

2018

# Technical Report

Assessment of Fundamental Knowledge

Approved September 2019



# Content

---

<b>Introduction</b> .....	<b>4</b>
<b>Part A – NDEB Certification</b> .....	<b>5</b>
<i>Purpose of the NDEB examinations/assessments</i> .....	5
<i>NDEB Certification</i> .....	5
<i>The Certification Process - Current Examinations for Graduates of Accredited Programs</i> .....	7
Written Examination .....	7
Objective Structured Clinical Examination (OSCE) .....	7
<i>Equivalency Process - Current Assessments for Graduates of Non-Accredited Programs</i> .....	8
Assessment of Fundamental Knowledge (AFK) .....	8
Assessment of Clinical Skills (ACS) .....	9
Assessment of Clinical Judgement (ACJ) .....	9
<b>Part B – Development</b> .....	<b>11</b>
<i>Test Construction Process and Validity Evidence</i> .....	11
<i>Item Review, Verification and Translation</i> .....	11
<i>Production</i> .....	12
<i>Staff Support</i> .....	13
Chief Examiner/ Assistant Chief Examiner .....	13
Executive Director and Registrar .....	13
NDEB staff .....	13
<i>Test Validity and Reliability</i> .....	13
Validity .....	13
Reliability .....	14
Documentation .....	14
NDEB By-laws .....	14
Competencies for a Beginning Dental Practitioner in Canada (Appendix C) .....	15
Assessment of Fundamental Knowledge Protocol .....	15
Written Examiner's Written and AFK.....	15
Instructions and Regulations for Test Administrators .....	15
<b>Part C – Administration</b> .....	<b>17</b>
<i>Locations and Procedures</i> .....	17
<i>Test Administrators</i> .....	17

<i>Administration Procedures</i> .....	18
<i>Reporting</i> .....	18
<i>Testing Accommodations</i> .....	18
<b>Part D – Scoring</b> .....	<b>19</b>
<i>Standards for Pass/Fail</i> .....	19
Standard Setting .....	19
Passing Standard .....	19
<i>Scoring</i> .....	19
Review .....	20
Excluding a Question from the Test Equating Process .....	21
Equating and Re-scaling .....	21
Pilot Testing .....	21
Reporting .....	21
Appeals.....	22
<b>Part E - Security</b> .....	<b>23</b>
<i>Credential Verification</i> .....	23
<i>Examinee Information</i> .....	23
<i>Administration</i> .....	23
<i>On-site Security</i> .....	23
<i>Exam Security</i> .....	24
<i>Security Analysis</i> .....	24
<i>Copyright</i> .....	24
<b>Part F - Outcome Summaries</b> .....	<b>25</b>
<b>Part G - Glossary</b> .....	<b>27</b>
<b>Part H – Appendices</b> .....	<b>28</b>
Abstracts and Minor Publications .....	30

# Introduction

The purpose of the NDEB, as stated in the Act, is to establish qualifying conditions for a single national standard certificate of qualification for general practitioner dentists. Organizations who administer high-stakes examinations/assessments must be concerned with validity, reliability and fairness because these measures are required in making pass/fail decisions affecting candidates for licensure or certification. Fairness to examinees and protection of the public are the foremost concerns for the NDEB and the NDEB has an obligation to provide the highest quality examination/assessment program possible.

This Technical Report is a summary of the processes followed by the NDEB to develop, administer, and score the Assessment of Fundamental Knowledge (AFK) administered in 2018. It provides a summary of the information needed to support the validity and reliability of the assessment. For additional detailed information, key references are included in Appendix A. Any background information is included to assist in understanding the development of the NDEB's examination/assessment processes.

This report serves as a reference for the members of the NDEB Examinations Committee, NDEB Board, and Provincial Dental Regulatory Authorities (DRAs). The processes described in this report may differ from those used in other years.

# Part A – NDEB Certification

## Purpose of the NDEB examinations/assessments

---

The purpose of the NDEB is, as per the Act of Parliament, to establish qualifying conditions for a single national certificate of qualification for general practitioner dentists. This purpose is restated in the NDEB's mission found on the corporate website.

The NDEB is responsible for developing, administering and scoring the examinations and assessments. To do this, the NDEB appoints an Examinations Committee who, along with the Chief Examiners and staff, oversee all aspects of the examination/assessment processes. The responsibilities of the Examinations Committee are outlined in the NDEB By-laws.

## NDEB Certification

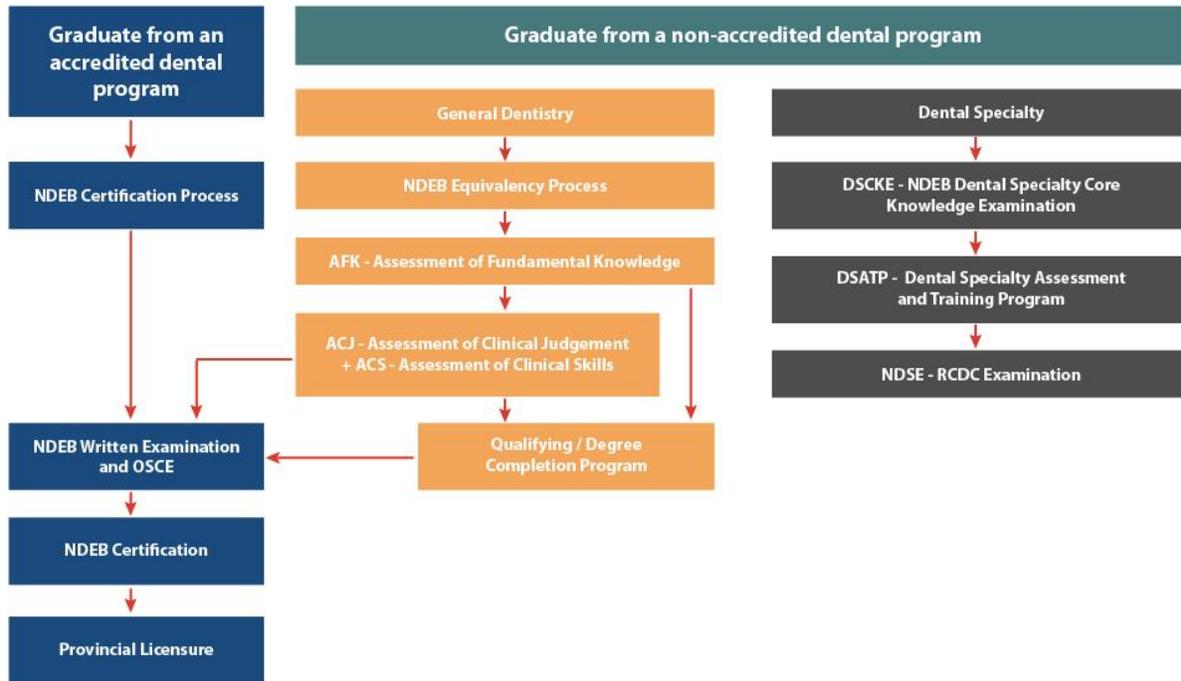
---

This section of the Technical Report is intended to provide an overview of all the examinations and assessments required to obtain an NDEB certificate.

Successful completion of the NDEB's Assessment of Fundamental Knowledge (AFK) is one of the conditions for receiving a licence to practice dentistry in Canada. A candidate, as defined under NDEB's By-laws, is granted a certificate upon presentation of the following documentation:

- Proper application to the Board which includes, if applicable, providing evidence to the satisfaction of the Board that the Candidate is considered in good standing with all Dental Licensing/Regulatory Authorities in all jurisdictions in which the Candidate has been or is currently registered or licensed;
- Evidence, to the satisfaction of the Board, of graduation from an Accredited Program or successful completion of the Board Equivalency Process
- Evidence, to the satisfaction of the Board, that the person has passed the Written Examination described in By-law 13.00 and the OSCE described in By-law 14.00.

The following diagram illustrates the pathways to obtaining NDEB certification and licensure as a dentist in Canada.



# The Certification Process - Current Examinations for Graduates of Accredited Programs<sup>1</sup>

---

## Written Examination

The purpose of the Written Examination is to assess the competence of a beginning dental practitioners in Canada through multiple-choice questions. The content categories that form the blueprint for the Written Examination are based on the 47 competencies for a beginning dental practitioner in Canada (Appendix C). The Written Examination assesses the following constructs: basic science knowledge and applied clinical science knowledge and judgement, including diagnosis, treatment planning, prognosis, treatment methods, and clinical decision-making.

The Written Examination consists of two books, each with 150 single-answer multiple-choice questions. Each book is given in a 2.5 hour (150-minute) examination session. The sessions are held in the morning and afternoon of one day at established examination centres. Generally, candidates complete the Written Examination with time remaining. Consequently, there is no evidence that the Written Examination is a speeded test.

Resources for the Written Examination can be found on the NDEB website and include:

- the Examination format
- the Examination Protocol including the blueprint, schedule, and exam regulations
- information on scoring and appeals
- a list of reference texts commonly used in Canadian dental programs

Approximately 3,500 questions, including many used on past examinations are also available on the NDEB website ([www.ndeb-bned.ca](http://www.ndeb-bned.ca)). In 2018, the Examinations Committee voted to no longer provide new released questions annually.

## Objective Structured Clinical Examination (OSCE)

The purpose of the OSCE is to assess the competence of a beginning dental practitioner in Canada through multiple-choice questions. The content categories that form the blueprint for the OSCE are based on the 47 competencies for a beginning dental practitioner in Canada (Appendix C). The OSCE is designed to test aspects of clinical judgement, including diagnosis, treatment planning, prognosis, treatment methods, and clinical decision-making.

The OSCE is a station-type examination administered in two half-day sessions the day after the Written Examination. OSCE stations generally have two questions and require the candidate to

---

<sup>1</sup> Accredited programs are programs recognized by the Commission on Dental Accreditation of Canada and include the 10 Canadian dental programs and programs in the United States, Australia, Ireland, and New Zealand that are recognized through reciprocity agreements with accreditation agencies in those countries.

review the information supplied (e.g. patient history, photographs, radiographic images, casts, models) and answer multiple response type questions. Each question has up to 15 answer options and one or more correct answer(s). Some stations may require the candidate to review the information supplied and write an acceptable prescription for a medication commonly prescribed by general dentists in Canada. Candidates have five minutes at each station to answer the questions. After five minutes, the candidates move to the next station.

Resources for the OSCE can be found on the NDEB website and include:

- the Examination format
- the Examination Protocol including the blueprint, schedule, and exam regulations
- information on scoring and appeals
- a list of reference texts commonly used in Canadian dental programs
- the OSCE frameworks

## Equivalency Process - Current Assessments for Graduates of Non-Accredited Programs<sup>2</sup>

---

Graduates of non-accredited dental programs are required to complete the NDEB Equivalency Process or a two-year Degree Completion Program prior to being eligible to participate in the Certification Process. The Equivalency Process comprises three assessments. Successful completion of the three assessments demonstrates that an individual is equivalent to a graduate of an accredited dental program.

Prior to taking the assessments, applicants are encouraged to take the on-line self-assessment available on the NDEB website. The self-assessment is 100 single-answer multiple-choice questions. Guidance is provided to individuals based on their self-assessment results. Additionally, applicants must provide a series of documents to the NDEB demonstrating their successful completion of a dental program. The NDEB performs an in-depth credential verification for each applicant prior to approving the applicant as a participant in the NDEB Equivalency Process.

### Assessment of Fundamental Knowledge (AFK)

The purpose of the AFK is to test biomedical science and applied clinical science knowledge. The AFK serves a dual purpose; it is both an admission requirement for Canadian Degree Completion Programs and one of the three assessments in the Equivalency Process. A passing

---

<sup>2</sup> Non-accredited dental programs are international dental programs that award a BDS/DDS/DMD degree and are not recognized by the Commission on Dental Accreditation of Canada through reciprocity agreements.

grade is required before a participant can continue to the other assessments in the Equivalency Process.

The AFK consists of two books, each with 150 multiple-choice questions. Each book is given in a three-hour session. The sessions are held in the morning and afternoon of a single day.

Resources for the AFK are found on the NDEB website and include:

- the Assessment format
- the Assessment Protocol including the blueprint, schedule, and exam regulations
- information on scoring and appeals
- a list of reference texts commonly used in Canadian dental programs
- NDEB released questions

### Assessment of Clinical Skills (ACS)

The purpose of the ACS is to assess clinical competence. During the two-day ACS, participants perform 12 dental procedures on simulated patients (manikins) in a clinical setting. Procedures must be performed as if working with real patients. Participants are required to use their judgment and follow accepted clinical care guidelines/standards.

Resources for the ACS are found on the NDEB website and include:

- the Assessment format
- the Assessment Protocol including the blueprint, schedule, and exam regulations
- information on scoring and appeals
- handpiece connection information
- frequently asked questions specific to the ACS
- an orientation video

### Assessment of Clinical Judgement (ACJ)

The purpose of the ACJ is to assess the participant's ability to formulate a diagnosis and make clinical decisions, as well as evaluate the participant's knowledge in oral radiology and ability to make a radiographic interpretation and diagnosis.

The ACJ consists of two books given in a single day. Each book contains single and multi-answer multiple choice questions. Questions may include patient histories, dental charts, radiographs and photographs of patients of all ages.

Resources for the ACJ can be found on the NDEB website and include:

- the Assessment format
- the Assessment Protocol including the blueprint, schedule, and exam regulations

- information on scoring and appeals
- a list of reference texts commonly used in Canadian dental programs
- ACJ frameworks

# Part B – Development

## Test Construction Process and Validity Evidence

---

The assessment development process follows the NDEB's development plan that is included in the Examiner's Manual and contains high-level information on the processes used to support the creation of defensible assessment content. Specific elements of that plan are detailed below.

Examiners who are content experts at Canadian Faculties of Dentistry are sent copies of the Examiner's Manual and other preparatory material for review prior to a question development workshop. During the workshop, Examiners are trained in question construction, then construct, and criticize potential new items in their discipline. Examiners are directed to write items that assess higher cognitive processes such as application and problem-solving. They are further instructed to avoid recall questions whenever possible. Examiners are also asked to avoid trivial questions. New items are reviewed and revised by a group of subject matter experts prior to being eligible for use on an assessment. In addition, all new items are reviewed and, if required, edited by the Chief Examiner and senior staff.

Examiners who are practicing general dentists recommended by Provincial Dental Regulatory Authorities select the items for every assessment in accordance with a blueprint. The results of past item analyses are used as a guide in the item selection process. Items are selected based on several criteria including consistency with the blueprint, taxonomy of cognitive levels, the need for anchor items, and statistical properties of the items.

## Item Review, Verification and Translation

---

After test items have been selected and a draft assessment form built by staff, the items are reviewed and translated using a multi-stage process. This first draft is reviewed and validated by groups of trained Examiners who verify the technical accuracy of the items. They may also consult with additional subject matter experts when required. This includes identifying item enemies and verifying the representativeness of the content domain and the significance of the content being tested (NDEB, 2010). During this review, questions are subjected to intensive review to verify the wording and the correct answer. Should a question need to be reworded, it is either revised for the assessment or replaced. The review focuses on three things. First, the technical content of the question is verified to ensure that it is consistent with acceptable practices and supported by the literature. Second, a sensitivity review is done to ensure that the question content is not offensive and does not discriminate against examinee subgroups. Third, a language review is done to ensure that the content does not exceed the language level needed to practice dentistry safely and effectively in Canada.

All assessments are available in both official languages. This includes all forms and preparation materials. After the first review, test items are translated by dentists familiar with the vocabulary used on the assessments. The questions and the translations are then reviewed by a group which includes bilingual subject matter experts who are approved by the Ordre des dentistes du Québec (ODQ). In addition, the NDEB has developed a detailed glossary of translated terms. This glossary is updated annually. This process ensures that examinees writing in either official language have equal opportunity to demonstrate their competence. The translation process ensures consistency between English and French versions of the questions.

Following this process, NDEB staff enter required revisions and build a second draft assessment. During a second review, trained Examiners, including bilingual Examiners approved by the ODQ, verify that all the changes have been made to the questions and that the French translation is accurate. NDEB staff enter any additional changes and produce revised copies of items so that all items are finalized during the review.

Following the second review, NDEB staff produce the assessment in the final format that will be used. During a final review, trained Examiners including bilingual Examiners approved by the ODQ, verify that all questions are correct in both languages and that the formatting of the document is correct. NDEB staff enter any additional changes and produce revised copies so that the assessment can be approved at the end of the review session.

## Production

---

Following the final review, four versions of the assessment are produced using an automated process that results in a random sequence of questions in each of the four versions. Each book contains identical items that are presented in a different order to limit potential cheating. The Chief Examiner, and a bilingual Examiner approved by the ODQ, review each version to ensure that the format and numbering of questions and distractors in each version is correct. The Chief Examiner and a bilingual Examiner approve the final versions by initialing each page of each version.

Prior to printing, the appropriate cover page and instruction pages are added to the documents. All printing is done on site. Documents that have been finalized are saved as .PDF files in a specific directory. The originals of the finalized documents, which include examiner initials, are copied on a specific on-site printer. After printing the batches of books, a random check of documents is performed by two staff members to verify that no errors have been made during the printing process. After this verification, a book seal is placed on every assessment booklet.

Computer-generated labels indicating names, NDEB identification numbers, and assigned seat numbers are affixed to the front of each book.

## Staff Support

---

The following is a summary of the staff roles involved in the test construction and production process.

### Chief Examiner/ Assistant Chief Examiner

The Chief Examiner is responsible for the development of the examination or assessment including coordination of question development, question selection, monitoring the item bank and results within the guidelines and parameters established by the NDEB as stipulated in the protocol.

### Executive Director and Registrar

The Executive Director and Registrar is responsible for staff supervision and the implementation of all policies approved by the Board to ensure the process operates efficiently and effectively.

### NDEB staff

The Examinations and Assessments Managers, in consultation with Executive Director, prepare and administer the examinations/assessments and manage the operational delivery, including arrangements with staff, instructions for Test Administrators, correspondence with Examiners, production and translation of the examinations/assessments, and the maintenance of the question bank. The Managers are supported by coordinators and assistants.

The Manager-Credential Verification and Program Services (CVPS) makes arrangements with hosting institutions and with specific individuals who are trained to administer the examinations/assessments at the test centres. These arrangements are made annually.

All staff is responsible for carrying out directives from the Examinations Committee as approved by the Board.

## Test Validity and Reliability

---

### Validity

The primary purpose of establishing content validity of credentialing examinations/assessments is to show that the process and results underlying their development are a valid reflection of that part of professional competence that the examinations/assessment purport to assess. That is, construct validity is about the relationships between the construct of professional competence and the examination instruments. The assessment content categories reflect both educational programs and the requirements of practice, and general practitioners select the content for the

examinations and assessments. In addition, each form is built to match the blueprint approved annually by the Board and contained in the protocols.

In addition to the logical basis for asserting construct validity, the NDEB has carried out several studies, both internal and published, that support validity claims (Appendix B).

## Reliability

Test reliability refers to the degree to which assessment scores for a group of examinees are consistent over repeated administration of the test and are therefore considered to be dependable and consistent for an individual examinee. Reliability is estimated using a reliability coefficient, which is a unit-free indicator that reflects the degree to which scores are free of random measurement error. Based on the data provided in the results section of this Technical Report, NDEB examinations/assessments display evidence of continued strong reliability.

## Documentation

Evidence of test validity is collected through multiple means, one of which is the documentation of development and administration procedures. The NDEB makes these documents publicly available. Only confidential material or material that could jeopardize the integrity of the examination/assessment is retained internally. These documents are also updated frequently (generally on an annual basis) to reflect the most recent information. References for these documents can be found in Appendix A.

To support the various sources of validity evidence, the NDEB produces the following documents:

### NDEB By-laws

The NDEB By-laws contain sections related to the NDEB's examination and assessment programs. Examples of relevant information include:

- certification eligibility
- the Board's certification and equivalency processes
- conduct and appeals policies
- Terms of Reference for various examination-related committees
- test accommodations
- misconduct

The By-laws are available on the NDEB website ([www.ndeb-bned.ca](http://www.ndeb-bned.ca)).

## Competencies for a Beginning Dental Practitioner in Canada (Appendix C)

This document outlines the body of knowledge that is assessed by the NDEB's examinations and assessments. A clearly outlined body of knowledge is key to establishing the content validity of examinations and assessments by providing a link between practice and the examination. This document is available in English and French on the NDEB website ([www.ndeb-bned.ca](http://www.ndeb-bned.ca)).

### Assessment of Fundamental Knowledge Protocol

Updated annually, the Assessment of Fundamental Knowledge (AFK) Protocol contains the information the participant needs to prepare to write the AFK. In addition to providing logistical information, this document is meant to reduce construct irrelevant variance related to testing. The document details the purpose and intended use of the assessment. Participants acquire advance information on assessment content, instructions and other procedures. At a high level, the AFK Protocol contains the following information:

- Content and format
- Schedule
- Validation of registration
- Instructions
- Sample questions
- Reference texts
- Examination regulations
- Passing standard
- Results
- Appeals and rescores
- Repeats

This document is available in English and French on the NDEB website ([www.ndeb-bned.ca](http://www.ndeb-bned.ca)) and is posted in every participant's online profile once the participant has registered for the AFK.

### Written Examiner's Written and AFK

Reviewed and updated annually, the Examiner's Manual for the Written Examination and the AFK is an internal document provided to examiners and outlines the question writing philosophy and guidelines for question format and style.

### Instructions and Regulations for Test Administrators

The purpose of this document is to describe, in detail, the procedures to follow before, during and after the administration of the AFK. This document ensures that participants have a similar experience when completing the assessment, regardless of where they write. The document also enhances security by providing a detailed quality assurance protocol. Participants are also

reminded on numerous occasions that having someone else take the assessment for them, disclosure of confidential examination material, or engagement in any other form of cheating is unacceptable and that such behavior may result in sanctions. This document contains:

- instructions prior to the assessment
- instructions for assessment day (which includes verbal instructions)
- procedures to follow during the administration of the assessment
- procedures to follow at the end of the assessment
- instructions following the assessment

# Part C – Administration

## Locations and Procedures

---

The AFK and ACJ are administered two times a year as established by Board policy. Except for approved testing accommodations, the assessment is administered on the same day at all centres. All assessments are written in a distraction-free and comfortable environment where participants are optimally able to demonstrate their competence.

The assessments are held at centres across the country, as well as in various centres outside of Canada provided a minimum number of registrations are received.

The NDEB tries to accommodate location preferences but may have to offer alternative locations due to space limitation at some assessment sites.

## Test Administrators

---

Each examination centre has one or more designated Test Administrator(s) appointed by the NDEB.

The Test Administrators' primary responsibilities include securing appropriate space at the examination centre, receiving the exam material and ensuring the security of examination materials before, during, and after the examination, appointing invigilators to assist in monitoring the examination, and ensuring the examinations are administered according to NDEB procedures.

When a new centre is established, or new Test Administrator appointed, NDEB staff visit the centre and meet with the individual who will be the designated Test Administrator to review their roles and responsibilities. All Test Administrators are required to adhere to the NDEB's instructions and regulations. These documents clearly outline the responsibility of the Test Administrator and examination day procedures allowing for standardized administration across all centres. Test Administrators are encouraged to communicate with NDEB staff with questions or concerns regarding the administration or their responsibilities.

Prior to the administration, NDEB staff communicates with the Test Administrators to review any new NDEB policies or procedures in relation to the administration of the assessment.

## Administration Procedures

---

The NDEB has developed standard administration procedures for each of the assessments. The documentation includes uniform directions for Test Administrators, invigilators and participants, the assessment schedule, and the security protocols that should be undertaken during the assessment.

Standard check-in procedures are in place for all participants at each examination centre. A set of standardized instructions is read to all participants in their language of choice prior to the commencement of the assessment. Participants are reminded of the rules of conduct and provided the opportunity to remove prohibited items from the examination room before the assessment starts. No variation from the assessment administration is allowed unless a test accommodation has been granted by the NDEB.

## Reporting

---

The Test Administrator is responsible for completing a report following the administration of the assessment. The report should include any irregularities that occurred that may have disrupted the administration of the assessment. The report will also include details regarding any misconduct that occurred prior, during, or after the assessment.

## Testing Accommodations

---

The purpose of testing accommodations is to remove construct-irrelevant barriers that would interfere with a participant's ability to demonstrate their competence. Pursuant to the NDEB By-laws and policies, test forms or administration conditions may be modified in order to accommodate participants requiring testing accommodations. Accommodations may be provided for a disability, medical condition or religious reason. Participants must submit a written request prior to the registration deadline and are required to provide supporting documentation. Accommodations may include an alternate writing date, separate examination room, large print booklets, special coloured paper or longer assessment times. The number of requests for these types of accommodations is small, and as such, the NDEB is unable to establish the validity of these modified examination forms for this specific population. Testing accommodations represent the only allowable variations in administration conditions, and these variations are documented in detail. In recent years, the number of assessment accommodations has increased, and most accommodations involve no modifications to assessment materials.

# Part D – Scoring

## Standards for Pass/Fail

---

It is the NDEB's statutory obligation to certify only those who are qualified to enter the dental profession in Canada. In the interest of public health, the NDEB establishes standards necessary to ensure competency.

### Standard Setting

A standard setting meeting was held in 2016 to review performance level descriptors and cut scores for the AFK. Twenty-three subject matter experts were involved in the standard setting procedure. The Yes/No modification of Angoff's method (Impara and Plake, 1997) was used. The cut score was recommended by the Examination Committee and approved by the Board. This standard, reflecting the minimally competent participant, was applied to the February and August 2018 AFK.

### Passing Standard

Based on the recommendation of an expert committee, in January 2015, the NDEB introduced a standardized passing score of 75 for all examinations and assessments. This change brought the NDEB in line with international standards for reporting passing scores. The new passing score has no impact on the difficulty or reliability of the NDEB's examinations or assessments.

## Scoring

---

Each of the three hundred multiple-choice items in the ACK is scored as correct (1) or incorrect (0). All answer sheets are scored centrally at the NDEB offices using a scanning program. A number of quality assurance steps are taken to ensure that the scoring is done accurately. For example, high and low scores are manually verified to ensure accuracy. In addition, a sample of answer sheets is also selected for manual verification. Questions that are flagged as not answered by a participant are reviewed manually if there are more than two occurrences per book. All these processes are contained in a detailed procedures manual.

After verification and scanning of answer score sheets and reviewing any procedural abnormalities, an initial statistical analysis is performed. Reports generated from the initial statistical analysis are provided to the Chief Examiner and other attendees at a statistics review meeting. During this meeting, the following reports are reviewed:

- Candidate Performance by Exam Summary
- Question Performance by Exam Summary
- Exam Performance Detail
- Question Performance – Top/Low/Biserial Distribution (Condensed) (required for examinations/assessments which include multi-answer test items)

## Review

During the review, the correctness of all answer keys is verified and non-performing or compromised items are eliminated from the examination/assessment. A final statistical analysis is then performed and results calculated with those items removed.

Using information provided in the Question Performance by Exam Summary report, questions identified by a colour prompt are printed for in-depth review.

- Colour highlights within the report are triggered by the following criteria:
  - difficulty: Less than .3
  - biserial: Less than .05 (unless the Difficulty is greater than .95)
  - language fairness assessment
- Chief Examiners review the identified questions to:
  - confirm the accuracy of the answer key to identify potential ambiguities, including the possibility of multiple correct answers
  - identify potential “trick” items or unclear wording
  - identify a possible English – French translation issue
  - establish consistency between images and/or models
  - identify item drift as evidenced by an unusual increase in percent correct. If significant drift in a test item is noted, staff will conduct an internet search to ascertain whether the item has been released to the web in any form, or whether there is evidence of item reconstruction.
- Workshop attendees use their expert judgement to determine if:
  - a question will be voided (i.e. will no longer be used on examinations/assessments) if it is unclear, ambiguous, tricky or if it presents a translation issue
  - a revision to the answer key is required

## Excluding a Question from the Test Equating Process

A question will be excluded from the test-equating process if:

- there is evidence of test reconstruction, coupled with significant drift
- it is released between the date it was used in the reference examination/assessment and the date of the current examination/assessment

The reason for excluding an item from the test equating process will be documented in writing and stored in the examination/assessment file.

## Equating and Re-scaling

In addition to the passing score, examinee scores are also re-scaled using the procedure described in Maguire (2004) which is provided in Appendix D. Several data quality assurance steps are taken to ensure that the equating and re-scaling is done in a fair manner while respecting the statistical assumptions that underlie these mathematical procedures.

## Pilot Testing

As part of an additional quality control step, the NDEB embeds new questions into examinations/assessments as pilot test items. These items are new and have not been properly evaluated by the participant population. Pilot items that perform well from a statistical perspective count toward the participant's score, while those items that do not perform well are not counted.

In addition, item statistics are used to improve items for future use. Due to the NDEB's pilot testing methodology, items are exposed to a live participant population, which includes all relevant subgroups.

## Reporting

The results of the assessment are posted on a secure website within six weeks of the administration date. Participants access their results by logging in to their online profile. When results are posted, participants receive an email notification. If there is an anticipated delay in the release of results, participants are notified by email. Participants are informed if they have passed or failed the assessment. Results are reported as Pass/Fail. Participants who fail will also receive their test equated, re-scaled score on the failed assessment and the pass mark for the assessment. This allows participants to determine how close they were to passing. They are also provided with instructions on how to appeal their score.

## Appeals

The appeal mechanism for written-style examinations is a manual rescore. The purpose of a manual rescore is to confirm that no errors were made during the electronic scoring process. Participants who receive a failing grade can, within three months of the release of results, request a manual rescore. This is done through the participant's online profile. Manual rescoring is completed by NDEB staff members who compare the answers on the answer score sheet with the master score sheet. The Manager then verifies the mark. The mark produced by the manual rescore will be the final mark.

A fee is charged for manual rescoring. Fees are posted on the NDEB website.

### Other Appeals

Within a specified timeframe, participants may appeal to the Board or Executive Committee in writing, with an accompanying filing fee, for the following:

- a decision of the Examinations Committee regarding misconduct
- compassionate grounds

# Part E - Security

The NDEB undertakes several measures to ensure the security of its processes.

## Credential Verification

---

Credential verification of applicants is performed to ensure that applicants to all processes are eligible for participation. While the credential verification process differs depending on the process applied for, each process includes source verification with the university to confirm the applicant's graduation.

## Examinee Information

---

The NDEB uses a third-party web tool called BrightTrac for its online portal. BrightTrac accounts are password-protected, and the data is stored on Amazon servers.

In-house, the NDEB has participant information in MS Access databases, and various documents are stored on NDEB servers. This information is only accessible to staff with valid network accounts and drive permissions.

## Administration

---

The NDEB is in regular communication with on-site staff to keep them apprised of changes to administration processes and emphasize the importance of security measures such as standardized check-in procedures and restricted items. Test Administrators and invigilators are trained to identify, manage, and report misconduct.

## On-site Security

---

The Test Administrator stores all examination material in a secure, locked area. After the completion of the assessments, all materials are returned to the NDEB office by courier. NDEB staff verifies the return of all materials including individually labeled books, identification cards, and, answer score sheets. These security measures help maintain the integrity of the assessments by limiting exposure to assessment items before and after the administration of the assessments.

## Exam Security

---

The NDEB's examination metadata and statistics are stored in a SQL Server database on a separate secure server that is only accessible via the database's user interface. Individuals who do not have permissions to access the NDEB network are restricted.

The questions themselves are also restricted to only those users who need to access them via their network group policy rules.

The NDEB has a policy that questions in progress are never sent via email. Rather, they are uploaded to either our password-protected SharePoint or Basecamp sites for sharing and collaboration.

All NDEB portable devices are encrypted using BitLocker so no one can access anything without the proper credentials.

## Security Analysis

---

During exam processing, a test analysis program is applied to the item results of all participants. Those with extreme values are flagged for attention. In rare cases, participants are informed that results of the assessment will be delayed pending a review.

## Copyright

---

NDEB staff regularly monitors online forums for exam content that is shared and follows-up with legal action as needed.

# Part F - Outcome Summaries

This report provides summary information on the structure of the AFK, as well as statistical summaries at the item and test levels.

Table of Assessment Items By Category

Root Category	AFKFeb2018	AFKAug2018
<b>Dental</b>		
<b>Anatomy/Occlusion/Operative</b>	27	30
<b>Endodontics/Dental Emergencies</b>	32	19
<b>Foundation Science</b>	46	63
<b>Oral Medicine/Pathology/Oral Facial Pain</b>	24	13
<b>Oral Surgery/Trauma</b>	24	12
<b>Orthodontics/Pediatrics</b>	21	28
<b>Periodontics</b>	16	16
<b>Pharmacology/Therapeutics/Local Anesthesia</b>	25	47
<b>Prosthodontics/Implants</b>	13	21
<b>Miscellaneous**</b>	39	16
<b>Total Scored</b>	267	265
<b>Rejected</b>	33	35
<b>Total</b>	300	300

\*\*Miscellaneous: "Abuse and Neglect", "Anxious Patient", "Ethics and Jurisprudence", "Geriatrics", "Infection Control", "Informed Consent", "Occupational Hazards", "Prevention", "Radiology", "Records", "Relationship general/oral health", "Scientific Literature", "Special Needs"

	Attempt	AFKFeb2018	AFKAug2018
<b>Number of Participants</b>	1	445	597
	2	177	225
	3	57	84
	<b>Total</b>	<b>679</b>	<b>906</b>
<b>Pass (#)</b>	1	197	282
	2	85	125
	3	32	54
	<b>Total</b>	<b>314</b>	<b>461</b>
<b>Pass (%)</b>	1	44.3	47.2
	2	48.0	55.6
	3	56.1	64.3
	<b>Overall</b>	<b>46.2</b>	<b>50.9</b>
<b>Passing Raw Score (%)</b>		<b>61.2</b>	<b>76.3</b>
<b>Mean Raw Score (%)</b>	1	58.6	73.1
	2	59.3	75.7
	3	61.6	77.9
	<b>Overall</b>	<b>59.0</b>	<b>74.2</b>
<b>Range Rescaled</b>	1	27 - 100	21 - 91
	2	41 - 95	30 - 91
	3	53 - 97	47 - 88
	<b>Overall</b>	<b>27 - 100</b>	<b>21 - 91</b>
<b>Mean Rescaled Score</b>	1	71.5	71.1
	2	72.3	73.9
	3	75.0	76.1
	<b>Overall</b>	<b>72.0</b>	<b>72.3</b>
<b>KR 20/ Cronbach's Alpha</b>		<b>0.94</b>	<b>0.96</b>

Note: Numbers are based on all participants who sat the assessment. This includes participants who have later been withdrawn as a result of a compassionate appeal.

# Part G - Glossary

AADE	American Association of Dental Examinations
ACFD	Association of Canadian Faculties of Dentistry
ADA	American Dental Association
ADAC	American Dental Association Commission on Dental Accreditation
ADC	Australian Dental Council
AERA	American Educational Research Association
APA	American Psychological Association
CDA	Canadian Dental Association
CDAC	Commission on Dental Accreditation of Canada
CDRAF	Canadian Dental Regulatory Authorities Federation
DRA	Provincial Dental Regulatory Authorities
NCME	National Council on Measurement in Education
NDEB	National Dental Examining Board of Canada
ODQ	Ordre des dentistes du Québec
RCDC	Royal College of Dentists of Canada

# Part H – Appendices

## Appendix A – Key Supporting References

American Educational Research Association, American Psychological Association and National Council on Measurement in Education. *Standards for Educational and Psychological Testing* (2014). Washington, DC: American Educational Research Association.

Angoff, W.H. (1971). Scales, norms and equivalent scores. In R.L. Thorndike (Ed.), *Education measurement* (2<sup>nd</sup> ed., 508-600). Washington DC: American Council on Education.

Hambleton, R. K., & Plake, B. S. (1995). Using an extended Angoff procedure to set standards on complex performance assessments. *Applied Measurement in Education*, 8(1), 41–56.

Impara, J. C. & Plake, B. S. (1997). Standard setting: An alternative approach. *Journal of Educational Measurement*, 34(4), 353-366.

National Dental Examining Board of Canada (2010). *Written Examination Chief Examiner's Manual*. Ottawa, ON: Author.

National Dental Examining Board of Canada (2014). *By-laws*. Ottawa, ON: Author.

National Dental Examining Board of Canada (2015a). *Instructions and Regulations for Test Administrators – Written Examination*. Ottawa, ON: Author.

National Dental Examining Board of Canada (2015b). *NDEB Glossary*. Ottawa, ON: Author.

National Dental Examining Board of Canada (2016). *Written Examination 2016 Protocol*. Ottawa, ON: Author

## Appendix B – Publications

- Boyd, M. A., Gerrow, J. D., Chambers, D. W., & Henderson, B. J. (1996). Competencies for Dental Licensure in Canada. *Journal of Dental Education*, 60(10), 842.
- Boyd, M. A., & Gerrow, J. D. (1996). A National Standard for Dentistry in Canada. *Journal of the Canadian Dental Association*, 62(12), 928.
- Buckendahl, C. W., Ferdous, A., & Gerrow, J. (2010). Recommending Cut Scores with a Subset of Items: An Empirical Illustration. *Practical Assessment Research & Evaluation*, 15(6).
- Buckendahl, C. W., & Gerrow, J. (2016). Evaluating the Impact of Releasing an Item Pool on a Test's Empirical Characteristics. *Journal of Dental Education*, 80(10), 1253–1260.
- Chambers, D. W., & Gerrow, J. D. (1994). Manual for Developing and Formatting Competency Statements. *Journal of Dental Education*, 58(5), 361.
- Charbonneau, A., Walton, J. N., & Morin, S. (2019). Association of Canadian Faculties of Dentistry Education Framework for the Development of Competency in Dental Programs. *Journal of Dental Education*, 83(4), 464–473.
- Davis, a, Buckendahl, C. W., & Gerrow, J. (2011). Evaluating Panelists' Bookmark Standard Setting Judgments: The Impact of Random Item Ordering. *International Journal of Testing*, 11(1), 24–37.
- Davis-Becker, S. W., Buckendahl, C., & Gerrow, J. (2011). Evaluating the Bookmark Standard Setting Method: The Impact of Random Ordering. *International Journal of Testing*, 11(24), 24–37.
- Gerrow, J. D., Boyd, M. B., Doyle, M. G., & Scott, D. (1996). Clinical Evaluation in Prosthodontics: Practical Methods to Improve Validity and Reliability. *Journal of Prosthetic Dentistry*, 75(6), 675.
- Gerrow, J. D., Boyd, M. A., Duquette, P., & Bentley, K. A. (1997). Results of the National Dental Examining Board of Canada's Written Examination and Implications for Licensure. *Journal of Dental Education*, 6(12), 921.
- Gerrow, J. D., Chambers, D. W., Henderson, B. J., & Boyd, M. A. (1998). Competencies for a Beginning Dental Practitioner in Canada. *Journal of the Canadian Dental Association*, 64(2), 94.
- Gerrow, J. D., Boyd, M. A., Donaldson, D., Watson, P. A., & Henderson, B. J. (1998). Modifications to the National Dental Examining Board of Canada's Certification Process. *Journal of the Canadian Dental Association*, 64(2), 98.
- Gerrow, J. D., Boyd, M. B., Scott, D., & Boulais, A. P. (1999). Use of Discriminant and Regression Analysis to Improve Certification Board Examinations. *Journal of Dental Education*, 63(6), 459.
- Gerrow, J. D., Murphy, H. J., Scott, M. A., & Scott, D. (2003). Concurrent Validity of Written and OSCE Components of the Canadian Dental Certification Examinations. *Journal of Dental Examinations*, 67(8), 896.

Gerrow, J. D., Boyd, M. A., & Scott, D. (2003). Portability of Licensure in Canada Based on Accreditation and Certification. *Journal of the American Colleges of Dentists*, 70(1), 8.

Gerrow, J. D., Murphy, H. J., Boyd, M. A., & Scott, D. (2006). An Analysis of the Contribution of a Patient-Based Component to a Clinical Licensure Examination. *Journal of American Dental Association*, 137, 1434.

Gerrow, J. D., Murphy, H. J., & Boyd, M. A. (2006). A Validity Survey of Competencies for the Beginning Dental Practitioner in Canada. *Journal of Dental Education*, 70(10), 1076.

Gerrow, J. D., Murphy, H. J., & Boyd, M. A. (2007). Review and Revision of the Competencies for a Beginning Dental Practitioner in Canada. *Journal of Canadian Dental Association*, 73(2), 157.

Wolkowitz, A., Davis-Becker, S., & Gerrow, J. (2016). Releasing Content to Deter Cheating: An Analysis of the Impact on Candidate Performance. *Journal of Applied Testing Technology*, 17(1), 33–40.

#### Abstracts and Minor Publications

Boyd, M. A., & Gerrow, J. D. (1997). An Analysis of the 1994 to 1996 Results of the National Dental Examining Board of Canada Written Examination. *Journal of Dental Research*, 76(43).

Boyd, M. A., Gerrow, J. D., & Duquette, P. (2003). Rethinking the OSCE as a Tool for National Competency Evaluation. *Proceedings Association of Dental Educators of Europe*. Dresden, Germany, September 2003.

Boyd, M. A., Gerrow, J. D., Haas, D. A., & Loney, R. W. (2004). National Dental Certification in Canada: An "Improved" OSCE Format. *Journal of Dental Education*, 68(2), 229.

Buckendahl, C., Ferdous, A., & Gerrow, J. (2008). Setting Cut Scores with a Subset of Items: An Empirical Illustration. *Annual Meeting of the National Council on Measurement in Education*, New York, NY. 2008

Davis, S., Buckendahl, C., & Gerrow, J. (2008). Comparing the Angoff and Bookmark Methods for an International Licensure Examination. *Annual Meeting of the National Council on Measurement in Education*, New York, NY. 2008.

Ferdous, A., Smith, R., & Gerrow, J. (2008). Considerations for Using Subsets of Items for Standard Setting. *Annual Meeting of the National Council on Measurement in Education*, New York, NY. 2008.

Gerrow, J. D., Boyd, M. A., & Duquette, P. (1997). The Development and Implementation Process for a New National Certification Examination in Canada. *Journal of Dental Education*, 61(2), 185.

Gerrow, J. D., Boyd, M. B., Scott, D., & Boulais, A. P. (1998). Use of Discriminant and Regression Analysis to Improve Certification Board Examinations. *Journal of Dental Education*, 62(1), 110.

Murphy, J., Gerrow, J. D., Scott, M. A., & Scott, D. (2002). Validity Evidence for the Canadian National Dental Examining Board Examinations. *Journal of Dental Education*, 66(2), 319.

## Appendix C – Competencies for a Beginning Dental Practitioner in Canada

A competent beginning dental practitioner in Canada must be able to provide oral health care for the benefit of individual patients and communities in a culturally sensitive manner.

Competency assumes that all behaviours are supported by foundation knowledge and skills in biomedical, behavioural and clinical dental science and by professional behaviour. Beginning dental practitioners in Canada must be able to apply foundation knowledge and skills to justify their decisions and actions and to evaluate outcomes. Therefore, foundation knowledge, skills and professional behaviour are understood to be a part of every competency.

Competency also assumes that all behaviours are performed to an acceptable level and that the practitioner can evaluate their quality and effectiveness. Competency cannot be achieved without the ability to self-evaluate. Moreover, there are no degrees of competence: a dentist is either competent or not competent. The competencies below refer to general dental practice and include the management of patients of all ages including those with special needs. It is assumed that all oral health care is provided in an ethical manner, in accordance with legal requirements at the national and provincial level.

A beginning dental practitioner in Canada must be competent to:

1. recognize the determinants of oral health in individuals and populations and the role of dentists in health promotion, including the disadvantaged.
2. recognize the relationship between general health and oral health.
3. evaluate the scientific literature and justify management recommendations based on the level of evidence available.
4. communicate effectively with patients, parents or guardians, staff, peers, other health professionals and the public.
5. identify the patient's chief complaint/concern and obtain the associated history.
6. obtain and interpret a medical, dental and psychosocial history, including a review of systems as necessary, and evaluate physical or psychosocial conditions that may affect dental management.
7. maintain accurate and complete patient records in a confidential manner.
8. prevent the transmission of infectious diseases by following current infection control guidelines.
9. perform a clinical examination.
10. differentiate between normal and abnormal hard and soft tissues of the maxillofacial complex.
11. prescribe and obtain the required diagnostic tests, considering their risks and benefits.
12. perform a radiographic examination.

13. interpret the findings from a patient's history, clinical examination, radiographic examination and from other diagnostic tests and procedures.
14. recognize and manage the anxious or fearful dental patient.
15. recognize signs of abuse and/or neglect and make appropriate reports.
16. assess patient risk (including, but not limited to, diet and tobacco use) for oral disease or injuries.
17. develop a problem list and establish diagnoses.
18. determine the level of expertise required for treatment and formulate a written request for consultation and/or referral when appropriate.
19. develop treatment options based on the evaluation of all relevant data.
20. discuss the findings, diagnoses, etiology, risks, benefits and prognoses of the treatment options, with a view to patient participation in oral health management.
21. develop an appropriate comprehensive, prioritized and sequenced treatment plan.
22. present and discuss the sequence of treatment, estimated fees, payment arrangements, time requirements and the patient's responsibilities for treatment.
23. obtain informed consent including the patient's written acceptance of the treatment plan and any modifications.
24. modify the treatment plan as required during the course of treatment.
25. provide education regarding the risks and prevention of oral disease and injury to encourage the adoption of healthy behaviors.
26. provide therapies for the prevention of oral disease and injury.
27. recognize and institute procedures to minimize occupational hazards related to the practice of dentistry.
28. achieve local anesthesia for dental procedures and manage related complications.
29. determine the indications and contraindications for the use of drugs used in dental practice, their dosages and routes of administration and write prescriptions for drugs used in dentistry.
30. manage dental emergencies.
31. recognize and manage systemic emergencies which may occur in dental practice.
32. manage conditions and diseases of the periodontium, provide periodontal treatment when indicated and monitor treatment outcomes.
33. assess the risk, extent and activity of caries and recommend appropriate non-surgical and surgical therapy.
34. manage dental caries, tooth defects and esthetic problems and, when restoration is warranted, use techniques that conserve tooth structure and preserve pulp vitality to restore form and function.
35. manage patients with orofacial pain and/or dysfunction.
36. manage surgical procedures related to oral soft and hard tissues and their complications

37. manage trauma to the orofacial complex.
38. manage conditions and pathology of the pulp and provide endodontic treatment when indicated.
39. manage abnormalities of orofacial growth and development and treat minor orthodontic problems.
40. recognize and manage functional and non-functional occlusion.
41. select and, where indicated, prescribe appropriate biomaterials for patient treatment.
42. manage partially and completely edentulous patients with prosthodontic needs including the provision of fixed, removable and implant prostheses.
43. make records required for use in the laboratory fabrication of dental prostheses and appliances.
44. design a dental prosthesis or appliance, write a laboratory prescription and evaluate laboratory products.
45. apply accepted principles of ethics and jurisprudence to maintain standards and advance knowledge and skills.
46. apply basic principles of practice administration, financial and personnel management to a dental practice.
47. demonstrate professional behaviour that is ethical, supersedes self-interest, strives for excellence, is committed to continued professional development and is accountable to individual patients, society and the profession.

#### Definition

To “manage” the oral health care needs of a patient is assumed to include all actions performed by a health care provider that are designed to alter the course of a patient's condition. Such actions may include providing education, advice, treatment by the dentist, treatment by the dentist after consultation with another health care professional, referral of a patient to another health care professional, monitoring treatment provided, but also may include providing no treatment or observation. “Manage” assumes the use of the least invasive therapy necessary to gain a successful outcome in accordance with patient wishes.

## Appendix D – Equating Procedure

Excerpts from Maguire (2004)

Each year, the National Dental Examining Board of Canada administers examinations to graduating students from Canadian Faculties of Dentistry. The results of the examinations are used as part of the credentialing process. In addition, the examination program plays a role in maintaining a national standard of competence for dentists entering practice in Canada. Consistent with the second purpose, it is of interest to trace the performance of candidate cohorts over successive years. Direct comparison of candidates' average performance in successive years could be made but if differences were observed, they could be due to differences in the candidates themselves, to differences between the two examinations (one may be more difficult than the other), or to a combination of both. The process of examination equating attempts to make the examination scores equivalent so that differences between equated scores can be attributed to the difference between cohorts of candidates. In effect, the equating process attempts to answer the question, how would candidates who wrote in 2013 have performed on the 2012 examination?

The equating procedure to be presented below is taken from Angoff (1971, pp579-583). It is based on an examination design in which instruments in successive years consist of two components: a common component (a set of items that appear in both years) and a unique component (sets of items that appear in one year, but not the other). Consider for example the examinations administered in 2012 (year 1) and 2013 (year 2). In 2012 a candidate's score can be thought of as:

$Y_1 = V_1 + U_1$  where V is the score on the common items and U is the score on the unique items. In 2013, a candidate's score would be:

$X_2 = V_2 + W_2$  where V is the score on the common items and W is the score on the unique items.

The goal of the equating process is to find a mathematical function that projects X onto Y or Y onto X. Unlike a regression equation, this function should yield consistent results regardless of the direction in which scores are to be equated, that is, projecting from 2012 to 2013 or from 2013 to 2012.

The general form of the equation for equating scores from 2013 to scores from 2012 is:

$$Y'_2 = bX_2 + a \quad (1)$$

or, if the direction were reversed, the equation would be:

$$X'_1 = \frac{1}{b}(Y_1 - a) \quad (2)$$

For simplicity, we will assume that 2012 will be treated as the base year, and we want to equate the 2012 score to it.

The details of the algebra can be found in Angoff's 1971 chapter, but essentially the functions are based on the supposition of a single combined sample of candidates, i.e. the 2012 group combined with the 2013 group. We will refer to this hypothetical sample as the 'total' group. There are two variables:

1. the scores on Y for all candidates (i.e. the scores on the 2012 examination).
2. the scores on X for all candidates (i.e. the scores on the 2013 examination).

Of course we only have Y scores for the 2012 candidates, and X scores for the 2013 candidates, but if all candidates had taken both examinations, the equating formula for mapping scores from 2013 to 2012 would be:

$$Y' = \frac{sd(Y_T)}{sd(X_T)} (X - mean(X_T) + mean(Y_T)) \quad (3)$$

where:

- $sd(Y_T)$  is the standard deviation of Y scores for the total sample,
- $sd(X_T)$  is the standard deviation of X scores for the total sample,
- $mean(Y_T)$  is the mean Y score for the total sample,
- $mean(X_T)$  is the mean X score for the total sample.

In terms of equation 1,

$$b = \frac{sd(Y_T)}{sd(X_T)} \quad \text{and} \quad a = mean(Y_T) - b(mean(X_T)) \quad (4)$$

The four values required for equation (3) are estimated using the common portions of the exams. The procedure, referred to in the literature as 'common item linear equating,' will be presented below. In this case the equating (common) portion of the examination forms part of the total score. The procedure is identical for situations in which the equating part of the examination is treated as a separate entity.

#### Equating Formulas – Common Item Equating

The actual procedure begins with the calculation of two scores in each of the two samples:

$Y_1$  = the score for 2001 candidates on the entire examination (300 items)

$V_1$  = the score for 2001 candidates on the common portion (110 items)

$X_2$  = the score for 2002 candidates on the entire examination (300 items)

$V_2$  = the score for 2002 candidates on the common portion (110) items.

To find the values needed for equation 3, four intermediate statistics must be estimated:

$$\text{var}(Y_T) = .5 \text{var}(Y_1) + .5 \text{var}(Y_2) + .25[\text{mean}(Y_1) - \text{mean}(Y_2)]^2 \quad (5)$$

$$\text{var}(X_T) = .5 \text{var}(X_1) + .5 \text{var}(X_2) + .25[\text{mean}(X_1) - \text{mean}(X_2)]^2 \quad (6)$$

$$\text{mean}(Y_T) = .5\text{mean}(Y_1) + .5(\text{mean}(Y_2)) \quad (7)$$

$$\text{mean}(X_T) = .5\text{mean}(X_1) + .5\text{mean}(X_2) \quad (8)$$

Four of the values that appear in equations 5 through 8 must be estimated under the assumption that the regression slopes of  $Y_1$  on  $V_1$  in Group 1 and  $X_2$  on  $V_2$  in Group 2 are the same. The four estimates are:

$$\text{var}(Y_2) = \text{var}(Y_1) - \left\{ \frac{\text{cov}(Y_1V_1)}{\text{var}(V_1)} \right\}^2 [\text{var}(V_1) - \text{var}(V_2)] \quad (9)$$

$$\text{var}(X_1) = \text{var}(X_2) + \left\{ \frac{\text{cov}(X_2V_2)}{\text{var}(V_2)} \right\}^2 [\text{var}(V_1) - \text{var}(V_2)] \quad (10)$$

$$\text{mean}(Y_2) = \text{mean}(Y_1) - \frac{\text{cov}(Y_1V_1)}{\text{var}(V_1)} [\text{mean}(V_1) - \text{mean}(V_2)] \quad (11)$$

$$\text{mean}(X_1) = \text{mean}(X_2) + \frac{\text{cov}(X_2V_2)}{\text{var}(V_2)} [\text{mean}(V_1) - \text{mean}(V_2)] \quad (12)$$

Calculation of the Equating Expressions:

Step 1. From the data, calculate the following values:

(a) Group 1 (2012): means and standard deviations of  $Y$  and  $V$ , also the covariance between  $Y$  and  $V$ .

(b) Group 2 (2013): Means and standard deviations of  $X$  and  $V$ , also the covariance between  $X$  and  $V$ .

Step 2. Substitute the values from Step 1 into equations (9) through (12).

Step 3. Substitute the values from Steps 1 and 2 into equations (5) through (8).

Step 4. Substitute the results of Step 3 into equations (3) and (4).

#### References

Angoff, W.H. (1971). Scales, norms, and equivalent scores. In R.L. Thorndike (Ed.), *Educational measurement* (2<sup>nd</sup> ed., 508-600). Washington DC: American Council on Education.