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University of Hawai'i at Mānoa
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2430 Campus Road, Gartley Hall
Honolulu, Hawai'i 96822

Website: <http://hawaiijournalhealth.org/>

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Prevalence of Vitamin D Deficiency in Military Dependent Infants in Hawai'i

Morgan F Smith, DO¹, Brandon L Rozanski, MD¹, Claire P Witmer, MD¹, Dolores Mullikin, MD², Sebastian K Welsh, MD¹

¹ Pediatrics Department, Tripler Army Medical Center, ² Pediatrics Department, Mary Bridge Children's Health Center

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Abstract

This study aimed to determine the prevalence of vitamin D deficiency and insufficiency among military dependent infants in the state of Hawai'i. A cross-sectional study was conducted at Tripler Army Medical Center and included samples from 30 healthy, full-term infants around 4 months of age. Serum 25-hydroxyvitamin D levels were measured, and caregivers completed questionnaires about the infant's diet, vitamin D supplementation, race/ethnicity, and military sponsor pay grade. Results revealed that 90% of infants had sufficient vitamin D levels (>20 ng/mL), with 3% deficient and 7% insufficient. The prevalence of deficiency and insufficiency was comparable to studies conducted in other regions of the United States. This is the first study to investigate infant vitamin D status in Hawai'i using serum 25-hydroxyvitamin D. Vitamin D status varied significantly by race/ethnicity. The average vitamin D level of Black or African American infants was in the insufficient range and was significantly lower than that observed in White/Caucasian and Hispanic infants. Notably, several exclusively breastfed infants who did not receive vitamin D supplementation had sufficient vitamin D levels. While study limitations include a small sample size and cross-sectional design, the findings warrant continued investigation into the prevalence of vitamin D deficiency and insufficiency among military dependent infants in Hawai'i. Future research should explore the influence of race/ethnicity and socioeconomic status on infant vitamin D levels in Hawai'i and consider the impact of maternal vitamin D status, especially in exclusively breastfed infants. This could lead to more targeted vitamin D supplementation recommendations in clinical practice and potentially improve resource allocation.

Abbreviations and Acronyms

AAP = American Academy of Pediatrics

AI = adequate intake

EAR = estimated average requirement

IU = international units

RDA = recommended dietary allowance

TAMC = Tripler Army Medical Center

UV = ultraviolet

25(OH)D = 25-hydroxyvitamin D

Introduction

Vitamin D plays a critical role in calcium absorption, bone development, and the prevention of nutritional rickets.¹⁻⁵ In 2008, the American Academy of Pediatrics (AAP) published a clinical report recommending that all infants receive 400 international units (IU) of vitamin D daily, either through vitamin D-fortified formula or oral supplementation for exclusively breastfed infants. These recommendations were based on clinical evidence and historical safety data, emphasizing the importance of considering factors such as skin pigmentation and geographic location, as infants with darker skin or those living at northern latitudes showed higher rates of vitamin D deficiency rickets.¹ In 2012, AAP endorsed updated recommendations from the National Academy of Medicine, which continued to support an adequate intake (AI) of 400 IU/day for infants under 12 months.³ For this age group, the report cited insufficient evidence to establish an estimated average requirement (EAR) or recommended dietary allowance (RDA), so experts used an AI level instead. In contrast, for children aged 1 to 18 years, evidence supports the establishment of both an EAR and RDA, resulting in higher recommended daily intake levels.³ While current guidelines prioritize dietary supplementation due to the risks associated with excessive sun exposure, most vitamin D is typically synthesized in the skin after ultraviolet (UV) radiation.^{1,3,6}

Despite abundant sun exposure in Hawai'i, studies have identified a high prevalence of vitamin D deficiency among adults living in the state.⁷⁻⁹ A high prevalence of neonatal vitamin D deficiency has also been implicated by a 2013 study at Tripler Army Medical Center (TAMC), which found that only 7% of cord plasma 25(OH)D (25-hydroxyvitamin D) samples from military dependent newborns met the recommended vitamin D levels.¹⁰ While cord blood reflects maternal vitamin D status, it has not been found to reliably predict infant serum levels or long-term vitamin D sufficiency.¹⁰⁻¹² Multiple studies have investigated infant vitamin D status in the United States (US) by measuring serum 25(OH)D, but most were conducted in areas of low UV index such as the Midwest or Northeast.¹³⁻¹⁶ A higher UV index is associated with increased cutaneous vitamin D synthesis.¹⁷ Another study measured serum 25(OH)D in infants 6-19 months of age in an area of relatively higher UV index - Sacramento, California.^{18,19} No study has yet investigated the prevalence of vitamin D deficiency in infants living in Hawai'i by measuring serum 25(OH)D.

The potential consequences of vitamin D deficiency, which include fractures and rickets, underscore the importance of preventive measures.⁴ Although no cases of infantile vitamin D deficiency rickets have been reported in Hawai'i, it is routine practice at TAMC to prescribe oral vitamin D supplementation to all newborns. This practice follows national guidelines, despite unknown parental adherence to vitamin D supplementation. A 2020 study showed that up to 73% of US parents do not administer vitamin D supplements to their infants as advised.²⁰

The utility of routine supplementation has recently been challenged. A 2023 randomized controlled trial involving Mongolian children aged 6 to 13 years found no difference in fracture rates between children who received vitamin D supplements and those in the placebo-supplementation group.⁴ Combined with low adherence, the lack of vitamin D deficiency-related rickets in Hawai'i, and abundant sun exposure, this raises doubts about the effectiveness and necessity of universal supplementation in the infant population.

To inform future clinical decision-making and resource distribution, this study aims to determine the prevalence of vitamin D deficiency among military dependent infants in the TAMC patient population. TAMC pharmacy purchases vitamin D drops so that supplementation may begin at birth, then transitions that cost to TRICARE, the US military's health care program, after the first bottle. At \$6.24 per bottle and an average of 115 deliveries each month, TAMC and TRICARE, spend approximately \$8800 and \$63000, respectively, on annual vitamin D supplements for infants of military families born in the state of Hawai'i. Annual medical funding at TAMC is \$420 million, so the cost of vitamin D supplementation accounts for less than 1% of TAMC's medical budget but is still an important consideration in terms of cost efficiency. Understanding the local vitamin D status is crucial for evaluating the value and necessity of this practice.

The study population is unique due to its connection with the US military. All participants in this study were dependents of an active-duty military service member. A legal guardian or caregiver with military sponsor status makes an infant eligible for TRICARE and qualifies them to receive care at TAMC. All military service members are assigned a pay grade based on their rank. Pay grades are standardized across all military branches as enlisted (E1-E9), warrant (W1-W5), or officer (O1-O10), with pay increasing at each higher grade or rank. Enlisted service members typically join the Army with a high school diploma, while officers are college graduates who receive a commission; this key educational distinction separates enlisted personnel from officers. Warrant officers, positioned between enlisted members and officers, are technical experts who are usually promoted from the enlisted ranks and receive specialized leadership training. Pay grade was ultimately included in the questionnaire as a proxy for socioeconomic status. The caregiver who completed the survey may or may not have been the military sponsor whose pay grade was recorded.

Methods

Study Design: This study employed a cross-sectional design to investigate vitamin D levels in military dependent infants at TAMC at approximately 4 months of age. The study protocol was approved by the Madigan Army Medical Center Institutional Review Board, approval #224073. Investigators adhered to the policies for protection of human subjects as prescribed in 45 Code of Federal Regulation 46.

Study Participants: A total of 40 infants were recruited and consented at the TAMC General Pediatrics Clinic during routine well-child visits between May 2024 and April 2025. Exclusion criteria included a history of prematurity (<37 weeks of gestation), birth weight less than 2000 grams, chronological age less than 3.5 months or greater than 4.5 months at the time of blood sample collection, presence of a chronic disease, or use of medications known to affect vitamin D metabolism during the first 4 months of life. Recruitment typically occurred on the same day as consent and sample collection. Most often, pediatric providers at TAMC who were not members of the research team would mention the study to their patients, and if they expressed interest the provider would notify the research team prior to the patient being discharged from the clinic. A research team member would then present to the clinic to discuss the study further in person. In a few cases, recruitment occurred days or weeks prior to the well-child visit via caregiver outreach using contact information included in the study advertisement flyer. Consent and sample collection occurred on the same day regardless of the recruitment method, during or after completion of the well-child visit. After sample collection, 8 infants were excluded due to inadequate blood samples for laboratory analysis. Additionally, 2 more infants were excluded due to laboratory processing errors. A total of 30 infants had adequate blood samples and were included in the final data analysis.

Clinical Data: The investigators conducted a chart review of the participant's medical records to gather clinical information, including the infant's age in days, sex, birth weight, and estimated gestational age at birth.

Laboratory Measurements: A single blood sample (0.5 mL) was collected from each participant in the TAMC General Pediatrics Clinic treatment room. The TAMC Core Laboratory measured serum levels using the Abbott Architect assay. Investigators reviewed the participants' medical records to obtain lab results and communicated the findings to caregivers by phone.

Nutritional and Demographic Data: At the time of sample collection, participants' caregivers completed a questionnaire through the institutional version of the online survey tool SurveyMonkey (SurveyMonkey, Inc, San Mateo, CA). The questionnaire collected information about the infant's diet (exclusive breastfeeding, formula feeding, or a combination), frequency of vitamin D supplementation, race/ethnicity, and the military sponsor's pay grade. If an infant had more than one caregiver who qualified as a military sponsor, the higher pay grade was recorded. Caregivers classified the infant's race/ethnicity using predefined categories: American Indian or Alaskan Native, Asian/Pa-

cific Islander, Black or African American, Hispanic, White/Caucasian, Multiple Ethnicity/Other. The study collected racial and ethnic data following current pediatric guidelines, which recommend considering skin pigmentation in vitamin D supplementation practices for infants, due to the higher prevalence of rickets from vitamin D deficiency among infants identified as Black.

Results

A total of 30 subjects provided sufficient blood volume for analysis (Table 1). The most frequently reported diet was exclusive breastfeeding (n=12, 40%), while the remaining subjects were evenly divided between formula-fed (n=9, 30%) and combination formula-breastfed (n=9, 30%). Among caregivers, 25% reported providing the recommended daily vitamin D supplementation, whereas 40% reported providing no supplementation.

The most frequently reported race/ethnicity was White/Caucasian (n=14, 47%), while the least frequent was Black or African American (n=2, 7%). Enlisted service members comprised 66% (n=20) of the infant's military sponsors, with the remainder consisting of officers. The average participant age was 125 days old (SD=4), with a mean estimated gestational age of 39 weeks (SD=1) and a mean birth weight of 3348.8 grams (SD=538).

Vitamin D status was classified in this study as deficient (< 12 ng/mL or < 30 nmol/L), insufficient (12-19 ng/mL or 30-49 nmol/L), or sufficient (>20 ng/mL or >50 nmol/L). The mean serum 25(OH)D was 47.32 ng/mL (SD=20.18). Vitamin D deficiency was identified in 3% (n=1) of infants, insufficiency in 7% (n=2), and sufficiency in 90% (n=27). Serum 25(OH)D levels varied by race/ethnicity (ANOVA, $F=3.81$, $P=.015$) and sponsor pay grade (ANOVA, $F=7.16$, $P<.001$) (Figure 1, Table 2). No other variables demonstrated statistically significant differences.

Discussion

This study investigated vitamin D levels in a cohort of 30 healthy, full-term infants at TAMC in the state of Hawai'i. The average serum 25(OH)D level was 47.32 ng/mL, compared to 35.2 ng/mL in 4-month-old infants in Massachusetts, where the UV index ranges from 1-8 compared to the typical UV index range of 7-13 in the state of Hawai'i.^{15,16} The difference in UV index may explain, in part, the difference between 25(OH)D levels in similarly-aged healthy populations. The 25(OH)D level found in Hawai'i is also higher than the 85 nmol/l (approximately 34 ng/mL) discovered in infants aged 6-19 months in California, a state of relatively high sun exposure.¹⁸ Vitamin D deficiency was found in 3% of the infants, and insufficiency in 7%, while 90% had sufficient levels. The combined 10% deficiency and insufficiency was like other studies (11% Liang et al, 11.9% Merewood et al). Prior to the study, a prevalence threshold of $\geq 5\%$ deficiency and/or insufficiency was determined to be clinically significant. This level was based on the World Health Organization's (WHO) prevalence cut-off value for public health significance regarding anemia, which was de-

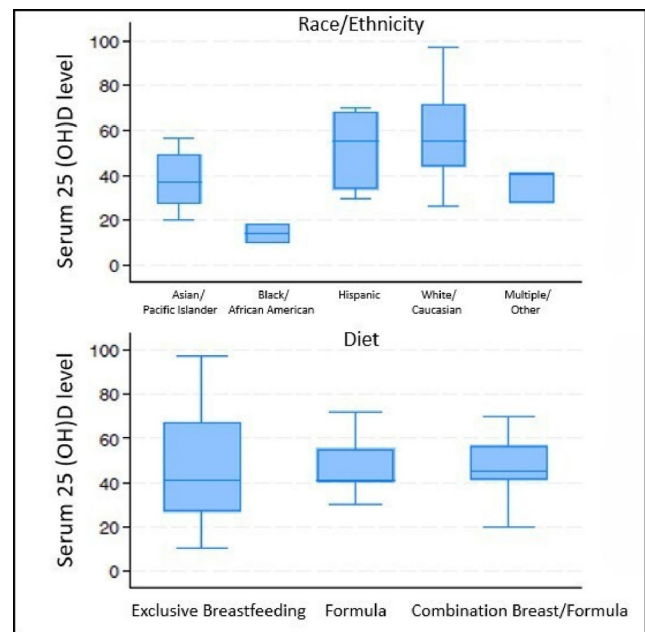


Figure 1. Serum 25-Hydroxyvitamin D (25(OH)D) Levels among Infants by Demographic and Clinical Variables, Tripler Army Medical Center, May 2024-April 2025^a

Box plots comparing serum 25(OH)D levels in ng/mL across race/ethnicity and diet. Boxes represent interquartile range; horizontal lines indicate medians; whiskers show the range within 1.5-times interquartile range (IQR).

^aThe average serum 25(OH)D level for Black or African American infants was in the insufficiency range and was significantly lower than levels observed in White/Caucasian and Hispanic infants (ANOVA, $F=3.81$, $P=.015$).

termined to be analogous to vitamin D deficiency since the WHO has not published prevalence cut-off values for the public health significance of vitamin D deficiency.²¹ If this determination is viewed as appropriate, this study shows that the military-dependent infant population in Hawai'i has a mild vitamin D deficiency and insufficiency population-level problem.²¹ Despite the prevalence reaching clinical significance, it is far below the previously reported prevalence of 93% in the TAMC neonatal population.¹⁰ Cord blood vitamin D levels likely do not accurately reflect postnatal vitamin D status due to maternal contribution and physiological changes after birth. Measuring serum 25(OH)D in infants offers a more precise assessment of their current vitamin D status.

Differences in mean vitamin D levels were observed among racial and ethnic groups. Black or African American infants had the lowest average serum 25(OH)D level (14.15 ng/mL), which approached the deficiency threshold and was markedly lower than levels observed in White/Caucasian (56.97 ng/mL) and Hispanic (51.38 ng/mL) infants. This disparity is likely attributable to increased melanin pigmentation in darker skin, which can reduce the efficiency of cutaneous vitamin D synthesis as significantly more sun exposure is required to generate adequate levels.¹ In a sun-rich environment like Hawai'i, these findings suggest that other factors, such as cultural practices, clothing habits, and outdoor time, may also influence vitamin D levels.

Table 1. Demographic and Neonatal Characteristics of Infant Vitamin D Study Participants, Tripler Army Medical Center, May 2024-April 2025

	# of Participants (% of total)
Total Participants	30 (100%)
Race/Ethnicity	
Asian/Pacific Islander	6 (20%)
Black or African American	2 (7%)
Hispanic	5 (17%)
White/Caucasian	14 (47%)
Multiple Ethnicity / Other	3 (10%)
Sex	
Male	11 (37%)
Female	19 (63%)
Military Sponsor's Pay grade (Monthly Basic Pay)^a	
E3 (\$2733.00)	2 (7%)
E4 (\$3027.30)	6 (21%)
E5 (\$3220.50)	3 (11%)
E6 (\$3276.60)	7 (25%)
E7 (\$3788.10)	2 (7%)
O2 (\$4606.80)	1 (4%)
O3 (\$5331.60)	4 (14%)
O4 (\$6064.20)	2 (7%)
O5 (\$7028.40)	1 (4%)
Diet	
Exclusive Breastfeeding	12 (40%)
Formula Fed	9 (30%)
Combination Breast and Formula	9 (30%)
Caregiver-Reported Days per Week of Vitamin D Administration^b	
0	12 (40%)
1	4 (13%)
4	3 (10%)
5	2 (7%)
6	1 (3%)
7	8 (27%)
Vitamin D Status	
Deficient	1 (3%)
Insufficient	2 (7%)
Sufficient	27 (90%)
Perinatal/Neonatal Characteristics	
	Mean (SD)
Birthweight in Grams	3348.8 (538)
Estimated Gestational Age at Birth in Weeks	39 (1)
Age at 25 (OH)D Testing in Days	125 (4)

^aNo participants reported a pay grade of E1, E2, E8, E9, O1, or O6-O10. Enlisted ranks start with the letter "E" with more senior level indicated by higher number in comparison to more junior level indicated by lower number. Similar for officer ranks that start with the letter "O". Fiscal Year 2025 Monthly Basic Pay Rates for Active-duty service members with 2 or less Cumulative Years of Service are included after each pay grade in parentheses.

^bNo caregivers reported vitamin D administration on average 2 or 3 days per week.

Infants identified as Asian/Pacific Islander and Multiple/Other demonstrated intermediate vitamin D levels, underscoring the heterogeneity within these broad categories and the complexity of the relationship between race/ethnicity and vitamin D levels. Within the Asian/Pacific Islander designation, considerable variation in skin pigmentation and cultural practices likely contribute to the observed variability and intermediate average. The "Multi-

ple/Other" category is too broad to draw specific conclusions from the results.

A major limitation of this study is its small sample size, particularly within subgroup analyses. The extremely low number of Black or African American participants limits the generalizability of findings to the broader population of Black or African American infants in Hawai'i. Further studies with larger and more representative samples are crucial.

Table 2. Mean Serum 25(OH)D Levels Among Infant Vitamin D Study Participants by Demographic and Clinical Variables, Tripler Army Medical Center, May 2024-April 2025

Variable	Mean 25 (OH)D (ng/mL) ^a	Standard deviation
All Participants	47.32	20.18
Diet		
Exclusive Breastfeeding	46.85	27.35
Formula Fed	47.73	14.60
Combination Breast and Formula	47.53	15.30
Race/Ethnicity		
Asian/Pacific Islander	37.91	13.66
Black or African American	*14.15	5.86
Hispanic	51.38	18.67
White/Caucasian	56.97	19.33
Multiple Ethnicity / Other	36.43	7.65
Caregiver-Reported Days per Week of Vitamin D Administration^b		
0	45.60	24.69
1	36.47	7.50
4	42.4	24.88
5	60.7	28.99
6	63.8	-
7	51.75	14.59
Military Sponsor's Pay grade^c		
E3	36.95	9.97
E4	33.36	16.91
E5	25	4.41
E6	53.54	12.52
E7	29.7	4.80
O2	71.5	-
O3	61.97	9.12
O4	89.25	11.38
O5	40.5	-
Sex		
Male	40.16	17.40
Female	51.46	20.94

^aMean 25 (OH)D level falls within insufficient category (12-19 ng/mL).

^bNo caregivers reported vitamin D administration on average 2 or 3 days per week

^cNo participants reported a pay grade of E1, E2, E8, E9, O1, or O6-O10.

Despite this limitation, these findings support the need for routine vitamin D supplementation and increased awareness of potential vitamin D insufficiency and deficiency in high-risk groups, including Black or African American infants, even in regions with abundant sunlight. Health care providers should consider these disparities when evaluating and treating infants.

Although significant variation in vitamin D levels was observed among sponsor pay grade groups, a clear linear trend was not identified. Some officer ranks (ie, O3, O4) showed significantly higher vitamin D levels compared to enlisted ranks, while others (ie, O5) did not. Similarly, vitamin D levels varied within the enlisted ranks. The distrib-

ution of race/ethnicity within each pay grade might not be uniform. A disproportionate number of participants from certain race/ethnic groups in lower pay grades could explain why this group has lower vitamin D levels. The small number of participants in each pay grade, especially at the officer ranks, and the potential interaction between race/ethnicity and pay grade make it difficult to draw definitive conclusions about socioeconomic influences. To properly analyze the effects of race/ethnicity and pay grade on an infant's vitamin D status, a statistical analysis controlling for both variables at the same time is necessary but was not conducted in this study. Larger studies with sufficient

sample sizes within each pay grade are needed to better understand the interaction between these 2 variables.

Notably, several exclusively breastfed infants, including 5 reported as White/Caucasian and 1 as Multiple Ethnicity/Other, had sufficient vitamin D levels despite not receiving the recommended vitamin D supplementation. This observation raises questions regarding the necessity and cost-effectiveness of universal supplementation at TAMC. While universal supplementation may contribute to the overall high sufficiency rate observed in this cohort, a more targeted approach could be more resource efficient.

Despite the low prevalence of vitamin D deficiency and insufficiency, these conditions can have long-term effects on bone health and growth. Even mild deficiency raises the risk of rickets, osteomalacia, and fractures later in life. Therefore, continuous monitoring and targeted interventions for at-risk infants remain crucial.

Strengths of this study include its focus on a specific pediatric population with unique environmental and demographic characteristics, the use of serum 25(OH)D as a direct measure of vitamin D status, and standardized data collection methods. However, as mentioned, generalizability is limited due to the small sample size. Other limitations include the cross-sectional design, which precludes causal inferences. Potential biases related to participant recruitment, such as voluntary participation and possible differences in health-seeking behaviors, may have influenced the results. Additionally, parental reporting of supplementation practices could introduce recall bias.

Future research should include longitudinal studies to monitor vitamin D status over time and assess the long-term impact of various supplementation strategies. Investigating parental knowledge, beliefs, and adherence to supplemental guidelines, as well as environmental and behavioral factors affecting sun exposure, would provide further insight.

The findings suggest that the practice of universal vitamin D supplementation at TAMC may warrant re-evaluation. A more tailored approach that targets infants at higher risk, based on factors such as race/ethnicity and/

or sponsor pay grade, could provide a more cost-effective strategy. Enhanced parental education on vitamin D and supplementation guidelines might also help optimize infant health outcomes. In the end, a personalized strategy that considers individual risk factors is crucial for making informed decisions about vitamin D supplementation.

Conclusion

Most infants in this study had sufficient vitamin D levels despite low adherence to supplementation recommendations. Significant variability observed in vitamin D levels across demographic groups raises questions about the need for universal supplementation in this population. A small sample size limits the ability to generalize the findings, and the cross-sectional design prevents determining causality. Future studies examining maternal serum 25(OH)D levels, especially in exclusively breastfed infants, may offer further insights for refining supplementation recommendations as many exclusively breastfed infants without supplementation in this study were found to be vitamin D replete.

Conflict of Interest Statement

The authors have no competing interests or conflicts of interest to disclose.

Disclaimer

The views expressed in this brief report reflect the results of research conducted by the authors and do not necessarily reflect the official policy or position of the Defense Health Agency, Department of Defense, nor the US Government.

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Effectiveness of Comprehensive Sexual Health Education in 9th Graders of Hawai'i's Public Charter School

Sarah J Thompson, BS¹, Darian L Finley, BS¹, Brooke J Chmiel, BS¹, Chakameh Akhavan, BA¹, Kalena N Spinola, BS¹, Michelle E Balshin, BA, BS¹, Keahealailani M Takushi, BS¹, Surekha Appikatla, MPH¹, Sharon K Hiu, DO¹

¹ School of Osteopathic Medicine of Arizona, A.T. Still University

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Abstract

Current results from the Hawai'i public high schools' Youth Risk Behavior Survey indicate that students continue to engage in risky sexual behaviors that may lead to sexually transmitted infections or unplanned teen pregnancies. This prompted a collaborative work between A.T. Still University-School of Osteopathic Medicine in Arizona 2nd year medical students and educators at a public charter school in Hawai'i to create a comprehensive sexual health education series. The series highlighted the importance of medically accurate knowledge to make informed decisions and promote personal health and wellness. It included lessons on: (1) reproductive anatomy, puberty, and menstruation, (2) pregnancy, family planning, and healthy relationships, (3) contraception, and (4) sexually transmitted infections (STI). Each lesson had a pre-presentation survey, the presentation, an interactive activity, a question and answer session, and a post-presentation survey. All post-presentation surveys showed a statistically significant increase in student knowledge ($P < .001$) indicating that medically accurate information can be effectively delivered to high school students. Students also reported that the activities with the lessons were educational and fun, as it taught them about their bodies, prevention of STI and unintended pregnancies, and the available resources for sexual health care and family planning. Collectively, the students had positive feedback on the lesson series.

Abbreviations and Acronyms

ATSU-SOMA: A.T. Still University-School of Osteopathic Medicine in Arizona

JABSOM: John A. Burns School of Medicine

MSM: men who have sex with men

PCS: public charter school

STD: sexually transmitted disease

STI: sexually transmitted infection

YRBS: Youth Risk Behavior Survey

Background

Implementing an effective and comprehensive sexual health education program in Hawai'i public schools is crucial for providing students the information needed to make responsible decisions about their sexual health. Prior to June 16, 2015, sexual health education in Hawai'i public schools was strictly abstinence-based and had to be from

1 of the 7 Hawai'i Department of Education approved curricula.¹ Abstinence-only based programs continue to receive federal funding despite their failure to reduce sexually transmitted infections (STI) and teen pregnancy, and despite evidence that Americans support a more comprehensive approach to sexual health education.¹ The current standard for sexual health education in the Hawai'i Board of Education Policy 103-5 requires comprehensive sexual health education to be offered at Hawai'i public schools. This includes, but is not limited to, education on healthy relationships, sexual health and sexuality, abstinence and contraceptive use, and methods of contraception to prevent pregnancy and STI.¹

The need for a comprehensive sexual health education program which aims to prevent STI and unplanned pregnancy while also promoting bodily autonomy for Hawai'i students is becoming increasingly important. Based on the 2013, 2015, and 2017 High School Youth Risk Behavior Surveys (YRBS) in Hawai'i, 60% of male students who had sexual contact with males (MSM) did not use a condom during their last sexual intercourse, and 50% of non-MSM high school students (males who had sexual contact with only females) did not use a condom during the last sexual intercourse.² While these statistics show that Hawai'i's youth are engaging in risky behaviors that can lead to unplanned pregnancy or STI transmission, it is also worth noting that Hawai'i's youth also engage in these behaviors at a higher rate than the national average which is measured at 41% of youth who did not use a condom during their last sexual intercourse.¹ Additionally, teen pregnancy rates have historically been high in Hawai'i, especially in rural areas. In 2010, Hawai'i ranked 10th in the US for the highest teen pregnancy rate at 65 per 1,000 women ages 15-19, compared to 57 per 1,000 women ages 15-19 nationally.³ National analyses show a correlation between young parenthood and homelessness.⁴ Teen mothers struggle with graduating from high school and face many financial and emotional obstacles when supporting themselves and their children.⁵ Lower teen pregnancy rates have been found in states offering comprehensive sex education programs that include education on abstinence, but do not emphasize it as the only method or most preferred option.¹

Findings about high-risk sexual behaviors from Hawai'i's youth make it imperative to provide comprehensive sexual health education programs in public schools especially in rural areas where there are higher rates of unplanned teen

pregnancy and STI. Without action or a curriculum mandate, schools and students may lack the resources necessary to offer effective sexual health education classes. Thus, this project aimed to construct and implement a comprehensive evidence-based sexual health education program that can equip students with the necessary knowledge to make educated choices when it comes to their sexual health.

Methodology

Due to the shared desire of the faculty and administration at a public charter school (PCS) to implement an extensive and comprehensive sexual health education program into the 9th grade health curriculum, this program was designed with consideration for current sexual health trends exhibited by Hawai'i's youth based on data collected from the 2013, 2015, and 2017 YRBS.² Prior to the program, all students were given take-home consent forms to discuss with their parents or legal guardians. The consent also covered participation in anonymous surveys from which parents or legal guardians could opt-out. Parents or legal guardians could withdraw their child/children from the program. Signed forms indicated parental consent and had to be received by the school prior to starting the first lesson. Participating students could opt out anytime they felt uncomfortable. Study design was given non-jurisdiction determination through the A.T. Still University Arizona Institutional Review Board (IRB Protocol #2024-012).

All 71 9th grade students were recruited into the program; however, only 50 students were enrolled in a health class during the time of implementation and were therefore eligible to participate. Of these, 48 students opted into the program and 2 students opted out. This curriculum was initially implemented in the Fall semester of 2023 with 10th grade students at the PCS using the same lesson plans, presentations, and pre- and post-survey questions described below. The current project was conducted in the Spring semester of 2024 with 9th grade students. All 48 participating students attended Lesson 1; however, attendance decreased to 42 students for Lessons 2–4 due to absences on the planned days. The participants were divided into 2 classrooms. Each classroom had at least 2 presenters who were 2nd year medical students from A.T. Still University-School of Osteopathic Medicine in Arizona (ATSU-SOMA). The series was designed to encompass four, 1-hour long class periods that began with a brief introduction of the presenters, as well as a reminder of classroom rules and expectations. This was followed by a 10-minute anonymous pre-presentation survey to gauge prior knowledge or interest on the respective subject matter. Lessons 1, 2, and 4 were previously developed by a project team member for high school health courses and modified by the project team, while Lesson 3 was created by the project team. All information included in lesson plans were confirmed with information found in academic journal articles and UpToDate.⁶ Questions on pre-participation surveys were worded to be objective with overt correct answers. Survey questions were created by the project team based on the topic of the les-

son (Table 1). This was followed by a 20-minute PowerPoint presentation that emphasized the goals and objectives of the specific lesson. Students then participated in a 15-minute engaging activity tailored to the specific topic, followed by a brief question and answer (Q & A) session. Extra time throughout the series was also allocated for additional questions from the students. At the end of each session, students received a small token of appreciation, such as a snack or health-themed sticker, to acknowledge their participation.

The content of the 4 lessons are summarized here:

Lesson 1: Reproductive Anatomy, Puberty, and Menstruation

The program emphasized the importance of creating a safe space for learning about sex and health while providing students with a standard foundation of knowledge regarding the reproductive system. Topics covered male and female reproductive anatomy, physiology, pubertal changes, and menstruation, including the use of different menstrual products. Students completed an anatomical diagram depicting important structures of the reproductive system and discussed how menstruation and puberty may affect them.

Lesson 2: Pregnancy, Family Planning, and Healthy Relationships

Pregnancy was discussed, including its physiological processes, associated mental and physical changes, and potential complications. Students participated in an interactive family planning simulation that put them in different socioeconomic scenarios with a budget allowing them to experience financial responsibility and parenting. It concluded by addressing consent and healthy relationships.

Lesson 3: Contraception

The lesson included a review of pregnancy, covering conception and an overview of labor and spontaneous vaginal delivery. Types of contraceptives and pregnancy termination were also introduced. Students simulated the anatomical changes of labor and delivery using a balloon and ping pong ball. The balloon represented the uterus, its opening the cervix, and the ping pong ball the fetal head. Local resources for family planning were provided to students.

Lesson 4: Sexually Transmitted Infections

The lesson focused on STI presentation and symptoms, prevention, and treatment. Students participated in a simulation activity that showed STI transmission, and how monogamy, abstinence, and contraception can lower infection rate. Students received information about local resources for STI testing and treatment. It ended with a review of all the sessions and allowed students to ask questions.

Sessions concluded with a 10-minute anonymous post-presentation survey which included the same pre-participation survey questions to assess changes in acquired knowledge. Post-presentation surveys included 1-2 free response questions meant to gain insight on the students'

Table 1. Pre- and Post-Survey Questions and Responses for a Sexual Health Education Curriculum, Hawai'i, 2024

Question	Pre-survey % Correct	Post-survey % Correct	P-value ^a
Lesson 1 - Reproductive Anatomy, Puberty, and Menstruation (n=48)			
MATCH the following male reproductive structures (term to definition).	42	67	.020
MATCH the following female reproductive structures (term to definition).	27	69	<.001
List THREE changes that may occur during puberty for MALES.	65	79	.281
List THREE changes that may occur during puberty for FEMALES.	63	77	.039
Why does menstruation happen and what are common symptoms females might experience?	31	38	.067
List TWO different forms of menstrual products.	58	90	<.001
All answers correct			<.001
Lesson 2 - Pregnancy, Family Planning, and Healthy Relationships (n=42)			
What are TWO early signs of a pregnancy?	81	95	.033
What is a healthy relationship and how does it differ from an unhealthy relationship?	45	52	.173
List ONE complication of teenage pregnancy.	62	88	<.001
What are the additional costs parents need to think about when having a child?	60	74	.083
Approximately, how much does raising a child cost (from birth to age 18)?	5	60	<.001
All answers correct			<.001
Lesson 3 - Contraception (n=42)			
What is contraception?	43	88	<.001
What are TWO uses of contraceptives?	19	38	.014
List THREE forms of contraceptives	36	69	<.001
List TWO options available for an unplanned pregnancy?	50	64	.183
All answers correct			<.001
Lesson 4 - Sexually Transmitted Infections (n=42)			
What is an STI and what makes it different from an STD?	57	76	.029
What is ONE reason why STI education is important?	74	93	.019
List TWO things you can do to decrease your risk of getting an STI.	57	88	.005
Why is STI testing important?	71	88	.018
All answers correct			<.001

^aPaired sample t-test

STI=sexually transmitted infection

feelings about the lesson. The lesson 4 post-presentation survey included a reflective question inquiring about the sexual health education series as a whole.

Pre-presentation and post-presentation surveys were anonymous and were directly distributed and collected by the classroom teachers. Individual responses were not matched; instead, the analysis focused on group-level changes in knowledge. All students were expected to complete the surveys unless their parent or legal guardian opted to have their child's survey information excluded from data collection. Data de-identifying procedures were not needed since the collected materials were anonymous.

Pre- and post-presentation survey data were analyzed to assess the changes in the perceived knowledge in the sexual health education series. Each content-based question was graded separately by 2 ATSU-SOMA students who were given the same answer key. The averages of both assigned grades were then used to determine the final score used for

data purposes. A third-party teacher from the PCS was also present for any assistance with illegible answers. The utmost effort was made to decipher student answers. If no verdict was reached, the answer would be marked as incorrect and given a 0. The total number and the percentage of correct answers were then calculated and compared for the pre-presentation vs. post-presentation surveys to assess for gained knowledge. Percentages were used to account for the possibility of absent students when comparing data between the different lessons. The survey data were compiled and analyzed using Microsoft Excel Version 2602 (Microsoft Corporation, Redmond, WA) and SPSS Version 29 (IBM Corp., Armonk, NY). Descriptive statistics, including frequencies and percentages, were calculated for all the questions. Paired samples *t*-test was used to compare the students' change in perceived knowledge from pre-survey to post-survey with a set statistical significance at $P < .05$. Answers to free response questions for each lesson were

logged and analyzed for key words and common themes. Participation in these surveys was not used for any grade assignment by the health teacher and was strictly used for data collection.

Data

There were 48 participants for lesson 1 and 42 participants for lessons 2, 3, and 4. The percentage of students who attained a perfect score (all correct) on each question was examined. Data analysis demonstrated that students showed an increase in perceived knowledge across all questions in all 4 lessons, with few questions showing drastic change compared to others, described in detail below (Table 1). Paired sample *t*-tests confirmed that the mean overall scores increased from pre- to post-survey for all lessons, along with the change being statistically significant, for all 4 lessons ($P < .001$).

There was a significant increase in students' overall mean knowledge scores ($n=48$) on reproductive anatomy, puberty and menstruation (Lesson 1, $P < .001$), with significant increases in knowledge in 4 of 6 topic areas: male reproductive structures (41% to 67%, $P = .020$), female reproductive structures (27% to 69%, $P < .001$), female puberty changes (63% to 77%, $P = .039$), and menstrual products (58% to 90%, $P < .001$) (Table 1).

There was a significant increase in students' ($n=42$) overall mean knowledge scores on pregnancy, family planning and healthy relationships (Lesson 2, $P < .001$), with significant increases in knowledge in 3 of 5 topic areas: early signs of pregnancy (81% to 95%, $P = .033$), teenage pregnancy complications (62% to 88%, $P < .001$), and cost of raising a child (5% to 60%, $P < .001$) (Table 1).

There was a significant increase in students' ($n=42$) overall mean knowledge scores on contraception (Lesson 3, $P < .001$), with significant increases in knowledge in 3 of 4 topic areas: contraception definition (43% to 88%, $P < .001$), uses of contraceptives (19% to 38%, $P = .014$), and contraceptive forms (36% to 69%, $P < .001$) (Table 1).

There was a significant increase in students' ($n=42$) overall mean knowledge scores on sexually transmitted infections (Lesson 4, $P < .001$), with significant increases in knowledge in 4 of 4 topic areas: STI versus STD definition (57% to 76%, $P = .029$), importance of STI education (74% to 93%, $P = .019$), ways to decrease STI risk (57% to 88%, $P = .005$), and importance of STI testing (81% to 88%, $P = .018$) (Table 1).

Some of the open-ended questions showed that this lesson helped students understand more about their bodies, how to stop teen pregnancies, and be protected against STIs. Valuable insights were gleaned from responses to the open-ended questions conducted at the end of each session. A common theme was that the activities associated with the lessons were educational and fun, which allowed better engagement and understanding. For example, one student from Lesson 1 shared, "I learned that there is a lot to learn about my body that I don't know," reflecting the extent to which these sessions can teach students about their own sexual anatomy. Another student reported that

Lesson 2 influenced their perspective on parenthood, reinforcing a desire to avoid early parenthood during high school. In another response, a student expressed, "I like sexual education because I want to be able to be safe in the future mentally and physically," demonstrating the possible impact of Lesson 3 on students' sense of empowerment and future wellbeing. Similarly, after Lesson 4, a student noted, "in my opinion, what I like about the sexual health education program is we are learning how to be protected and what to do if you get something transmitted to you during sex," showing the real-life applicability of these lessons. These sentiments were echoed by others who shared that the program helped them to learn more about their own bodies and gain a clearer understanding of STI and unintended pregnancies prevention, and the available options and resources for family planning.

Discussion

This sexual health education series for 9th grade students at the PCS was accepted positively by both students and faculty, and showed an overall significant increase ($P < .001$) in student knowledge for each lesson. The survey responses also suggest that this series of lessons was successful in educating and engaging students about sexual health in which they gained a deeper understanding about topics ranging from sexual anatomy to prevention of STI and unintended pregnancies. Students felt better prepared to make informed decisions, and a greater ability to protect themselves and seek help when necessary. Students seem to resonate with the practical applications such as how to protect oneself from STI and what to do with a potential health concern, suggesting programs that incorporate real-life scenarios can likely increase students' sense of confidence and competence in managing their sexual health.

Overall, the survey feedback highlights the success of the program in achieving its educational objectives. The findings align with existing literature that emphasizes the importance of comprehensive sexual education to shape adolescents' information base and to empower them to make responsible decisions.⁷

Implications

The initiative was designed in the hope of serving as a blueprint for Hawai'i schools lacking a comprehensive sexual health education curriculum. The expectation is that these schools may construct programs with similarly engaging lessons that highlight bodily autonomy and health literacy in hopes to equip students with the knowledge needed to make educated decisions about their own health, and ultimately reduce rates of STIs and teen pregnancies in Hawai'i. Early sexual health education is critical, as adolescents begin forming behaviors that influence their long-term health before puberty. Providing medically accurate lessons about STIs, unintended pregnancy, and bodily autonomy equips students with the knowledge and skills needed to make informed decisions about their own health, ultimately supporting efforts to reduce teen pregnancy and STI rates in the community.⁸

When it comes to implementing sexual health curriculum into classrooms, one of the biggest obstacles is teacher preparedness. For example, in Chicago public schools, it was found that teachers lacked available preparation time to create sexual health curricula and often felt discomfort and difficulty with delivering the material.⁹ Due to the nature of the material, it is also important that sexual health education is taught by educators who are knowledgeable, skilled and comfortable addressing a wide-range of sexual health topics.¹⁰ This sexual health series can be adapted to a community-based project similar to the Hawai'i Community Comprehensive Sexuality Education Project, developed by the University of Hawai'i John A. Burns School of Medicine (JABSOM) in 2021, which aimed to promote sexuality education in elementary and high schools through evidence-based information.⁷ With their program, medical students and resident physicians facilitated roundtable discussions with students and educators, providing lesson plans selected by participating schools. That model served as a training opportunity for medical trainees to develop skills in delivering sexual health information, while simultaneously educating students.

Similarly to JABSOM's program, the curriculum described in this study was also developed by medical students to ensure medical accuracy; however, it is organized into a standardized, lesson-based format suitable for classroom implementation. Instructional materials, including PowerPoint slides and classroom activities, can be shared with educators for independent use. In future implementations, medical students could initially teach the lessons to students with the intent to model instruction for classroom educators, who could then continue to deliver the curriculum and share it with other teachers once they are comfortable with the material. This would allow for sustainability of school-based sexual health education while maintaining medical accuracy without requiring a health care professional to facilitate instruction.

Study limitations

Survey design. The surveys designed for this initiative were not intended to be used for longitudinal study. In the future, it would be beneficial to gather data with a pre-survey prior to the first lesson and a comprehensive post-survey at the end of the last lesson.

Lesson design. Despite the great depth of information that was covered, the lessons created and chosen for the study were not all-encompassing of sexual health education, as there was only time to lecture on 4 core subjects. In addition to covering the discussed topics in more detail, this curriculum could be expanded by including discussions on gender identity, media's effect on sexual health choices, sex trafficking, and diverse relationships such as asexual, non-monogamous, or polyamorous relationships. Additionally, the current lessons could also be adjusted in the future to also make it less heteronormative and more inclusive of the lesbian, gay, bisexual, transgender, queer, and other sexual and gender minority community. Prior research shows that many of the provided sexual health education curricula lack topics such as these, and as a result, students may feel ignored if they do not identify as heterosexual.¹¹

Conclusion

Overall, the project showed promising success as an effective sexual health education series as all 4 lessons had a statistically significant increase in student knowledge from pre-survey to post-survey responses. It is hoped that Hawai'i schools that lack a comprehensive sexual health education curriculum can use these lessons as a blueprint for constructing their own sexual health programs that prioritize bodily autonomy and health literacy with the goal of providing students with the knowledge needed to make educated decisions about their own sexual health.

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Conflict of Interest and Disclosures

None of the authors identify any conflict of interest.

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Problem-Based Learning (PBL) Model in Teaching Medical Laboratory Science at University of Hawai'i

Violet Nxedhlana, PhD, MT (ASCP)¹

¹ Department of Medical Technology, University of Hawai'i at Mānoa, John A Burns School of Medicine

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The Medical School Hotline of the University of Hawai'i John A. Burns School of Medicine was founded in 1993 by Satoru Izutsu PhD (former vice-dean UH JABSOM). It is a regularly scheduled column and is edited by Kathleen Kihmm Connolly PhD, HJH&SW Contributing Editor.

Introduction

The Medical Technology (MT) Program at the John A. Burns School of Medicine (JABSOM) uses the Problem-Based Learning (PBL) model approach. PBL addresses many theories of learning, including collaborative and social learning theory and information processing.¹ PBL improves students' abilities to think critically, enhance problem-solving capabilities, teamwork, and knowledge transfer.² Integration of these skills promotes restructuring of students' coherence that helps them to make sense of the issues.³ PBL discourages memorization but promotes the construction of knowledge, fosters attitudes, ethics, and improves research skills.⁴ These skills are critical to meeting the demands of a professional Medical Technologist or Medical Laboratory Scientist (MLS) within a dynamic global economy.

PBL theory became popular in the 1970s as a learning model in medical schools.² PBL was introduced in 1969 at McMaster University in Canada as an innovative instructional strategy and has since proliferated and been adopted by other institutions around the world.⁴ The strategy is based on the principles of cognitive learning theory. PBL encourages self-directed learning, congruent with modern principles of learning. It consists of carefully designed scenarios that require students to use a range of skills. PBL relies on presenting students with ill-structured (messy), open-ended, and real-life problems with possible answers.⁵ The parameters of the problem are not well-defined, just like the real world, and students work through the ambiguity and uncertainty to find a solution.

PBL is group-dependent, encourages collaboration among group members, and promotes working toward finding a consensus. The groupwork challenges students to explain their reasoning from different viewpoints. Grouping ensures that students actively involve themselves in their education.⁶ The approach allows students to control how fast they learn, as they can ask questions and get immediate feedback. All educational levels can use the PBL method to promote noteworthy discussions within the group. The most appropriate instructional strategy for PBL is to clearly define the learning objectives. Clear and concise instructions help students understand expectations, which allows them to mold their behaviors to meet the goal.⁷

PBL and the JABSOM Medical Technology Program

The PBL theory is the learning approach of choice for the MT Program at JABSOM. The learning theory advances the idea that learning starts by identifying problems that need solutions. In the MT program at JABSOM, the teaching method is influenced by investigation through laboratory testing to help physicians make diagnoses and manage patient health. MLSs are analytical people. Since the PBL teaching method was introduced more than ten years ago, graduates' critical thinking skills and collaborative work have improved. Reports from laboratory partners suggest that graduates are now better prepared to meet the laboratory demands from the first day. The American Society for Clinical Pathology Board of Certification (ASCP-BOC) examination pass rates have stayed above 90%, exceeding the 75% passing rate benchmark required by the accreditation agency, National Accrediting Agency for Clinical Laboratory Science (NAACLS). JABSOM's MT curriculum challenges students to solve problems, both in the classroom and in clinical training. It uses different learning methods in the classroom to promote the PBL theory.

Case Studies

Case studies are used extensively in the MT program. Case studies present a given scenario, usually the patient's age and sex, and the presenting symptoms. The program includes laboratory test results followed by a series of questions. The case studies challenge students to review, analyze, and synthesize the data to answer the relevant questions. Students are challenged to see beyond the obvious. The students must use the interpretation and application cognitive skills to correlate laboratory results to disorders or diseases. Basic case studies involve presenting students with laboratory results from a single laboratory section.

As an example, students are provided with several hematology and chemistry parameters from a laboratory test. Even though many of the testing parameters may be within normal reference range, students must recognize abnormal results. The following represents an example of abnormal results: an increase in Mean Corpuscular Volume (macrocytosis), low vitamin B12 and folate, reticulocytopenia, elevated homocysteine, and elevated methylmalonic acid. The students should be able to interpret these results as potential megaloblastic anemia. As the students progress in the program, case studies become more complex, with lab results from multiple laboratory sections such as hematology,

chemistry, and/or urinalysis. A typical case study is shown below.

Peer Learning

Peer learning has its roots in the social constructivist theory. Vygotsky (1978) argued that peer learning enriches students' social and cognitive learning processes. These learning processes become more dynamic as students explore diverse perceptions and viewpoints via firsthand experiences. The MT faculty provides prompts that require assigned students to explore the topic extensively and present it in class. The presenter becomes the subject-matter expert who must share the knowledge with the other students. The audience asks the presenter questions about the topic. The students use Socratic questioning techniques to stimulate critical thinking and invoke discussions. Below is an example of a prompt that may be assigned to a student.

Describe the etiology of the major disease states associated with the adrenal glands. Provide an overview of the gland, including morphology and functions. Include types of hormones and their functions. Discuss causes, symptoms, and steps in the diagnosis of Cushing's disease. Discuss Addison's disease. Differentiate primary and secondary Cushing's Syndrome and Addison's disease, using laboratory data and symptoms. Discuss the mechanism of action and the physical and chemical properties of the hormones regulated.

This in-depth question provides a framework that allows the student to invest time in learning about Cushing's and Addison's diseases. The assigned student addresses all parts of the question, which in turn generates questions from the audience.

Group Assignments

Group work promotes collaboration and critical thinking among learners. Learning groups provide students with opportunities to express their opinions as they search for practical solutions to problems. When students work in groups, they too become teachers. Group work forces students to explain their reasoning from different perspectives. Grouping maximizes students' opportunities to be actively involved in their own learning.⁶ The approach gives students control of their pace of learning, as students can ask questions and get immediate feedback. The MT students at JABSOM are challenged to write standard oper-

ating procedures. Each group is assigned a topic based on the hands-on laboratory exercises completed in class. One group may be assigned to write a procedure to perform a manual erythrocyte sedimentation rate (ESR) test or a manual coagulation test. These group tasks build character by promoting the collaboration needed to solve a problem.

Clinical Rotation Projects

Upon completion of the didactic part of the MT program at JABSOM, the MT students complete a clinical training regimen at one of the following laboratories. The MT program assigns students to Adventist Health at Castle, Clinical Laboratories of Hawaii (CLH), Diagnostic Laboratory Services (DLS), Kaiser Healthcare, Kuakini Medical Center, and Tripler Army Medical Center. During the training cycle, the students may get individual and/or group assignments based on the PBL model. Assignments may include a parallel investigation to solve a problem encountered in the training laboratory. As a case in point, students are expected to identify a problem encountered during routine testing, such as finding a missing specimen. The student must document the process involved, from how and when the discovery was made to how the issue was resolved. The MT program expects students to utilize recalled knowledge to interpret or apply written, numeric, or visual data encountered in the situation. The program provides an opportunity for students to share the results with other students. The goal is to transfer knowledge gained in the program into real-life contexts.

Conclusion

The PBL methodology is an appropriate mode for teaching courses in MT. MLs are problem-solvers. Problems begin from the preanalytical phase, through the analytical phase, to the postanalytical phase of the testing process. PBL promotes deeper learning, collaboration, critical thinking, problem solving, communication, and teamwork, which are essential in operating a clinical laboratory. The development of these skills, through a PBL approach, provides students with a competitive advantage in the job market while leading to better content knowledge and increased student motivation.

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