experience on misconceptions in optics in optometry

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ABSTRACT

In several countries such as the UK, the optometric profile has shifted towards a healthcare professional. The optics lecturer has thus to help students with often a limited interest and background in optics to become professionals with a reasonable understanding of the main optical phenomena and how they can be put in use in optometric instruments. In this context, and in order to help improving teaching strategies, the aim of this study was to identify misconceptions in optics among optometry students, and to assess if these misconceptions would change with professional experience and continuous education. An on line, anonymous, survey was carried out among first, second, third year Optometry students and qualified optometrists registered for at least two years with the General Optical Council. The number of respondents in the four groups was respectively 67, 54, 22 and 74. The survey consisted of 40 True/False/Pass questions regarding the nature of light (7), geometrical optics (8), visual optics (11) physical optics and ophthalmic applications (14). Results show that the misconceptions identified are similar to those reported in other science groups (e.g. image formation, wave nature of light) with the exception of few more directly related to Optometry concepts. If globally, students understanding improve with academic education, a number of misconceptions however persist along their studies and new misconceptions may also appear as students are introduced to new concepts, which may not always be clarified afterwards with professional experience.

Keywords: optometry, misconception, optics, continuous education.

1. INTRODUCTION

Research in Science education has shown that science students often start University with incorrect ideas about how the natural world works[1,2]. An important task for any lecturer is to identify these misconceptions to help the student achieving an in depth understanding of the topic[3] (the term misconception has various synonyms[4] and is used here to reflect vague or wrong ideas).

Optometry students start their course with a limited background in optics but are assumed to graduate with a reasonable understanding of the nature of light, the main optical phenomena and how they can be put in use in optometric instruments (e.g. image formation and correction of myopia or imaging of the retina)[5]. In the UK, the modern optometrist is however considered to be first of all a healthcare specialist and the teaching in optics in Optometry represents nowadays only a small fraction of the whole curriculum. The syllabus in Optics is often traditionally divided into three topics: geometrical optics, physical optics and visual optics and usually correspond to a volume of no more than 75 hours. Once qualified, optometrists have the possibility to consolidate or expand this knowledge through Continuous Education and Training although most CET materials focus on clinical topics.

In this context, the purpose of this study was to identify misconceptions in optics among optometry students; to compare them to those identified in the education research literature among other categories of students; and finally to compare them to those possibly identified among qualified optometrists.

2. METHODS

2.1 Survey

A survey was carried out among 1st, 2nd and 3rd (last) year Optometry students at the University of Manchester, as well as qualified optometrists. The first three groups (denoted Y1, Y2, Y3) represented respectively 71, 78 and 72 students.

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Participants were contacted by email with information about the nature and goal of the survey. The survey was done online with the software SelectSurvey.net, it was accessible during several weeks and completely anonymous. In addition, participation was volunteer and no personal information was collected. It consisted of 40 True/False questions. For each question, respondents had also the possibility not to answer the question. The study was carried out during the first week of the second semester. The first year students (Y1) had then recently finished their course in geometrical optics (semester 1). The second group (Y2) had then followed two courses in geometrical and physical optics (respectively in semester 1 and 2 of their first year). The third group (Y3) had gone through the three courses: geometrical, physical and visual optics (2nd semester Y2). The data from two mature students with, respectively, a PhD in Chemistry and Physics was removed for analysis.

The fourth group (denoted here “Optom") consisted of experienced optometrists registered for at least two years with the General Optical Council (GOC). This criterion was used to ensure that the respondents would not be recent graduates and would have a minimum professional experience. The potential respondents (986) were contacted with the help of the GOC and a total of 74 respondents participated in the study. The number of respondents in the 4 groups (Y1 to Optom) was respectively 67, 54, 22 and 74. Considering a confidence level of 90%, the margins of error associated to each group are respectively 2.4%, 6.2%, 14.7% and 9.6%. This last number was calculated taking into account that approximately 24,000 optometrists, dispensing opticians, student opticians and optical businesses were registered with the GOC at the time of the study (2012).

The 40 questions are presented hereafter. In order for half of the correct answers to be true (and the other half false), two questions were presented as negative statements. The questions were derived from related studies[6-8] and our teaching experience. Some statements, e.g. question 2, may appear disconcerting to someone educated in Optics but correspond to statements encountered in students’ written work.

2.2 Questionnaire

Nature of light

1. Light is an electromagnetic radiation.
2. Photons have a sinusoidal shape.
3. Light can propagate in complete vacuum.
4. The distance light travels depends on its energy.
5. The following radiations are correctly ordered, by decreasing photon energy: X-ray, UV, Visible, Infrared, Microwaves, Radio Waves.
6. The shorter the wavelength the more energy the radiation carries.
7. Each point on a luminous object emits light in one direction only.

Geometrical optics - Questions 8-11 refer to the figure depicted in Fig.-1.

8. A sharp image can be seen on the screen regardless of where the screen is placed relative to the lens
9. To see a larger sharp image on the screen the screen should be moved further back.
10. The size of the image depends on the size (diameter) of the lens used to form the image.
11. Blocking part of the lens would block the corresponding part of the image.

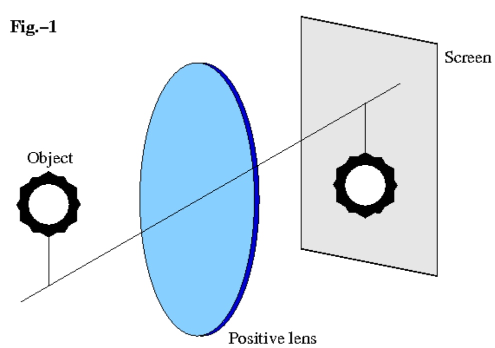

Figure 1. Figure associated with questions 8-11

12. In figure 2, the lens will focus the three rays to the point P'.

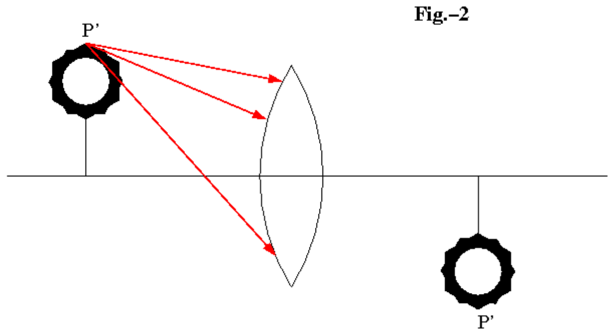

Figure 2. Figure associated with question 12

13. Light passing through a transparent window is deviated twice.
14. An observer can see more of his/her image in a mirror by moving further away from it.
15. Light travels at a finite speed but if we observe an object through a telescope, we can catch the emitted light earlier.

Visual Optics

16. We can see because light travels to our eyes and then from the eyes to the object.
17. Light is not essential to see since we can see a little in a dark room.
18. The image on our retina of the objects we look at is upside down.
19. The focal length of a 10D lens in air is 10cm.
20. A refractive error of -4D means that the patient cannot see clearly further than 4m without correction.
21. A myopic eye with an amplitude of accommodation of 3D and a far point at (-1)m will have a near point at 25cm.
22. The ability to resolve two close objects can be used as a measure of visual acuity.
23. Visual acuity is related to the optical quality of the eye and the retina's neural circuitry.
24. On a Snellen chart, if someone can only see the line 6/12 at 5m, his Snellen acuity is 5/12.
25. A 9/6 Snellen letter subtends 5 minutes of arc at 9 meters.
26. The visible part of the electromagnetic spectrum ranges approximately from 400 to 780nm.

Physical Optics

27. After passing through a convergent lens the speed of light is increased.
28. Myopia is a low order aberration.
29. We can move from the wave description (physical optics) to the ray description of light (geometrical optics) if the wavelength is infinitely small compared to the physical dimensions of the objects it interacts with.
30. Interference is the addition of 2 or more waves to create a new wavelength.
31. The pattern of bright and dark fringes cast by the sun through venetian blinds is an example of interferences.
32. Diffraction can reduce the eye's optical resolution if the pupil's diameter is very small (<3mm).
33. Coherence is a property of a wave that basically describes its ability to interfere with a similar wave.

Anti-reflection (AR) coatings and optical devices

34. The resolving power of an optical instrument is inversely proportional to the wavelength.
35. Anti-reflection coatings stop aberrations from occurring.
36. A purple reflection can often be observed on glasses coated with an AR coating. This is due to light dispersion by the uncoated edge of the lens.
37. Anti-reflection coatings are of a higher refractive index than the lens and therefore allow more light to pass through.

Polarisation

38. Plane polarised light travels only in one direction.
39. Polarising sunglasses use the technique of diffraction grating to eliminate the glare and harmful rays of the sun.
40. The light from cars' headlights is polarized

3. RESULTS

To illustrate students' performances, the percentage of correct answers per question (i.e. the percentage of students having answered correctly) is reported in Table 1 for each group, with cells highlighted in pale red when less than 50% of the students answered correctly and in pale blue when between 50 and 70% answered correctly. Since students could choose to skip a question, the percentage of incorrect answers is also given. Only two questions were correctly answered by 100% of the students and these were questions 8 and 27 for the Y3 group.

Table 1. Left panel: percentage of correct answers given per question and per group (ordered by decreasing order for Y1 group). Cells are highlighted in pale red when this percentage is less than 50% and in pale blue if between 50% and 70%. Right panel: percentage of incorrect answers given per question and per group (ordered by decreasing order for Y3 group).

Question	Year 1	Year 2	Year 3	Optom	Question	Year 1	Year 2	Year 3	Optom
8	88%	93%	100%	93%	14	78%	74%	86%	80%
26	85%	98%	91%	80%	38	75%	80%	86%	74%
18	82%	87%	86%	96%	30	61%	74%	73%	57%
19	82%	80%	95%	92%	31	63%	65%	68%	47%
1	81%	96%	91%	95%	11	82%	67%	64%	32%
3	79%	94%	95%	86%	25	31%	46%	59%	49%
17	79%	81%	86%	91%	21	37%	46%	55%	27%
5	76%	87%	68%	61%	24	15%	28%	55%	20%
24	76%	69%	45%	76%	2	39%	41%	50%	34%
22	73%	91%	91%	77%	4	60%	43%	45%	45%
7	70%	78%	86%	74%	37	39%	43%	41%	74%
23	70%	91%	91%	88%	32	30%	22%	36%	51%
6	69%	96%	95%	74%	12	34%	33%	36%	28%
13	67%	78%	82%	81%	33	12%	13%	36%	27%
20	61%	78%	95%	96%	5	16%	11%	32%	31%
9	60%	70%	68%	74%	34	18%	35%	27%	46%
12	60%	61%	59%	65%	39	75%	67%	27%	36%
16	60%	72%	91%	93%	9	33%	30%	27%	18%
27	60%	78%	100%	88%	28	25%	37%	23%	47%
10	57%	65%	82%	84%	40	40%	44%	23%	3%
33	54%	78%	64%	64%	29	16%	19%	18%	23%
29	48%	56%	73%	62%	13	28%	19%	18%	15%
28	45%	41%	68%	47%	10	34%	31%	18%	9%
34	43%	37%	55%	41%	7	21%	19%	14%	18%
2	40%	56%	45%	54%	17	13%	15%	14%	7%
25	40%	37%	32%	35%	18	7%	13%	14%	1%
32	37%	67%	64%	42%	36	46%	43%	9%	41%
15	34%	54%	95%	84%	22	12%	4%	9%	16%
37	34%	52%	55%	20%	26	4%	2%	9%	15%
40	33%	48%	77%	93%	23	15%	6%	9%	8%
4	31%	54%	50%	51%	16	30%	22%	9%	4%
35	27%	48%	95%	86%	1	13%	4%	9%	4%

14	22%	22%	14%	16%	6	22%	4%	5%	22%
21	18%	31%	41%	64%	15	36%	24%	5%	11%
30	16%	22%	27%	38%	19	12%	17%	5%	4%
31	15%	24%	32%	47%	20	27%	9%	5%	1%
11	13%	24%	27%	61%	35	51%	44%	0%	11%
38	12%	17%	9%	20%	3	13%	4%	0%	9%
36	10%	46%	86%	53%	27	25%	15%	0%	7%
39	1%	28%	68%	59%	8	10%	6%	0%	1%

To facilitate the analysis by looking more globally at the results, one can calculate from table 1, for each group, the median and the average ± one standard deviation for the percentage of correct, incorrect and pass (i.e. skipped) answers. This information is presented in table 2.

Table 2. Second column: median for the percentage of correct answers per question (e.g. here, half of the questions were answered correctly by at least 55% of Year 1 students). Columns 3-5: average for the percentage (± one standard deviation) of correct, incorrect and pass answers (e.g. here, in average, each question was answered correctly by 69% of the Year 3 students).

	Median (%)	Average (%)		
	Correct	Correct	Incorrect	Pass
Y1	55	50±25	33±21	17±12
Y2	66	62±25	30±22	8±7
Y3	75	69±26	28±25	3±4
Optom	74	68±23	26±22	6±3

As we could expect, the proportion of students answering correctly increases from Y1 to Y3 with half of the questions being answered correctly by at least 75% of 3rd year students against 55% in first year (table 2). Similarly, the average proportion of correct answers per question was 50% in first year and 69% in 3rd year. This increase was paralleled by a strong reduction in the proportion of questions not answered (from 17% to 3%). Globally the largest improvement from one year to the other (in terms of number of questions) is from Y1 to Y2 (particularly for questions 6, 32, 33, 36, 39, cf. table 1) which is not surprising since the 2nd year students benefited from one additional year of study and having received 24 hours of lectures in physical optics. Also most questions in this survey are related to geometrical/physical optics (i.e. topics covered in Y2).

If globally results appear to improve from Y1 to Y3 (higher number of correct answers and lower number of pass), several questions show however an increase in the number of incorrect answer (cf. Table 1) from Y1 to Y3, e.g.: 2 (39% → 56%), 5 (nature of light 16%→32%), 14 (image formation 78% → 86%), 21 (37% → 55%), 24(15% → 55%), 25 (31% → 59%) (Visual optics), 30 (interferences), 33 (coherence 12% → 36%), 38 (polarisation 75% → 86%) or little improvement. This increase in the percentage of incorrect answers (when students are offered to skip the question) can be considered as an evidence for the development of misconceptions. For instance, where a first year student may pass on a question related to interference, a 3rd year student may feel confident he knows the correct answer, although the limited teaching he received did not allow him to build a sound understanding of the phenomenon.

Comparing data between Y3 and Optom (cf. table 1) results may appear at first glance surprising since the Optom group scored less on half of the questions. A closer examination of the results show that Optom performed globally better with questions related to geometrical and visual optics (particularly 11,21,24) and less well on more academic or technical questions (e.g. 6, 28/aberrations, 32/physical optics, 37/coatings). The strong reduction in percentage of correct answers for these questions can be partly explained by the fact that some of these questions are relative to the wave nature of light or quite academic (6,28,32) and so may be challenging for respondents who graduated several years ago and probably mainly developed their clinical skills. The Optom group showed an improvement in terms of a lower proportion of incorrect responses meaning that the number of misconceptions may decrease but these variations are however here too small to be significant.

4. DISCUSSION

The aim of this study was to identify misconceptions in optics among optometry students, as well as qualified optometrists to improve teaching strategies. A number of subjects have been identified that should receive particular attention in lectures to avoid letting students leave university with a too inaccurate understanding of a topic (e.g. interference, polarisation). This situation is obviously common to several fields (e.g. physics, engineering) and just like ophthalmologists performing laser surgery are not experts in laser physics, optometrists do not need an in depth understanding of the nature of light or the physics of different optometric/ophthalmic devices to practice, as evidenced by our "Optom" group. How much optics is needed for an optometrist in his daily work, or to answer questions of the public as an "expert" in optics, or to follow technical changes and innovations (e.g. to discuss the importance of blue filters, to read devices technical documentations, etc.) is however not the question of this study[5]. We assume here that, optics is an important part of the curriculum and that our results can help improving its teaching.

Comparison with other studies is difficult since most studies have been conducted on relatively younger groups (e.g. primary or secondary school[9,10,11] or students in 1st year when our first group (Y1) had already followed a couse in geometrical optics) and did not test the understanding of complex phenomenon such as polarisation. The fact that a number of final year students still misunderstand various phenomena is in agreement with the literature[12].
The misconceptions identified are however similar to those reported in other science groups[13,14] (i.e. wave nature of light, image formation[15-17]) with the exception of few more directly related to Optometry concepts. As expected, students' score globally improved with academic level particularly from Year 1 to Year 2. A number of misconceptions however persist along their studies and some new misconceptions seem to appear as students are introduced to new concepts (e.g. interference or polarisation) which may not always be clarified with experience.

To help students improving their understanding, this questionnaire should not be used to assess their level. Confronting directly these misconceptions would be like reasserting new statements that students, again would probably incorrectly use in a new context. It should rather be used as a basis for discussion to help students identify misunderstandings and remediate it by verbalizing their thinking [18]. In addition, within the framework of a limited number of hours, it would be advantageous to develop kits allowing to carry out simple practical work at home (e.g. image formation, wave nature of light), in addition to the many animated illustrations available on line), to help students actively build knowledge through experience.

Several factors may have influence these results. Firstly, participation to the survey was voluntary and anonymous and there is no guarantee that the respondents answered carefully each question. Secondly, the nature of the test is subjective and even a correct answer may not reflect a good understanding of the topic (although each True/False statement was phrased carefully to avoid any misinterpretation). Finally, the number of respondents in Y3 and in the Optom group is relatively low. This is all the more important for the Optom group that no age limit was set. Therefore, in addition to varying experience, respondents may have also received different educations.

5. CONCLUSION

These preliminary results (a further analysis is in progress[19]) suggest that optometry students may leave university with an incomplete or incorrect understanding of some optics related topics, understanding that will not improve with professional experience. Particular care should thus be given to the teaching of image formation and topics involving the wave nature of light. Professional experience will not significantly help optometrists in clarifying misconceptions developed during their academic education. Optometrists could thus perhaps benefit from an increase in Continuous Education and Training material focused on these topics.

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