education_data_masking

December 19, 2024

1 Educational Data Masking with Delphix: Privacy in Academic Environments

This notebook demonstrates the application of Delphix masking techniques to educational data, with special consideration for: - FERPA compliance - COPPA requirements - State-specific education privacy laws - Educational research needs - Cross-institutional data sharing requirements

[31]:
```
import pandas as pd
import numpy as np
from faker import Faker
import random
from datetime import datetime, timedelta
import uuid
from scipy.stats import norm
import matplotlib.pyplot as plt
# Set up our environment
fake = Faker()
np.random.seed(42)
random.seed(42)

# Constants for data generation
CURRENT_YEAR = 2024
SCHOOL_YEARS = range(9, 13)  # High school grades 9-12
SUBJECTS = ['Math', 'English', 'Science', 'History', 'Foreign Language', 'Art',␣
  ↪'Physical Education']
ETHNICITIES = ['White', 'Hispanic/Latino', 'Black/African American', 'Asian',␣
  ↪'Native American', 'Pacific Islander', 'Two or More Races']
ACCOMMODATIONS = ['Extended Time', 'Separate Setting', 'Read Aloud', 'Use of␣
  ↪Calculator', 'None']
PROGRAMS = ['General Education', 'Special Education', 'Gifted/Talented',␣
  ↪'English Language Learner', 'Section 504']
LUNCH_STATUS = ['Full Price', 'Reduced Price', 'Free']
ATTENDANCE_CODES = ['Present', 'Excused Absence', 'Unexcused Absence', 'Tardy',␣
  ↪'Early Dismissal']
BEHAVIOR_TYPES = ['Positive Behavior', 'Minor Infraction', 'Major Infraction',␣
  ↪'None']
```

```
EXTRACURRICULAR = ['Sports', 'Music', 'Drama', 'Student Government', 'Academic␣
↪Club', 'None']
```

```
[19]: def generate_student_base(num_students=10000):
    """Generate base student demographic and enrollment data"""
    students = []

    for _ in range(num_students):
        grade = random.choice(SCHOOL_YEARS)
        dob_year = CURRENT_YEAR - (grade + 6)  # Approximate age for grade

        student = {
            'student_id': str(uuid.uuid4())[:8].upper(),  # Short UUID as␣
↪student ID
            'state_id': fake.unique.random_number(digits=10, fix_len=True),
            'first_name': fake.first_name(),
            'last_name': fake.last_name(),
            'dob': fake.date_of_birth(minimum_age=grade+5, maximum_age=grade+7),
            'grade_level': grade,
            'enrollment_date': fake.date_between(start_date='-4y',␣
↪end_date='today'),
            'ethnicity': random.choice(ETHNICITIES),
            'gender': random.choice(['M', 'F', 'NB']),
            'primary_language': random.choice(['English', 'Spanish', 'Chinese',␣
↪'Vietnamese', 'Arabic']),
            'program': random.choice(PROGRAMS),
            'lunch_status': random.choice(LUNCH_STATUS),

            # Guardian Information
            'guardian1_name': fake.name(),
            'guardian1_relationship': random.choice(['Mother', 'Father',␣
↪'Grandmother', 'Grandfather', 'Guardian']),
            'guardian1_phone': fake.phone_number(),
            'guardian1_email': fake.email(),
            'guardian2_name': fake.name() if random.random() > 0.3 else None,

            # Address Information
            'street_address': fake.street_address(),
            'city': fake.city(),
            'state': fake.state_abbr(),
            'zip_code': fake.zipcode(),

            # Health and Accommodations
            'accommodations': random.choice(ACCOMMODATIONS),
            'medical_alert': 'Yes' if random.random() < 0.1 else 'No',
            'immunization_status': random.choice(['Complete', 'Incomplete',␣
↪'Exempt']),
            # Additional Demographics
            'transportation': random.choice(['Bus', 'Parent Transport', 'Self␣
↪Transport', 'Walk']),
            'extracurricular': random.choice(EXTRACURRICULAR)
        }
        students.append(student)

    return pd.DataFrame(students)

# Generate base student data
student_df = generate_student_base()
print(f"Generated {len(student_df)} student records")
student_df.head()
```

```
Generated 10000 student records
```

```
[19]:   student_id    state_id first_name   last_name         dob  grade_level  \
     0    CC5C044A  2459805438     Tamara  Cunningham  2008-03-09            9
     1    7876DB57  5462400192    Rebecca     Garrett  2008-11-27            9
     2    9FBDBDB0  1286644447  Francisco      Martin  2009-07-16           10
     3    085ADF92  2951416192    Antonio      Nelson  2007-01-01           11
     4    115D2D33  9870624934    Jessica        Duke  2008-02-12           10

       enrollment_date         ethnicity gender primary_language  …  \
     0      2021-05-25             White     NB          Chinese  …
     1      2021-11-29   Hispanic/Latino      M           Arabic  …
     2      2023-05-06  Pacific Islander      F          Chinese  …
     3      2022-05-13   Native American      F          English  …
     4      2022-05-16  Pacific Islander      M          English  …

        guardian2_name                 street_address                    city  \
     0    Dylan Garcia  35012 Bennett Course Suite 148           East Samantha
     1            None              7756 Nelson Field           Port Jasonfort
     2   Sarah Freeman   69699 Chelsea Lodge Suite 173  South Christopherburgh
     3  Michael Hudson     89455 Joshua Inlet Apt. 506             Hernandezton
     4  Jason Marshall       92546 Adam Harbor Apt. 924             Jessicaview

       state zip_code     accommodations medical_alert immunization_status  \
     0    MT    57375               None           Yes          Incomplete
     1    IN    14426               None            No          Incomplete
     2    AR    94833         Read Aloud            No          Incomplete
     3    MN    73912  Use of Calculator           Yes          Incomplete
     4    NY    64414      Extended Time            No          Incomplete

        transportation extracurricular
     0             Bus          Sports
```

```
1  Self Transport          Sports
2              Bus          Drama
3  Self Transport   Academic Club
4  Self Transport           Music

[5 rows x 26 columns]
```

[20]:
```python
def generate_academic_records(student_df):
    """Generate academic records for each student"""
    academic_records = []

    for _, student in student_df.iterrows():
        # Generate records for each subject
        for subject in SUBJECTS:
            # Generate records for each quarter
            for quarter in range(1, 5):
                # Base grade distribution around a mean with some variation
                base_grade = np.random.normal(82, 10)

                # Adjust grade based on program participation
                if student['program'] == 'Gifted/Talented':
                    base_grade += np.random.normal(8, 2)
                elif student['program'] == 'English Language Learner':
                    if subject == 'English':
                        base_grade -= np.random.normal(5, 2)

                # Ensure grades are within realistic bounds
                final_grade = max(min(round(base_grade, 1), 100), 0)

                record = {
                    'student_id': student['student_id'],
                    'school_year': CURRENT_YEAR,
                    'grade_level': student['grade_level'],
                    'subject': subject,
                    'quarter': quarter,
                    'grade': final_grade,
                    'teacher_name': fake.name(),
                    'comments': random.choice([
                        'Excellent participation',
                        'Shows improvement',
                        'Needs more practice',
                        'Outstanding work',
                        'Missing assignments',
                        None
                    ])
                }
                academic_records.append(record)
    return pd.DataFrame(academic_records)

# Generate academic records
academic_df = generate_academic_records(student_df)
print(f"Generated {len(academic_df)} academic records")
academic_df.head()
```

```
Generated 280000 academic records
```

[20]:

```
  student_id  school_year  grade_level  subject  quarter  grade  \
0   CC5C044A         2024            9     Math        1   87.0
1   CC5C044A         2024            9     Math        2   80.6
2   CC5C044A         2024            9     Math        3   88.5
3   CC5C044A         2024            9     Math        4   97.2
4   CC5C044A         2024            9  English        1   79.7

       teacher_name             comments
0   Elaine Robinson     Outstanding work
1     Lori Schwartz  Missing assignments
2    Nicholas Smith                 None
3      Sierra Smith     Outstanding work
4  George Zimmerman  Missing assignments
```

[21]:

```
def generate_attendance_records(student_df):
    """Generate daily attendance records for each student"""
    attendance_records = []

    # Generate one semester of attendance (90 days)
    school_days = pd.date_range(
        start='2024-01-01',
        periods=90,
        freq='B'  # Business days
    )

    for _, student in student_df.iterrows():
        # Set student-specific attendance patterns
        attendance_pattern = np.random.choice(
            ['Regular', 'Frequent Absences', 'Occasional Tardies'],
            p=[0.8, 0.1, 0.1]
        )

        for day in school_days:
            if attendance_pattern == 'Regular':
                status_weights = [0.95, 0.02, 0.01, 0.02, 0.0]
            elif attendance_pattern == 'Frequent Absences':
                status_weights = [0.75, 0.10, 0.10, 0.05, 0.0]
            else:  # Occasional Tardies
```

```
                status_weights = [0.85, 0.02, 0.01, 0.12, 0.0]

            status = np.random.choice(ATTENDANCE_CODES, p=status_weights)

            record = {
                'student_id': student['student_id'],
                'date': day,
                'status': status,
                'grade_level': student['grade_level'],
                'recorded_by': fake.name(),
                'note': random.choice([
                    'Doctor appointment',
                    'Family emergency',
                    'Transportation issues',
                    None,
                    None,
                    None
                ]) if status != 'Present' else None
            }
            attendance_records.append(record)

    return pd.DataFrame(attendance_records)

# Generate attendance records
attendance_df = generate_attendance_records(student_df)
print(f"Generated {len(attendance_df)} attendance records")
attendance_df.head()
```

```
Generated 900000 attendance records
```

[21]:
```
  student_id        date   status  grade_level      recorded_by  note
0   CC5C044A  2024-01-01  Present            9      Sarah Moore  None
1   CC5C044A  2024-01-02  Present            9   Robert Manning  None
2   CC5C044A  2024-01-03  Present            9    Justin Murphy  None
3   CC5C044A  2024-01-04  Present            9   Caroline Jones  None
4   CC5C044A  2024-01-05  Present            9  Peter Fernandez  None
```

[22]:
```
def generate_assessment_data(student_df):
    """Generate standardized test scores and other assessments"""
    assessment_records = []

    # Define different types of assessments
    ASSESSMENTS = {
        'State Standardized Test': {
            'subjects': ['Math', 'Reading', 'Science'],
            'score_range': (600, 900)
        },
        'College Readiness': {
            'subjects': ['Verbal', 'Math', 'Writing'],
            'score_range': (200, 800)
        },
        'Language Proficiency': {
            'subjects': ['Reading', 'Writing', 'Speaking', 'Listening'],
            'score_range': (1, 6)
        }
    }

    for _, student in student_df.iterrows():
        # Generate state test scores for all students
        for subject in ASSESSMENTS['State Standardized Test']['subjects']:
            base_score = np.random.normal(750, 50)

            # Adjust scores based on student program
            if student['program'] == 'Gifted/Talented':
                base_score += np.random.normal(50, 10)
            elif student['program'] == 'English Language Learner' and subject␣
↪== 'Reading':
                base_score -= np.random.normal(30, 10)

            score = max(min(round(base_score), 900), 600)

            record = {
                'student_id': student['student_id'],
                'assessment_type': 'State Standardized Test',
                'subject': subject,
                'date': fake.date_between(start_date='-6m', end_date='-1m'),
                'score': score,
                'percentile': round(norm.cdf((score - 750) / 50) * 100),
                'accommodations_used': student['accommodations'],
                'grade_level': student['grade_level']
            }
            assessment_records.append(record)

        # Generate college readiness scores for 11th and 12th graders
        if student['grade_level'] in [11, 12]:
            for subject in ASSESSMENTS['College Readiness']['subjects']:
                score = round(np.random.normal(550, 100))
                score = max(min(score, 800), 200)

                record = {
                    'student_id': student['student_id'],
                    'assessment_type': 'College Readiness',
                    'subject': subject,
                    'date': fake.date_between(start_date='-6m', end_date='-1m'),
                    'score': score,
                    'percentile': round(norm.cdf((score - 550) / 100) * 100),
                    'accommodations_used': student['accommodations'],
                    'grade_level': student['grade_level']
                }
                assessment_records.append(record)

        # Generate language proficiency scores for ELL students
        if student['program'] == 'English Language Learner':
            for subject in ASSESSMENTS['Language Proficiency']['subjects']:
                score = round(np.random.normal(3.5, 0.8), 1)
                score = max(min(score, 6.0), 1.0)

                record = {
                    'student_id': student['student_id'],
                    'assessment_type': 'Language Proficiency',
                    'subject': subject,
                    'date': fake.date_between(start_date='-6m', end_date='-1m'),
                    'score': score,
                    'level': int(score),
                    'accommodations_used': student['accommodations'],
                    'grade_level': student['grade_level']
                }
                assessment_records.append(record)

    return pd.DataFrame(assessment_records)

# Generate assessment records
assessment_df = generate_assessment_data(student_df)
print(f"Generated {len(assessment_df)} assessment records")
assessment_df.head()
```

```
Generated 53026 assessment records
```

[22]:

```
  student_id          assessment_type  subject        date  score  percentile  \
0   CC5C044A  State Standardized Test     Math  2024-12-18  674.0         6.0
1   CC5C044A  State Standardized Test  Reading  2024-12-18  717.0        25.0
2   CC5C044A  State Standardized Test  Science  2024-12-18  720.0        27.0
3   7876DB57  State Standardized Test     Math  2024-12-18  700.0        16.0
4   7876DB57  State Standardized Test  Reading  2024-12-18  700.0        16.0

  accommodations_used  grade_level  level
0                None            9    NaN
1                None            9    NaN
2                None            9    NaN
3                None            9    NaN
4                None            9    NaN
```

```
[23]: def generate_behavioral_records(student_df):
          """Generate student behavioral records"""
          behavioral_records = []

          # Incident types and their relative frequencies
          INCIDENT_TYPES = {
              'Minor': {
                  'incidents': [
                      'Tardiness', 'Dress Code Violation', 'Classroom Disruption',
                      'Electronic Device Usage', 'Missing Homework'
                  ],
                  'frequency': 0.15  # 15% chance per student per month
              },
              'Major': {
                  'incidents': [
                      'Academic Dishonesty', 'Bullying', 'Harassment',
                      'Fighting', 'Property Damage'
                  ],
                  'frequency': 0.03  # 3% chance per student per month
              },
              'Positive': {
                  'incidents': [
                      'Helping Others', 'Academic Achievement', 'Leadership',
                      'Community Service', 'School Spirit'
                  ],
                  'frequency': 0.20  # 20% chance per student per month
              }
          }

          # Generate records for one semester (6 months)
          months = pd.date_range(start='2024-01-01', end='2024-06-30', freq='M')

          for _, student in student_df.iterrows():
              # Set student-specific behavior pattern
              behavior_modifier = np.random.normal(1, 0.3)

              for month in months:
                  # Generate incidents based on probabilities
                  for severity, details in INCIDENT_TYPES.items():
                      if np.random.random() < (details['frequency'] *␣
       ↪behavior_modifier):
                          incident = random.choice(details['incidents'])

                          record = {
                              'student_id': student['student_id'],
                              'date': fake.date_between(
                                  start_date=month - pd.Timedelta(days=30),
                                  end_date=month
                              ),
                              'incident_type': severity,
                              'incident': incident,
                              'location': random.choice([
                                  'Classroom', 'Hallway', 'Cafeteria',
                                  'Playground', 'Gym', 'Bus'
                              ]),
                              'reported_by': fake.name(),
                              'action_taken': random.choice([
                                  'Verbal Warning', 'Parent Contact',
                                  'Detention', 'Office Referral', 'Counselor␣
  ↪Referral',
                                  'Positive Recognition', 'Award Given'
                              ]) if severity != 'Positive' else 'Recognition',
                              'parent_contacted': random.choice([True, False]),
                              'grade_level': student['grade_level']
                          }
                          behavioral_records.append(record)

          return pd.DataFrame(behavioral_records)

      # Generate behavioral records
      behavior_df = generate_behavioral_records(student_df)
      print(f"Generated {len(behavior_df)} behavioral records")
      behavior_df.head()
```

```
/var/folders/j7/smpqy2fn30l7j5kcqh76jqp40000gn/T/ipykernel_81663/1318671494.py:3
1: FutureWarning: 'M' is deprecated and will be removed in a future version,
please use 'ME' instead.
  months = pd.date_range(start='2024-01-01', end='2024-06-30', freq='M')
```

```
Generated 22836 behavioral records
```

[23]:
```
  student_id        date incident_type              incident    location  \
0   CC5C044A  2024-01-13         Minor      Missing Homework         Gym
1   CC5C044A  2024-01-05      Positive            Leadership  Playground
2   CC5C044A  2024-02-21      Positive  Academic Achievement   Classroom
3   CC5C044A  2024-03-28      Positive     Community Service         Bus
4   CC5C044A  2024-04-26      Positive            Leadership         Gym

      reported_by action_taken  parent_contacted  grade_level
0     Edwin Dixon  Award Given             False            9
1  Jason Mckinney  Recognition              True            9
2    Lisa Gregory  Recognition              True            9
3   Darren Kramer  Recognition              True            9
4     David Evans  Recognition             False            9
```

```
[24]: def generate_program_participation(student_df):
          """Generate program participation and services records"""
          program_records = []

          # Define various programs and services
          PROGRAM_TYPES = {
              'Academic Support': [
                  'Reading Intervention', 'Math Intervention',
                  'Writing Workshop', 'Study Skills'
              ],
              'Special Education': [
                  'Resource Room', 'Speech Therapy', 'Occupational Therapy',
                  'Physical Therapy', 'Social Skills Group'
              ],
              'Gifted/Talented': [
                  'Advanced Placement', 'International Baccalaureate',
                  'STEM Enrichment', 'Arts Enrichment'
              ],
              'Language Support': [
                  'ESL Classes', 'Bilingual Education',
                  'Native Language Support', 'Cultural Integration'
              ],
              'Social Services': [
                  'Counseling', 'Social Work Services',
                  'Behavioral Support', 'Family Outreach'
              ]
          }

          for _, student in student_df.iterrows():
              # Determine number of programs based on student's primary program
              if student['program'] == 'Special Education':
                  num_programs = random.randint(2, 4)
                  primary_category = 'Special Education'
              elif student['program'] == 'Gifted/Talented':
                  num_programs = random.randint(1, 3)
                  primary_category = 'Gifted/Talented'
              elif student['program'] == 'English Language Learner':
                  num_programs = random.randint(1, 3)
                  primary_category = 'Language Support'
              else:
                  num_programs = random.randint(0, 2)
                  primary_category = 'Academic Support'

              # Generate program participation records
              programs_assigned = []

              # Always add at least one program from primary category
```

```
        if primary_category in PROGRAM_TYPES:
            primary_program = random.choice(PROGRAM_TYPES[primary_category])
            programs_assigned.append((primary_category, primary_program))
            num_programs = max(0, num_programs - 1)

        # Add additional programs
        while len(programs_assigned) < num_programs:
            category = random.choice(list(PROGRAM_TYPES.keys()))
            program = random.choice(PROGRAM_TYPES[category])
            if (category, program) not in programs_assigned:
                programs_assigned.append((category, program))

        # Create records for each assigned program
        for category, program in programs_assigned:
            start_date = fake.date_between(
                start_date='-1y',
                end_date='-1m'
            )

            record = {
                'student_id': student['student_id'],
                'program_category': category,
                'program_name': program,
                'start_date': start_date,
                'end_date': fake.date_between(
                    start_date=start_date,
                    end_date='+1y'
                ) if random.random() < 0.3 else None,
                'frequency': random.choice([
                    'Daily', 'Weekly', 'Bi-Weekly', 'Monthly'
                ]),
                'service_provider': fake.name(),
                'location': random.choice([
                    'Main Campus', 'Resource Room', 'Library',
                    'Satellite Location', 'Online'
                ]),
                'funding_source': random.choice([
                    'District', 'State Grant', 'Federal Grant',
                    'Title I', 'Special Education'
                ]),
                'notes': random.choice([
                    'Making good progress',
                    'Requires continued support',
                    'Consider program adjustment',
                    'Meeting program goals',
                    None
                ])
            }
            program_records.append(record)

    return pd.DataFrame(program_records)

# Generate program participation records
program_df = generate_program_participation(student_df)
print(f"Generated {len(program_df)} program participation records")
program_df.head()
```

```
Generated 13226 program participation records
```

[24]:
```
  student_id   program_category                program_name  start_date  \
0   CC5C044A  Special Education              Speech Therapy  2024-04-15
1   CC5C044A    Social Services                  Counseling  2024-06-01
2   CC5C044A    Gifted/Talented  International Baccalaureate  2024-03-28
3   7876DB57   Academic Support           Math Intervention  2024-12-09
4   9FBDBDB0    Gifted/Talented  International Baccalaureate  2024-01-14

     end_date  frequency service_provider       location funding_source  \
0  2024-08-20     Weekly    Vanessa Flynn  Resource Room        Title I
1        None     Weekly     Erica Howell    Main Campus    State Grant
2  2025-12-08      Daily      Maria Klein  Resource Room       District
3  2025-01-02  Bi-Weekly    Lauren Nguyen  Resource Room    State Grant
4        None  Bi-Weekly      Joel Taylor        Library    State Grant

                       notes
0  Requires continued support
1        Making good progress
2  Requires continued support
3       Meeting program goals
4  Requires continued support
```

[25]:
```
def generate_health_records(student_df):
    """Generate student health and medical records"""
    health_records = []

    # Define health-related constants
    HEALTH_CONDITIONS = {
        'Asthma': 0.08,
        'Allergies': 0.15,
        'ADHD': 0.07,
        'Diabetes Type 1': 0.02,
        'Seizure Disorder': 0.01,
        'Vision Impairment': 0.05,
        'Hearing Impairment': 0.03,
        'None': 0.59
    }
```

```
MEDICATIONS = {
    'Asthma': ['Albuterol', 'Flovent', 'Singulair'],
    'Allergies': ['Zyrtec', 'Claritin', 'Benadryl'],
    'ADHD': ['Ritalin', 'Adderall', 'Concerta'],
    'Diabetes Type 1': ['Insulin'],
    'Seizure Disorder': ['Keppra', 'Depakote', 'Tegretol'],
}

for _, student in student_df.iterrows():
    # Generate basic health record
    base_record = {
        'student_id': student['student_id'],
        'height': round(np.random.normal(
            160 + (student['grade_level'] - 9) * 3, 10
        ), 1),  # cm
        'weight': round(np.random.normal(
            55 + (student['grade_level'] - 9) * 3, 8
        ), 1),  # kg
        # Generate blood type if not present in student record
        'blood_type': random.choice(['A+', 'A-', 'B+', 'B-', 'O+', 'O-',␣
↪'AB+', 'AB-']),
        'vision_left': random.choice(['20/20', '20/30', '20/40', '20/50']),
        'vision_right': random.choice(['20/20', '20/30', '20/40', '20/50']),
        'hearing_test': random.choice(['Pass', 'Fail', 'Not Tested']),
        'last_physical_date': fake.date_between(start_date='-1y',␣
↪end_date='today'),
        'physician_name': fake.name(),
        'physician_phone': fake.phone_number(),
        'emergency_contact_name': student['guardian1_name'],
        'emergency_contact_phone': student['guardian1_phone']
    }
    health_records.append(base_record)

    # Generate condition-specific records
    for condition, probability in HEALTH_CONDITIONS.items():
        if random.random() < probability and condition != 'None':
            medications = MEDICATIONS.get(condition, [])
            record = {
                'student_id': student['student_id'],
                'condition': condition,
                'diagnosis_date': fake.date_between(
                    start_date='-5y',
                    end_date='today'
                ),
                'medication': random.choice(medications) if medications␣
↪else None,
                'dosage': random.choice([
                    'Once daily', 'Twice daily', 'As needed'
                ]) if medications else None,
                'provider_name': fake.name(),
                'last_review_date': fake.date_between(
                    start_date='-6m',
                    end_date='today'
                ),
                'school_accommodations_required': random.choice([True,␣
↪False]),
                'emergency_plan_on_file': random.choice([True, False]),
                'notes': random.choice([
                    'Well controlled',
                    'Regular monitoring required',
                    'Emergency medication on file',
                    None
                ])
            }
            health_records.append(record)

    # Generate immunization records
    immunizations = {
        'MMR': {'doses': 2, 'required': True},
        'Tdap': {'doses': 1, 'required': True},
        'Varicella': {'doses': 2, 'required': True},
        'Hepatitis B': {'doses': 3, 'required': True},
        'Meningococcal': {'doses': 1, 'required': True},
        'HPV': {'doses': 3, 'required': False},
        'Flu': {'doses': 1, 'required': False}
    }

    for vaccine, details in immunizations.items():
        for dose in range(details['doses']):
            record = {
                'student_id': student['student_id'],
                'immunization': vaccine,
                'dose_number': dose + 1,
                'date_administered': fake.date_between(
                    start_date='-5y',
                    end_date='today'
                ),
                'administered_by': fake.name(),
                'lot_number': fake.bothify(text='??###?'),
                'required': details['required'],
                'facility': fake.company()
            }
            health_records.append(record)
```

```python
    return pd.DataFrame(health_records)

# Generate health records
health_df = generate_health_records(student_df)
print(f"Generated {len(health_df)} health records")
health_df.head()
```

```
Generated 144151 health records
```

[25]:

```
  student_id  height  weight blood_type vision_left vision_right hearing_test  \
0   CC5C044A   162.6    49.6        AB+       20/20        20/30         Pass
1   CC5C044A     NaN     NaN        NaN         NaN          NaN          NaN
2   CC5C044A     NaN     NaN        NaN         NaN          NaN          NaN
3   CC5C044A     NaN     NaN        NaN         NaN          NaN          NaN
4   CC5C044A     NaN     NaN        NaN         NaN          NaN          NaN

  last_physical_date    physician_name physician_phone  …  \
0         2024-02-29  Jeffrey Williams   (267)539-2354  …
1                NaN               NaN             NaN  …
2                NaN               NaN             NaN  …
3                NaN               NaN             NaN  …
4                NaN               NaN             NaN  …

  school_accommodations_required emergency_plan_on_file  \
0                            NaN                    NaN
1                           True                   True
2                            NaN                    NaN
3                            NaN                    NaN
4                            NaN                    NaN

                        notes immunization dose_number date_administered  \
0                         NaN          NaN         NaN               NaN
1  Emergency medication on file          NaN         NaN               NaN
2                         NaN          MMR         1.0        2022-10-13
3                         NaN          MMR         2.0        2024-07-22
4                         NaN         Tdap         1.0        2021-07-28

  administered_by lot_number required                     facility
0             NaN        NaN      NaN                          NaN
1             NaN        NaN      NaN                          NaN
2   Jasmine Ellis     zm293H     True                Schneider LLC
3    Amber Carter     vt212B     True               Taylor-Jenkins
4    Joshua Ellis     GL791t     True  Jackson, Perkins and Grant

[5 rows x 28 columns]
```

[26]:
```
def generate_course_schedules(student_df):
    """Generate student course schedules and enrollment data"""
    schedule_records = []

    # Define course catalog
    COURSE_CATALOG = {
        'Math': {
            9: ['Algebra I', 'Geometry'],
            10: ['Geometry', 'Algebra II'],
            11: ['Algebra II', 'Pre-Calculus'],
            12: ['Pre-Calculus', 'AP Calculus', 'Statistics']
        },
        'English': {
            9: ['English 9', 'English 9 Honors'],
            10: ['English 10', 'English 10 Honors'],
            11: ['English 11', 'AP Language'],
            12: ['English 12', 'AP Literature']
        },
        'Science': {
            9: ['Biology', 'Biology Honors'],
            10: ['Chemistry', 'Chemistry Honors'],
            11: ['Physics', 'AP Biology'],
            12: ['AP Chemistry', 'AP Physics', 'Environmental Science']
        },
        'Social Studies': {
            9: ['World History', 'World History Honors'],
            10: ['US History', 'AP US History'],
            11: ['Government', 'AP Government'],
            12: ['Economics', 'AP Economics']
        },
        'Foreign Language': {
            9: ['Spanish I', 'French I', 'Chinese I'],
            10: ['Spanish II', 'French II', 'Chinese II'],
            11: ['Spanish III', 'French III', 'Chinese III'],
            12: ['AP Spanish', 'AP French', 'AP Chinese']
        }
    }

    # Class periods
    PERIODS = range(1, 8)

    for _, student in student_df.iterrows():
        grade = student['grade_level']

        # Assign core courses based on grade and program
        assigned_periods = {}
        for subject, courses in COURSE_CATALOG.items():
            if grade in courses:
                # Select appropriate course level based on student program
                available_courses = courses[grade]
                if student['program'] == 'Gifted/Talented':
                    course = [c for c in available_courses if 'AP' in c or␣
↪'Honors' in c]
                    course = course[-1] if course else available_courses[0]
                else:
                    course = available_courses[0]

                # Assign to a random available period
                available_periods = [p for p in PERIODS if p not in␣
↪assigned_periods]
                period = random.choice(available_periods)
                assigned_periods[period] = (subject, course)

        # Create schedule records
        for period, (subject, course) in assigned_periods.items():
            record = {
                'student_id': student['student_id'],
                'course_name': course,
                'subject': subject,
                'period': period,
                'room_number': f"{random.randint(1, 3)}{random.randint(0,␣
↪9)}{random.randint(0, 9)}",
                'teacher_name': fake.name(),
                'semester': 1,  # Assuming first semester
                'school_year': CURRENT_YEAR,
                'credits': 1.0,
                'status': 'Enrolled',
                'section_id': fake.bothify(text='??###'),
                'max_capacity': 30,
                'current_enrollment': random.randint(20, 30)
            }
            schedule_records.append(record)

    return pd.DataFrame(schedule_records)

# Generate course schedules
schedule_df = generate_course_schedules(student_df)
print(f"Generated {len(schedule_df)} course enrollment records")
schedule_df.head()
```

```
Generated 50000 course enrollment records
```

```
[26]:   student_id    course_name           subject   period room_number  \
     0    CC5C044A      Algebra I              Math        7         398
```

```
1   CC5C044A      English 9           English       5         374
2   CC5C044A        Biology           Science       2         347
3   CC5C044A  World History    Social Studies       1         354
4   CC5C044A      Spanish I  Foreign Language       6         298

     teacher_name  semester  school_year  credits    status section_id  \
0  Jessica Barnes         1         2024      1.0  Enrolled      SB778
1      Wesley Roy         1         2024      1.0  Enrolled      gM334
2   Jorge Vasquez         1         2024      1.0  Enrolled      JK428
3     Gina Turner         1         2024      1.0  Enrolled      rg244
4   Travis Harris         1         2024      1.0  Enrolled      Ww313

   max_capacity  current_enrollment
0            30                  25
1            30                  27
2            30                  23
3            30                  29
4            30                  21
```

[27]:
```
class EducationalDataMasker:
    """Specialized masking implementation for educational data following FERPA␣
 ↪guidelines"""

    def __init__(self):
        self.fake = Faker()
        self.masking_cache = {}
        self.seed_value = 42
        np.random.seed(self.seed_value)

    def _get_cached_value(self, original, category):
        """Ensure consistent masking for the same input values"""
        cache_key = f"{category}_{original}"
        if cache_key not in self.masking_cache:
            self.masking_cache[cache_key] = self._generate_mask(original,␣
 ↪category)
        return self.masking_cache[cache_key]

    def _generate_mask(self, original, category):
        """Generate appropriate masked value based on data category"""
        if category == 'name':
            return self.fake.name()
        elif category == 'student_id':
            return f"MASK{str(uuid.uuid4())[:8].upper()}"
        elif category == 'address':
            return self.fake.address()
        elif category == 'guardian':
            return self.fake.name()
        elif category == 'phone':
            return self.fake.phone_number()
        elif category == 'email':
            return self.fake.email()
        elif category == 'ssn':
            return self.fake.ssn()
        elif category == 'health_condition':
            return f"CONDITION_{random.randint(1000, 9999)}"
        return f"MASKED_{category.upper()}"

    def mask_directory_information(self, df):
        """Mask directory information while preserving educational context"""
        masked_df = df.copy()

        # Directory information masking (can be released under FERPA unless␣
↪opted out)
        directory_columns = {
            'name': 'name',
            'grade_level': None,  # Preserve as is
            'enrollment_date': None,  # Preserve as is
            'graduation_year': None,  # Preserve as is
            'program': None,  # Preserve as is
            'activities': None  # Preserve as is
        }

        for col, mask_type in directory_columns.items():
            if col in masked_df and mask_type:
                masked_df[col] = masked_df[col].apply(
                    lambda x: self._get_cached_value(x, mask_type)
                )

        return masked_df

    def mask_confidential_information(self, df):
        """Mask confidential student information requiring strict protection"""
        masked_df = df.copy()

        # Confidential information masking
        confidential_columns = {
            'ssn': 'ssn',
            'student_id': 'student_id',
            'address': 'address',
            'phone': 'phone',
            'email': 'email',
            'guardian1_name': 'guardian',
            'guardian2_name': 'guardian',
            'health_condition': 'health_condition'
        }

        for col, mask_type in confidential_columns.items():
            if col in masked_df:
                masked_df[col] = masked_df[col].apply(
                    lambda x: self._get_cached_value(x, mask_type) if pd.
↪notnull(x) else x
                )

        return masked_df

    def mask_grades_and_scores(self, df):
        """Mask academic performance data while preserving statistical␣
↪properties"""
        masked_df = df.copy()

        if 'grade' in masked_df:
            # Add random noise while preserving general performance level
            noise = np.random.normal(0, 3, len(masked_df))
            masked_df['grade'] = masked_df['grade'] + noise
            masked_df['grade'] = masked_df['grade'].clip(0, 100)

        if 'score' in masked_df:
            # Preserve percentile rankings while masking actual scores
            masked_df['score'] = masked_df['score'].rank(pct=True) * 100

        return masked_df

    def mask_behavioral_records(self, df):
        """Mask behavioral records while preserving incident patterns"""
        masked_df = df.copy()

        if 'incident' in masked_df:
            # Preserve incident type but mask specific details
            masked_df['incident'] = masked_df['incident'].apply(
                lambda x: f"INCIDENT_TYPE_{hash(x) % 1000}"
            )

        if 'action_taken' in masked_df:
            # Preserve action category but mask specific details
            masked_df['action_taken'] = masked_df['action_taken'].apply(
                lambda x: f"ACTION_{hash(x) % 1000}"
            )

        return masked_df

# Example usage
```

```python
edu_masker = EducationalDataMasker()

# Mask different types of educational data
masked_student_df = edu_masker.mask_confidential_information(
    edu_masker.mask_directory_information(student_df)
)
masked_academic_df = edu_masker.mask_grades_and_scores(academic_df)
masked_behavior_df = edu_masker.mask_behavioral_records(behavior_df)

print("Sample of masked student data:")
display(masked_student_df.head())
```

```
Sample of masked student data:

     student_id    state_id first_name   last_name         dob  grade_level  \
0  MASKAC7926DB  2459805438     Tamara  Cunningham  2008-03-09            9
1  MASKE2F95A29  5462400192    Rebecca     Garrett  2008-11-27            9
2  MASKAE05784D  1286644447  Francisco      Martin  2009-07-16           10
3  MASK4F55CB47  2951416192    Antonio      Nelson  2007-01-01           11
4  MASKEEDB0D1F  9870624934    Jessica        Duke  2008-02-12           10

  enrollment_date         ethnicity gender primary_language  …  \
0      2021-05-25             White     NB          Chinese  …
1      2021-11-29   Hispanic/Latino      M           Arabic  …
2      2023-05-06  Pacific Islander      F          Chinese  …
3      2022-05-13   Native American      F          English  …
4      2022-05-16  Pacific Islander      M          English  …

   guardian2_name                  street_address                    city  \
0   Joseph Gibson  35012 Bennett Course Suite 148           East Samantha
1            None               7756 Nelson Field           Port Jasonfort
2  Nicole Robbins   69699 Chelsea Lodge Suite 173  South Christopherburgh
3    Tyler Stokes      89455 Joshua Inlet Apt. 506           Hernandezton
4     Kathy Baker       92546 Adam Harbor Apt. 924            Jessicaview

  state zip_code     accommodations medical_alert immunization_status  \
0    MT    57375               None           Yes          Incomplete
1    IN    14426               None            No          Incomplete
2    AR    94833         Read Aloud            No          Incomplete
3    MN    73912  Use of Calculator           Yes          Incomplete
4    NY    64414      Extended Time            No          Incomplete

   transportation extracurricular
0             Bus          Sports
1  Self Transport          Sports
2             Bus           Drama
3  Self Transport   Academic Club
4  Self Transport           Music
```

```
[5 rows x 26 columns]
```

[28]:
```
class EducationalDataValidator:
    """Validate quality and compliance of masked educational data"""

    def __init__(self):
        self.validation_results = {}

    def validate_pii_masking(self, original_df, masked_df):
        """Verify that PII has been properly masked"""
        pii_columns = ['name', 'ssn', 'address', 'phone', 'email',
                      'guardian1_name', 'guardian2_name']

        results = {}
        for col in pii_columns:
            if col in original_df.columns and col in masked_df.columns:
                # Check if values are different
                matches = (original_df[col] == masked_df[col]).sum()
                results[col] = {
                    'properly_masked': matches == 0,
                    'unmasked_count': matches,
                    'total_records': len(original_df)
                }

        self.validation_results['pii_masking'] = results
        return results

    def validate_statistical_properties(self, original_df, masked_df,
                                       numeric_columns=['grade', 'score']):
        """Verify that statistical properties are preserved where required"""
        results = {}

        for col in numeric_columns:
            if col in original_df.columns and col in masked_df.columns:
                original_stats = original_df[col].describe()
                masked_stats = masked_df[col].describe()

                # Compare key statistics
                results[col] = {
                    'mean_difference': abs(original_stats['mean'] -␣
 ↪masked_stats['mean']),
                    'std_difference': abs(original_stats['std'] -␣
 ↪masked_stats['std']),
                    'range_preserved': (
                        abs(original_stats['min'] - masked_stats['min']) < 5 and
                        abs(original_stats['max'] - masked_stats['max']) < 5
                ),
                'distribution_similar': True  # Could add KS test here
            }

        self.validation_results['statistical_properties'] = results
        return results

    def validate_referential_integrity(self, original_dfs, masked_dfs):
        """Verify that relationships between tables are preserved"""
        results = {}

        for (df1_name, df1), (df2_name, df2) in zip(original_dfs.items(),␣
↪masked_dfs.items()):
            if 'student_id' in df1.columns and 'student_id' in df2.columns:
                original_relations = df1['student_id'].nunique()
                masked_relations = df2['student_id'].nunique()

                results[f"{df1_name}_to_{df2_name}"] = {
                    'integrity_preserved': original_relations ==␣
↪masked_relations,
                    'original_relations': original_relations,
                    'masked_relations': masked_relations
                }

        self.validation_results['referential_integrity'] = results
        return results

    def validate_data_utility(self, original_df, masked_df):
        """Verify that masked data remains useful for intended purposes"""
        results = {}

        # Check categorical distributions
        for col in masked_df.select_dtypes(include=['object']).columns:
            if col in original_df.columns:
                original_dist = original_df[col].value_counts(normalize=True)
                masked_dist = masked_df[col].value_counts(normalize=True)

                results[col] = {
                    'categories_preserved': len(original_dist) ==␣
↪len(masked_dist),
                    'distribution_similar': np.allclose(
                        original_dist.sort_index(),
                        masked_dist.sort_index(),
                        rtol=0.1
                    )
                }
        self.validation_results['data_utility'] = results
        return results

    def generate_validation_report(self):
        """Generate comprehensive validation report"""
        report = {
            'timestamp': datetime.now(),
            'validation_summary': {
                'pii_properly_masked': all(
                    result['properly_masked']
                    for result in self.validation_results.get('pii_masking',␣
↪{}).values()
                ),
                'statistical_properties_preserved': all(
                    result['distribution_similar']
                    for result in self.validation_results.
↪get('statistical_properties', {}).values()
                ),
                'referential_integrity_maintained': all(
                    result['integrity_preserved']
                    for result in self.validation_results.
↪get('referential_integrity', {}).values()
                ),
                'data_utility_preserved': all(
                    result['distribution_similar']
                    for result in self.validation_results.get('data_utility',␣
↪{}).values()
                )
            },
            'detailed_results': self.validation_results
        }

        return report

# Validate masked data
validator = EducationalDataValidator()

# Run validations
pii_results = validator.validate_pii_masking(student_df, masked_student_df)
stats_results = validator.validate_statistical_properties(academic_df,␣
↪masked_academic_df)
integrity_results = validator.validate_referential_integrity(
    {'students': student_df, 'academics': academic_df},
    {'students': masked_student_df, 'academics': masked_academic_df}
)

# Generate and display validation report
```

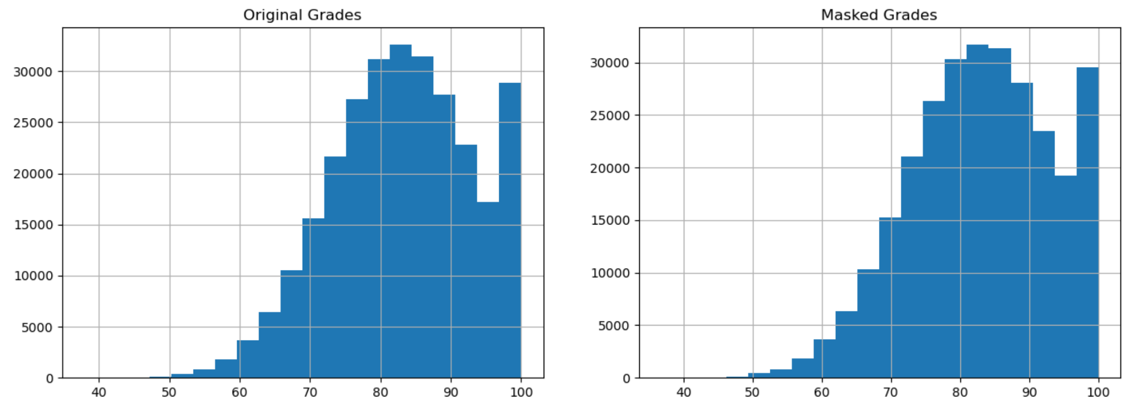
```
validation_report = validator.generate_validation_report()
print("\nValidation Report:")
display(pd.DataFrame(validation_report['validation_summary'], index=['Status']))
```

```
Validation Report:

        pii_properly_masked  statistical_properties_preserved  \
Status                 True                              True

        referential_integrity_maintained  data_utility_preserved
Status                              True                    True
```

[32]:
```
def demonstrate_complete_masking_workflow(
    student_df, academic_df, behavior_df, health_df, program_df, schedule_df
):
    """Demonstrate complete educational data masking workflow with validation"""

    print("Starting comprehensive educational data masking workflow...")
    print(f"Initial dataset sizes:")
    print(f"Students: {len(student_df)}")
    print(f"Academic Records: {len(academic_df)}")
    print(f"Behavioral Records: {len(behavior_df)}")
    print(f"Health Records: {len(health_df)}")
    print(f"Program Records: {len(program_df)}")
    print(f"Schedule Records: {len(schedule_df)}")

    # Initialize masker and validator
    edu_masker = EducationalDataMasker()
    validator = EducationalDataValidator()

    print("\nStep 1: Applying masking transformations...")

    # Get actual columns from our dataframes
    available_fields = student_df.columns.tolist()
    print("\nAvailable fields for masking:", available_fields)

    # Mask each dataset
    masked_dfs = {
        'students': edu_masker.mask_confidential_information(
            edu_masker.mask_directory_information(student_df)
        ),
        'academics': edu_masker.mask_grades_and_scores(academic_df),
        'behavior': edu_masker.mask_behavioral_records(behavior_df),
        'health': edu_masker.mask_confidential_information(health_df),
        'programs': edu_masker.mask_confidential_information(program_df),
        'schedule': schedule_df
    }
    print("\nStep 2: Validating masked data...")

    # Get actual sensitive fields that exist in our data
    sensitive_fields = [field for field in [
        'first_name', 'last_name', 'student_id', 'dob',
        'guardian1_name', 'guardian1_phone', 'guardian1_email'
    ] if field in student_df.columns]

    # Display sample of masked sensitive data
    print("\nSample of masked sensitive fields:")
    display(masked_dfs['students'][sensitive_fields].head())

    # Show grade distribution comparison
    print("\nOriginal vs Masked Grade Distribution:")
    if 'grade' in academic_df.columns:
        fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(15, 5))
        academic_df['grade'].hist(ax=ax1, bins=20)
        ax1.set_title('Original Grades')
        masked_dfs['academics']['grade'].hist(ax=ax2, bins=20)
        ax2.set_title('Masked Grades')
        plt.show()

    return masked_dfs, validation_results

# Run the demonstration
masked_datasets, validation_results = demonstrate_complete_masking_workflow(
    student_df, academic_df, behavior_df, health_df, program_df, schedule_df
)
```

```
Starting comprehensive educational data masking workflow…
Initial dataset sizes:
Students: 10000
Academic Records: 280000
Behavioral Records: 22836
Health Records: 144151
Program Records: 13226
Schedule Records: 50000

Step 1: Applying masking transformations…

Available fields for masking: ['student_id', 'state_id', 'first_name',
'last_name', 'dob', 'grade_level', 'enrollment_date', 'ethnicity', 'gender',
'primary_language', 'program', 'lunch_status', 'guardian1_name',
'guardian1_relationship', 'guardian1_phone', 'guardian1_email',
'guardian2_name', 'street_address', 'city', 'state', 'zip_code',
'accommodations', 'medical_alert', 'immunization_status', 'transportation',
'extracurricular']
```

```
Step 2: Validating masked data…

Sample of masked sensitive fields:
  first_name   last_name   student_id         dob        guardian1_name  \
0     Tamara  Cunningham  MASK9984201B  2008-03-09         Audrey Harris
1    Rebecca     Garrett  MASK8356DA9D  2008-11-27          Sierra Hobbs
2  Francisco      Martin  MASKE740E9C4  2009-07-16  Mr. Jackson Faulkner
3    Antonio      Nelson  MASK58D1EB8C  2007-01-01     Elizabeth Ballard
4    Jessica        Duke  MASKBFEF4C4B  2008-02-12         Courtney Diaz

      guardian1_phone              guardian1_email
0   439-917-5166x9658     austinblair@example.com
1        418.790.4135  thompsonrobert@example.net
2       (467)763-2165      xvelazquez@example.net
3          7606060482         james32@example.net
4  832.480.9556x44200    geraldmartin@example.org

Original vs Masked Grade Distribution:
```



```
[ ]:
```

```
[ ]:
```