Genetics and Molecular Diagnostics in the Clinical Laboratory Science Curriculum

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OBJECTIVE: To determine the nature and extent of education in human genetics and molecular diagnostics in clinical laboratory science (CLS) programs throughout the U.S.

DESIGN: A written survey was mailed to 263 CLS programs. Data were expressed as raw numbers and percentages of responses.

SETTING: State University of New York, Upstate Medical University.

PARTICIPANTS: There were 162 responses and 151 usable surveys. Most respondents (86.8%) were department chairs/CLS program directors; 13.2% were CLS faculty or educational coordinators.

MAIN OUTCOME MEASURES: Questions were designed to determine frequency of CLS programs providing education in genetics, specific molecular methods and clinical applications, format of instruction, satisfaction levels with education provided, and perceptions on importance of teaching genetics, molecular diagnostics, and related hands-on experiences.

RESULTS: Over 92% of CLS programs teach human genetics and molecular diagnostics in varied formats. Polymerase chain reaction was the most frequently taught molecular method; microorganism detection, the most commonly taught clinical application. More programs teach theory than provide hands-on experience in molecular diagnostics. Only 59 (39.1%) teach related ethical issues. Sixty-seven respondents (44.4%) were dissatisfied with the education they provide, due to lack of time to teach the material (n = 49; 73.1%), lack of knowledgeable faculty (n = 43; 64.2%), and expense of methods (n = 37; 55.2%). Most respondents felt it was important to include human genetics (n = 145; 96%) and molecular diagnostics (n = 149; 98.7%) in their curriculum, and related hands-on experiences in the student laboratory (n = 106; 70.2%) or clinical rotation (n = 135; 89.4%). Over 82% (n = 124) expected instruction of molecular diagnostics to increase in the next five years.

CONCLUSION: Most CLS programs include human genetics and molecular diagnostics in their curriculum, and expect the education they provide to increase in the next 5 years. In order to meet this expectation, CLS programs may need to provide opportunities for faculty training, seek funding to cover the cost of methods, and consider innovative curriculum changes.

ABBREVIATIONS: CLS = clinical laboratory science; PCR = polymerase chain reaction.

INDEX TERMS: clinical laboratory science education; genetics; laboratory testing; medical technology education; molecular testing.

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During the past two decades, we have witnessed exponential growth in the fields of genetics and molecular biology. The Human Genome Project, an international effort whose ultimate goals are to map the entire set of human genes and to determine their complete DNA sequence, reached a major milestone last year when the first working draft of the sequence was published.[1,2] Scientists estimate that the human genome contains about 35,000 genes, and at least one disease-related mutation has been discovered for 1,100 of these genes.[3]

This knowledge has resulted in the evolution of molecular techniques from esoteric research tools into methods which play an integral role

Table 1. Distribution of responding CLS programs by institution type

Type of institution	Responding programs	% total programs
Private university (non-medical)	5	3
State university (non-medical)	30	20
Private four-year college	5	3
State four-year college	2	1
Private academic medical center	8	5
State academic medical center	25	17
Hospital	66	44
Other*	10	7
Total	**151**	**100**

*Other includes five universities with medical schools, one college of health sciences, two reference laboratories, one consortium, and one community foundation

in laboratory medicine.[4-6] These methods are being incorporated into the clinical laboratory at an increasing pace and have had a tremendous impact on laboratory diagnosis and patient management. Some examples of the numerous clinical applications of molecular tests which are important to the current practice of medicine include viral load tests for human immunodeficiency virus; rapid detection of slow-growing microbial pathogens such as *Mycobacterium tuberculosis*; detection of genetic diseases such as cystic fibrosis and determination of gene carrier status; tests for mutations leading to thrombotic conditions such as Factor V Leiden deficiency; tests for diagnosis of hematologic malignancies; and genetic tests for heritable forms of solid tumors.[6-10] The number of molecular tests performed in the clinical laboratory is expected to increase further as our knowledge of genes in humans and pathogenic organisms continues to expand.[5]

It follows that the demand for clinical laboratory scientists with experience in molecular diagnostics is also expected to increase.[8] Clinical laboratory scientists should therefore be knowledgeable in the basic principles and uses of these technologies. The ideal place for instruction in this area to begin is in educational settings, so that clinical laboratory science (CLS) graduates will be prepared to work with molecular techniques in their clinical practice. The importance of genetics education was reflected in a recent survey of allied health program directors, in which 86% of the respondents perceived a need for education in genetic technologies at the undergraduate level.[11] In addition, the U.S. Department of Health and Human Services has recently funded a project, "Human Genetics Curricula for the Health Professionals", whose aim is to recommend specific educational content in the area of genetics to be incorporated into allied health programs throughout the country.[12]

It is especially important for students of CLS, who will be directly involved in performing molecular tests and ensuring their accuracy, to have a thorough understanding of the underlying principles of the assays performed and of factors which could affect test results. An informal telephone survey of CLS program directors conducted by one of us in 1992 and a formal survey conducted by Kasper in 1993 however, indicated that only 8% to 16% of the responding programs required a genetics course as part of their curriculum or as a prerequisite.[13,14] We wondered if the amount of education provided by CLS programs had increased to reflect the theoretical and technical advances in genetics that have occurred since that time. We also wished to obtain information about the content of the instruction provided. Relatively little information has been published about the education healthcare professionals receive in genetic technology.[15] We therefore developed and administered a written survey to determine the extent of education in human genetics and molecular diagnostics that is taking place in CLS Programs throughout the United States. Questions were designed to determine the nature of this education in both didactic and clinical settings.

MATERIALS AND METHODS

The survey consisted mainly of multiple choice questions with fixed responses in which individuals were asked to circle one or more answers which applied to themselves or to their program. Blank spaces were included with some of these questions to allow individuals to specify answers which were not provided. Two of the questions listed a variety of molecular methods or their clinical applications, and the respondents were requested to place a check mark next to all items that were taught in their program as well as the level of instruction provided. The final question of the survey was open-ended, allowing respondents to write additional comments about education in genetics and molecular diagnostics.

Table 2. Instruction of basic principles of genetics in CLS programs

	TYPE OF INSTITUTION			
Format of Instruction	**University or College*** **# responses (%)§**	**Academic Medical Center†** **# responses (%)**	**Hospital or Ref Lab‡** **# responses (%)**	**Total** **# responses (%)**
Prerequisite	14 (29.2)	13 (39.4)	34 (48.6)	60 (39.7)
Separate required course	10 (20.8)	3 (9.1)	1 (1.4)	14 (9.3)
Part of another course	11 (22.9)	8 (24.2)	10 (14.3)	31 (20.5)
Separate elective course	5 (10.4)	2 (6.1)	12 (17.1)	20 (13.2)
Spread throughout curriculum	15 (31.3)	11 (33.3)	22 (31.4)	50 (33.3)
Not taught	3 (6.3)	3 (9.1)	7 (10)	11 (7.3)
	n = 48	*n* = 33	*n* = 70	*n* = 151

* Includes state and private non-medical universities and 4-year colleges, universities with medical schools, and a college of health sciences
† Includes state and private academic medical centers
‡ Includes hospitals, reference laboratories, a consortium, and a community foundation
§ Data represent raw numbers of responses and percent of responses in the appropriate category of institution type (in parentheses)

Prior to widespread distribution in the spring of 2001, a pilot survey was mailed to 12 CLS program directors and was reviewed by two faculty members at the State University of New York, Upstate Medical University, for clarity and content of the items. The survey was then revised and mailed to department chairs/directors of 263 CLS programs throughout the United States, along with a cover letter and postage-paid return envelope. The recipients were allowed two weeks to respond, and were asked to give the survey to another faculty member in their department if they were unable to reply.

The final survey consisted of 23 questions (two with multiple parts) which could be classified into one of three types: questions describing the individual completing the survey and the format of their CLS program, questions about the content of education provided in human genetics and molecular diagnostics, and questions regarding the opinions of the respondents on the importance of education in these areas. Data for each item were compared both as raw numbers of responses and percentages of the total number of usable surveys.

This study received exempt status from the Institutional Review Board of State University of New York, Upstate Medical University, and was partially funded by a grant from the Research Foundation of that institution.

RESULTS

Of the 263 surveys that were mailed, 162 individuals responded, giving a response rate of 61.6 %. Ten of the respondents indicated that their programs had been closed, and did not complete the survey, while one survey was returned as undeliverable; therefore 151 usable surveys were obtained.

The majority of the respondents (131; 86.8%) were department chairs/program directors, and 128 respondents (84.8%) had over ten years of experience in CLS education. Ninety-five of the programs (62.9%) were of the 3 + 1 or 4 + 1 format, 45 programs (29.8%) were 2 + 2, 3 programs (2%) were 4 + 0, and eight programs (5.3%) were of another format, e.g., 4-year integrated. Four of the departments offered a separate major in biotechnology, and nine departments offered a major in cytotechnology/cytogenetics. Table 1 shows the distribution of programs according to the type of institution they were located in.

Respondents were asked how the basic principles of genetics and molecular diagnostics are taught in their curriculum. The formats of instruction provided by CLS programs are shown in Tables 2 and 3, and are compared according to institution type. When asked if the ethics of genetics testing was taught in their curriculum, over half of the individuals (n = 84; 55.6%) indicated "No" as their response, while 40 respondents (26.5%) indicated that this subject was spread throughout their curriculum, 16 respondents (10.6%) replied that the subject was taught in a separate required course, and three respondents (2%) indicated that the subject was taught in a separate elective course.

Respondents were also asked about the content of instruction they provide in the area of molecular diagnostics, and whether this instruction took place as didactic instruction of theory, observational experiences for students, and/or hands-on experiences in the student

Table 3. Instruction of molecular diagnostics in clinical laboratory science programs

	TYPE OF INSTITUTION			
Format of Instruction	**University or College* # responses (%)§**	**Academic Medical Center† # responses (%)**	**Hospital or Reference Laboratory‡ # responses (%)**	**Total # responses (%)**
Prerequisite	4 (8.3)	4 (1.3)	7 (10)	14 (9.3)
Separate required didactic course	10 (20.8)	11 (33.3)	5 (7.1)	25 (16.6)
Separate elective didactic course	3 (6.3)	1 (3)	6 (8.6)	10 (6.6)
Part of another didactic course	18 (37.5)	12 (36.4)	20 (28.6)	52 (34.4)
Separate required clinical rotation	1 (2.1)	4 (1.3)	13 (18.6)	17 (11.3)
Separate elective clinical rotation	2 (4.2)	2 (6.1)	2 (2.9)	7 (4.6)
Spread throughout curriculum	17 (35.4)	12 (36.4)	22 (31.4)	51 (33.8)
Not taught	3 (6.3)	0 (0)	8 (11.4)	12 (7.9)
	n = 48	n = 33	n = 70	n = 151

*Includes state and private non-medical universities and 4-year colleges, universities with medical schools, and a college of health sciences
†Includes state and private academic medical centers
‡Includes hospitals, reference laboratories, a consortium, and a community foundation
§Data represent raw numbers of responses and percent of responses in the appropriate category of institution type (in parentheses)

laboratory or in clinical rotation. Tables 4 and 5 show the number of programs teaching various molecular techniques and their clinical applications, as well as the format of instruction for each item.

Respondents were then asked how satisfied they were with the level of education provided to their students in the areas of human genetics and molecular diagnostics. Results from those questions are shown in Table 6. Those who were very satisfied or somewhat satisfied with the education they provide in molecular diagnostics indicated that their satisfaction was due mainly to availability of knowledgeable faculty in the area (n = 51; 66.2%), and/or ample time in the curriculum to teach the subject (n = 34; 44.2%). Only six of the respondents (7.8%) felt that availability of clinical sites that perform molecular methods contributed to their satisfaction, while nine respondents (11.7%) indicated that their satisfaction was due to ample funds to cover the cost of the methods.

Forty-nine of the respondents (73.1%) who were somewhat dissatisfied or very dissatisfied with the education they provide in molecular diagnostics indicated that their dissatisfaction was due to lack of time in the curriculum to teach the material, while 43 (64.2%) felt their dissatisfaction was due to lack of knowledgeable faculty in the area, and 37 (55.2%) replied that the prohibitive cost of the methods contributed to their dissatisfaction. Only three respondents who were dissatisfied (4.5%) felt that a lack of clinical sites performing these methods was a contributing factor to their dissatisfaction.

Respondents were also asked how important they felt it was for CLS programs to include information on human genetics and molecular diagnostics in their curriculum. The responses to those questions are shown in Table 7. When asked how important they felt it was for students to receive hands-on experience in molecular diagnostics in the student laboratory, or in clinical rotation, the majority felt that it was at least somewhat important (Table 8).

One hundred and five (69.5%) of the respondents expected the amount of education provided by their program in the area of genetics to increase in the next five years, and 124 respondents (82.1%) expected the amount of education they provide in molecular diagnostics to increase in the same time frame.

DISCUSSION

Our results indicate that over 92% of CLS programs in the U.S. teach the principles of genetics and molecular diagnostics in their curriculum, although the format of instruction varies widely. Only 14 of the 151 respondents indicated that genetics was a separate required course in their curriculum, and most of these programs were located at a non-medical university or college. However, the principles of genetics are taught in a variety of other ways in the remaining programs. Almost 40% of the programs, the majority of which are hospital based, include genetics as a prerequisite to their program, about 20% of the programs include genetics as part of another course, and slightly over 13% have genetics as a separate elective course. In one-third of the programs, regardless of institution type, the principles of genetics are spread throughout the curriculum. The courses in which they are taught vary, and include general biology, blood banking, hematology, immunology, microbiology, clinical chemistry, pathophysiology, and molecular techniques.

Table 4. Molecular diagnostic methods taught in CLS curricula

Method	Theory*	Hands-on any location†	Hands-on student lab	Hands-on clinical rotation	Observation	Not taught
Polymerase chain reaction	133 (88.1%)	64 (42.4%)	34 (22.5%)	32 (21.2%)	51 (33.8)%	10 (6.6%)
Southern blot	109 (72.2%)	27 (17.9%)	15 (9.9%)	12 (7.9%)	17 (11.3%)	27 (17.9%)
Fluorescent in situ hybridization	86 (60%)	14 (9.3%)	8 (5.3%)	10 (6.6%)	15 (9.9%)	44 (29.1%)
Ligase chain reaction	81 (53.6%)	21 (13.9%)	6 (4%)	17 (11.3%)	18 (11.9%)	49 (32.5%)
DNA sequencing	76 (50.3%)	10 (6.6%)	7 (4.6%)	7 (4.6%)	7 (4.6%)	54 (35.6%)
NASBA‡	64 (42.4%)	13 (8.6%)	6 (4%)	9 (6%)	6 (4%)	61 (40.4%)
Transcription-mediated amplification	61 (40.4%)	10 (6.6%)	8 (5.3%)	4 (2.6%)	10 (6.6%)	57 (37.7%)
Dot blot hybridization	60 (39.7%)	5 (3.3%)	2 (1.3%)	4 (2.6%)	7 (4.6%)	61 (40.4%)
Branched DNA amplification	50 (33.1%)	6 (4%)	3 (2%)	5 (3.3%)	4 (2.6%)	64 (42.4%)
DNA chip technology	44 (29.1%)	1 (0.7%)	1 (0.7%)	3 (2%)	3 (2%)	61 (40.4%)
Strand displacement amplification	32 (21.2%)	3 (2%)	1 (0.7%)	3 (2%)	2 (1.3%)	77 (51%)

* Data represent raw numbers of responses and percent of total responding programs (in parentheses)
† Hands-on experience in either the student laboratory or the clinical rotations
‡ NASBA = nucleic acid sequence based amplification

The principles of molecular diagnostics are also taught in a variety of ways. Slightly over 23% of the programs, most of which are in universities, colleges, or academic medical centers, have a separate didactic course in molecular diagnostics, while almost 16%, most of which are hospital-based programs, offer a clinical rotation in this specialty area. About one-third of the programs include molecular diagnostics as part of another didactic course, and another third spread the principles of molecular diagnostics throughout the curriculum. The courses specified by the respondents in which molecular diagnostics are taught vary widely, and include many of the same courses in which human genetics are taught, as well as biochemistry, instrumentation, virology, and parasitology. Only 9.3% of the programs include molecular diagnostics as a prerequisite.

Of the molecular methods taught, the polymerase chain reaction (PCR) was taught most frequently (88.1% of programs). This is not surprising, since PCR has a variety of applications in the clinical laboratory.[4] The next most frequently taught methods are Southern blot (72.2% of programs), fluorescent in situ hybridization (FISH) (60% of programs), ligase chain reaction (LCR) (53.6% of programs), and DNA sequencing (50.3% of programs). Other molecular methods were covered by less than half of the programs surveyed. The above numbers represent instruction of the theory underlying these methods, while hands-on experience with these procedures was less frequent. For PCR, 33.8% of programs provided observational experiences for their students, 22.5% provided hands-on experience in the student laboratory, and 21.5% provided hands-on experience in clinical rotation. These numbers were lower for other molecular procedures.

Detection of microorganisms was the most frequently cited clinical application of molecular diagnostics taught in CLS curricula, with over 80% of programs including theoretical instruction on this topic, 45.7% providing hands-on experience in clinical rotation, 21.2% providing hands-on experience in the student laboratory, and 36.4% providing observational experiences. These numbers reflect the rapid integration of molecular methods in diagnostic microbiology.[8] Other clinical applications, including HLA typing, detection of hematologic malignancies, detection of genetic disorders, viral load assays, and paternity testing, were covered in theory by the majority of programs, but were accompanied by observational or hands-on experiences by fewer programs. DNA fingerprinting was taught in less than half of the programs.

When CLS program directors/faculty were asked how satisfied they were with the level of education they provide, 62.9% indicated that they were either somewhat satisfied or very satisfied with the education they provide in human genetics, and 50.3% indicated satisfaction with the education they provide in molecular diagnostics. The most commonly cited reason for satisfaction was the availability of knowledgeable faculty in the area. Other reasons for satisfaction, cited by approximately 40% of the respondents, were ample time in the curriculum to provide the instruction and availability of clinical sites that perform molecular methods. Only 11.7% of the respondents indicated that their satisfaction was due to ample funds to cover the cost of the methods. One of the respondents stated that they had received a grant to purchase necessary equipment to perform molecular methods and to train faculty. Another respondent stated that commercial companies donate supplies to help provide educational experiences in his/her program.

Almost 32% of the respondents stated that they were somewhat dissatisfied or very dissatisfied with the education they provide in human genetics, while 44.4% indicated dissatisfaction with the education they provide in molecular diagnostics. The major reasons for dissatisfaction were lack of time in the curriculum to teach the material (73.1%), followed by lack of knowledgeable faculty in the area (64.2%), and prohibitive cost of molecular methods (55.2%). Fewer

Table 5. Clinical applications of molecular methods taught in CLS curricula

Clinical Application	Theory*	Hands-on any location†	Hands-on student lab	Hands-on clin rotation	Observation	Not taught
Detection of microorganisms	122 (80.8%)	77 (51%)	32 (21.2%)	69 (45.7%)	55 (36.4%)	10 (6.6%)
HLA typing	119 (78.8%)	30 (19.9%)	7 (4.6%)	27 (17.9%)	25 (16.6%)	15 (9.9%)
Hematologic malignancy detection	113 (74.8%)	50 (33.1%)	20 (13.2%)	43 (28.5%)	34 (22.5%)	21 (13.9%)
Genetic disorders detection	109 (72.2%)	28 (18.5%)	10 (6.6%)	22 (14.6%)	28 (18.5%)	23 (15.2%)
Viral load assays	105 (69.5%)	24 (15.9%)	2 (1.3%)	20 (13.2%)	29 (19.2%)	26 (17.2%)
Paternity testing	105 (69.5%)	18 (11.9%)	9 (6%)	12 (7.9%)	16 (10.6%)	25 (16.6%)
DNA fingerprinting	66 (43.7%)	16 (10.6%)	12 (7.9%)	3 (2%)	7 (4.6%)	46 (30.5%)

* Data represent raw numbers of responses and percent of total responding programs (in parentheses)
† Hands-on experience in either the student laboratory or the clinical rotations

than 5% of the dissatisfied respondents indicated that their dissatisfaction was due to lack of clinical sites that perform molecular methods. Our results suggest that there is a need to train additional faculty in the principles of genetics and molecular diagnostics. One respondent indicated that he/she would like to see more hands-on workshops and self-study programs in molecular diagnostics. Innovative curriculum changes may also be needed in order to incorporate these methods into some CLS curricula. In addition, program directors may wish to explore various sources of funding to help cover the cost of molecular methods.

Over 70% of the respondents felt that it is essential or very important to include human genetics in their curriculum, and 96% felt it was at least somewhat important. Moreover, nearly 70% expected the amount of genetics education provided by their program to increase over the next five years. While a few respondents felt that information on molecular diagnostics should be reserved for graduate level education or specialty training, approximately 83% of the respondents felt it was essential or very important to include molecular diagnostics in their undergraduate curriculum, with 98.7% feeling it was at least somewhat important.

Table 6. Satisfaction levels of CLS program directors/faculty with education provided

Level of Satisfaction	Human genetics # responses (%)*	Molecular diagnostics # responses (%)
Very satisfied	24 (15.9%)	23 (15.2%)
Somewhat satisfied	71 (47%)	53 (35.1%)
Somewhat dissatisfied	40 (26.5%)	53 (35.1%)
Very dissatisfied	8 (5.3%)	14 (9.3%)
No opinion	7 (4.6%)	6 (4%)

* Data represent raw numbers of responses and percent of total responding programs (in parentheses)

Table 7. Perceptions of CLS program directors/faculty on the importance of including information on human genetics and molecular diagnostics in the curriculum

Level of importance	Human genetics # responses (%)*	Molecular diagnostics # responses (%)
It is essential	58 (38.4%)	69 (45.7%)
It is very important	48 (31.8%)	56 (37.1%)
It is somewhat important	39 (25.8%)	24 (15.9%)
It is not important	4 (2.6%)	1 (0.7%)
No opinion	1 (0.7%)	1 (0.7%)

* Data represent raw numbers of responses and percent of total responding programs (in parentheses)

As one respondent stated, "I believe it will become increasingly important for genetics and molecular diagnostics curriculum to be increased due to advances in these fields." Over 82% of the respondents expect the amount of education provided by their program in molecular diagnostics to increase over the next five years.

Our data suggest that one area which needs to be expanded in CLS education is the provision of hands-on experiences with molecular diagnostic techniques. Over 70% of the respondents felt it was important to provide hands-on experiences with these methods in the student laboratory, and nearly 90% of the respondents felt it was important to provide these experiences in clinical rotation. While the majority of programs provide education on the theory of a variety of molecular methods, the number of programs providing hands-on experiences with these methods is lower. Inclusion of hands-on experience with these technologies in CLS education will likely increase in the future as commercial development of the methods makes them simpler to perform and more cost-effective. In the meantime, however, programs may wish to explore ways of increasing hands-on experiences with molecular techniques. As one respondent stated, "As molecular diagnostics applications become mainstream in the clinical laboratory, students who enter the workforce without formal training in this area will be under-qualified, especially when applying for a position where these skills are desirable."

Our results suggest another area which needs expansion in CLS curricula is instruction of the ethics of genetic testing. A surprising finding of our study was that over 55% of CLS programs do not provide instruction on this topic, and only 10.2% teach it in a separate required course. Genetic testing is not only important in clinical diagnosis, but also has profound social and economic implications of which clinical laboratory scientists should be aware.[15] The U.S. Department of Energy and National Institutes of Health recognized the importance of these ethical implications when they decided to devote 3% to 5% of their annual Human Genome Project Budgets to the study of ethical, legal,

and social issues such as privacy of genetic information and implementation of standards and quality control measures in genetic testing procedures.[16] Since clinical laboratories are directly involved with these issues, this area should not be ignored.

As advances in genetics continue to be made, it will be important for CLS students to be aware of those developments and how they affect laboratory testing. As one CLS educator stated, "I feel that molecular biology will continue to become an integral part of laboratory testing and the foundation for growth and development of the profession." "It is the medicine of the future," stated another respondent. "We must move quickly to keep up!"

CONCLUSIONS

Major advances are being made in the science of genetics, resulting in increased use of molecular technology in the clinical laboratory. The majority of CLS programs teach genetics and molecular diagnostics in their curriculum, and the format of instruction varies widely, as would be expected in order to meet the needs of different curricula. Polymerase chain reaction was the most commonly taught molecular method, and detection of microorganisms, the most commonly taught clinical application of molecular diagnostics. While many programs provide didactic instruction of the theory underlying molecular methods, fewer provide hands-on experiences for their students. The majority of CLS program directors and faculty surveyed felt it was important to include information on human genetics, molecular diagnostics, and related hands-on experiences in their curriculum. Although over half of the respondents indicated that they were at least somewhat satisfied with the instruction they currently provide in human genetics and molecular diagnostics, over 80% expect the amount of education in this area to increase in their curriculum over the next five years. Our study suggests that increasing the amount of instruction in this area will require additional faculty training, curriculum changes to allow for inclusion of the material, and procurement of funding to cover the cost of methods. Our findings also indicate that the instruction of the ethics of genetic testing requires more attention in CLS curricula.

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Table 8. Perceptions of CLS program directors/faculty on the importance of including hands-on experience in molecular diagnostics in the curriculum

Level of importance	In the student lab # responses (%)*	In clinical rotation # responses (%)
It is essential	20 (13.2%)	24 (15.9%)
It is very important	34 (22.5%)	52 (34.4%)
It is somewhat important	52 (34.4%)	59 (39.1%)
It is not important	29 (19.2%)	8 (5.3%)
No opinion	10 (6.6%)	6 (4%)

* Data represent raw numbers of responses and percent of total responding programs (in parentheses)

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